

Abort Region Determinator Support Console Handbook

Mission Operations Directorate
Flight Design and Dynamics Division

PCN 06-1
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National Aeronautics
and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

ABORT REGION DETERMINATOR SUPPORT CONSOLE HANDBOOK

PCN 06-1
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ARD Support Console Handbook PCN History

<u>PCN #</u>	<u>Date</u>	<u>Change Summary</u>
97-1	11-14-97	<p>Replace front cover.</p> <p>Add PCN History page ii.</p> <p>Replace table of appendices page xii.</p> <p>Add Change Control Process Documentation, Appendix F</p> <p>Update PLOAD Procedures, replace pages 4-17 to 4-19.</p> <p>Add new MSK descriptions, replace pages E-20 through E-23 and add pages E-24 through E25.</p> <p>Update L-1 Week Checklist (Appendix D), replace pages D-2 through D-13 and add pages D-13a through D-13l.</p> <p>Updated Ascent Event Summary Procedures, replace pages 2-18 through 2-19 and add page 2-19a.</p>
98-1	3-2-98	<p>Replace front cover.</p> <p>Replace PCN History, page ii</p> <p>Replace Section 3, pages 3-1 to 3-18 with pages 3-1 to 3-14</p> <p>Delete ARD Support Questions from Section 6; delete pages 6-111 to 6-114 and replace with 6-111 and 6-112</p> <p>Delete Appendix B, delete B-1 to B-7 and replace with B-1, B-2.</p> <p>Replace Appendix C, pages C-1 and C-2</p> <p>Replace Appendix D content page, page D-1</p> <p>Replace the ILC Checklist in Appendix D, pages D-14 to D-16</p> <p>Delete the Default FPR Values pages in Appendix D; replace D-17 and D18 with blank page D-17 and D-18</p> <p>Replace the FDO Data Pack checklist and delete the Products Databook Checklist, both in Appendix D; replace D-19, D-20</p> <p>Replace the "Number of Parameters Changed for DOL Operations" section in Appendix D, pages D-21 and D-22</p> <p>Replace Appendix E, pages E-1 to E-26</p>
98-2	5-26-98	<p>Replace front cover</p> <p>Replace signoff sheet and pages ii to xii with pages iii to xxi. Includes PCN History (page iv)</p> <p>Add blank page 2-45</p> <p>Replace Appendix D pages D-19 and D-20, add blank page D-30</p> <p>Replace Documentation Change Process, page F-1</p> <p>Replace Section 4.1.3.3.3, pages 4-18 and 4-19</p> <p>Replace Appendix A pages A-3 through A-6</p>
98-3	8-18-98	<p>Replaced front cover</p> <p>Replaced signoff sheet and PCN history, pgs. ii, iv</p> <p>Replaced table of contents, pgs. ix - xii, xiv</p> <p>Replaced Section 2, (all)</p> <p>Replaced Appendix D, (all)</p>
98-4	10-16-98	<p>Replaced front cover</p> <p>Replaced signoff sheet, pg. ii</p> <p>Replaced blank page with PCN history, pg. v</p> <p>Replaced table of contents, pg. xx</p> <p>Replaced Section 4.1.4.3 page, pg. 4-24</p> <p>Replaced Section 4.2.7.3, pg. 4-83</p> <p>Replaced Appendix B, pgs. B-1 and B-2</p> <p>Replaced Appendix D pgs. D-5 thru D-16, added D-17, 18</p>
98-5	11-23-98	<p>Replaced front cover</p> <p>Replaced signoff sheet, pg. ii</p> <p>Replaced PCN history, pg. v</p>

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<u>PCN #</u>	<u>Date</u>	<u>Change Summary</u>
		Replaced table of contents, pg. xi Replaced Table 4-1, pgs. 4-2 thru 4-5 Continued Table 4-1 on pgs. 4-5a thru 4-5b Replaced Section 4 pgs. 4-79 thru 4-109 with pgs. 4-79 thru 4-100 Replaced Appendix D page D-6
99-1	5-7-99	Replaced front cover Replaced signoff sheet, pg. ii Replaced PCN history, pg. v Replaced table of contents, all Replaced Section 3, all Replaced Section 4, all Replaced Section 5, all
99-2	12-7-99	Replaced front cover Replaced signoff sheet, pg. ii Replaced PCN history, pg. v Replaced table of contents, pgs. x, xi, xiv, xviii Replaced Section 4, all Replaced Appendix D, pgs. D-5, D-6, D-7
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01-1	2-8-01	Replaced front cover Replaced signoff sheet, pg. ii Replaced PCN history, pg. v Replaced Section 4.2.11, pgs. 4-73 & 74 Replaced Appendix D
02-1	5-28-02	Replaced front cover Replaced signoff sheet, pg. ii Replaced PCN history, added pg. vi Inserted Blank Page, pg. vii Replaced table of contents, all Replaced Section 2, all Replaced Appendix A, all Replaced Appendix D, D-5 thru D-18
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03-1	10-10-03	Replaced front cover

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<u>PCN #</u>	<u>Date</u>	<u>Change Summary</u>
		Replaced signoff sheet, pg. ii Replaced PCN history, pg. vi, vii Replaced table of contents, ix, xi – xii, xiv - xvi Updated Section 2, pgs. 10, 12, 13, 15 - 18, 21 - 28 Replaced Section 5, all Updated Appendix A, pgs. 8 - 10 Replaced Appendix C, all Replaced Appendix E, all Updated Appendix F, pg. 1
Final Rev. A	07-06-05	Update out-of-date Chapter 1 content. Changes to account for new AutoGMED script. Changes to account for new Workstation ARDTools. Updates to account for new TSA reconfiguration agreements and MCC cycles. Transfer DOLILU transfer responsibility from GPO to FDO/ARD Support. Add a check on ET mass history at liftoff. Add new procedure for delayed SRB separation. Add new procedures on verifying IYs while in BFS. Updates “OMS Prop Fail”, “OMS He Leak”, “OMS Helium Tank Fail”, and “Three Low-Level Sensors Failed Dry” procedures per FDO procedural updates. Update Item 9 procedures to account for situations where the Item 9 is after OMS Assist stop or where the Item 9 is interconnected. Updated RCS Leg/Manifold Failure/Recovery prodecures to account for situations where a leg fails partially into a dump or a leg is recovered after a previous failure. Add new section entitled “BFS Engage” to correspond to new FDO Console Handbook “BFS ENGAGE” section. Add new section entitled “SSME Hard Over”. Add all ARD Support checklists to Appendix D. Update FDO Electronic Datapack (Appendix D). Update Example Non-Standard Database Change Description.
PCN 06-1	06-27-06	Replaced front cover Replaced signoff sheet, i Replaced PCN history page, v Replaced Table of Contents, all Replaced list of Figures, all Replaced list of Tables, all Updated Section 2, pgs. 17, 19-32 Updated Section 4, pgs. 1, 4, 7, 61-98 to add new procedures for SSME Stuck Actuator Hardover, update “OMS Engine Fail” and “OMS He Leak” procedures, and consolidate old procedures into common “OMS Prop Leak/Fail and He Tank Fail” procedures per FDO procedural updates. Update Appendix D procedures and checklists. Updated Section 6, pg. 4 Replaced Appendix D, all Updated Appendix F, pg. 1

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1 INTRODUCTION

This document explains the duties and responsibilities of the Abort Region Determinator (ARD) Support Officer and provides a generalized set of procedures for performing both on-console and off-console tasks. Console operating procedures and ascent processors are explained, with sufficient background information to make sense to trainees while at the same time being useful to experienced personnel.

This handbook is divided into six major sections. It begins with a description of the duties and responsibilities of the ARD Support engineer. The next section contains procedures for performing off-console tasks. This is followed by a discussion of on-console activities. Next, flight preparations and procedures are discussed, including possible ascent scenarios that one may encounter. The latter part of this handbook describes various computer tools. It ends with a discussion of several ascent topics of interest.

1.1 BACKGROUND INFORMATION

The ARD is a launch/abort processor resident in the Mission Control Center (MCC). The ARD provides realtime cyclic ascent performance prediction capability. The ARD calculates abort capability for all of the intact abort modes: Abort To Orbit (ATO), Abort Once Around (AOA), Transoceanic Abort Landing (TAL), and Return To Launch Site (RTL). The ARD also has the ability to calculate abort capability for certain contingency abort modes and the capability to achieve the nominal Main Engine Cut-Off (MECO) targets. Additionally, the ARD can extrapolate the current vehicle state to determine a predicted MECO state for input to the Down Range Abort Evaluator (DAE) in order to assess the capability to reach a TAL site.

One question a trainee might ask is, "Why is the ARD used for abort boundary calls? Why not just use the abort mode boundary inertial velocities from the ASAB-23 product to make the calls?" The answer is that the ARD has visibility into certain dispersions through the vehicle state vector and, therefore, can carry a lower Flight Performance Reserve (FPR) than was used to determine the mode boundaries in ASAB-23. Secondly, the ARD offers the only means of making accurate predictions under off-nominal conditions, such as Space Shuttle Main Engine (SSME) thrust limiting cases (e.g., fuel flow meter shift, stuck throttle, etc.).

The primary realtime user of the MCC ARD is the Flight Dynamics Officer (FDO). The ARD prediction of the vehicle's performance allows the FDO to make abort boundary calls or abort decisions, if necessary, regarding all abort modes mentioned above. The ARD Support Officer has been a Multi-Purpose Support Room (MPSR) console position for the ascent FDO since STS-1. The ARD Support position has the responsibility of assuring proper configuration of the ARD. The ARD Support must oversee ARD database maintenance, provide realtime ARD input recommendations to the Trajectory Officer (TRAJ), and check inputs made by Computer Flight Dynamics (DYNAMICS, or DYN, for short) personnel.

Because powered flight lasts only about 8-1/2 minutes and events can go from bad to worse quickly, timely response to anomalies is mandatory. The FDO bases abort calls on ARD predictions, and it is absolutely critical that this tool be properly configured. The ARD Support is instrumental in maintaining and monitoring the ARD during ascent.

The ARD Support engineer has three major areas of responsibility: realtime console support, preflight general support and database maintenance, and general analysis tasks. These are described briefly in the sections that follow.

Figure 1-1 shows a functional breakdown of the ARD Support's preflight and flight responsibilities, with further breakdown into on-console and off-console duties.

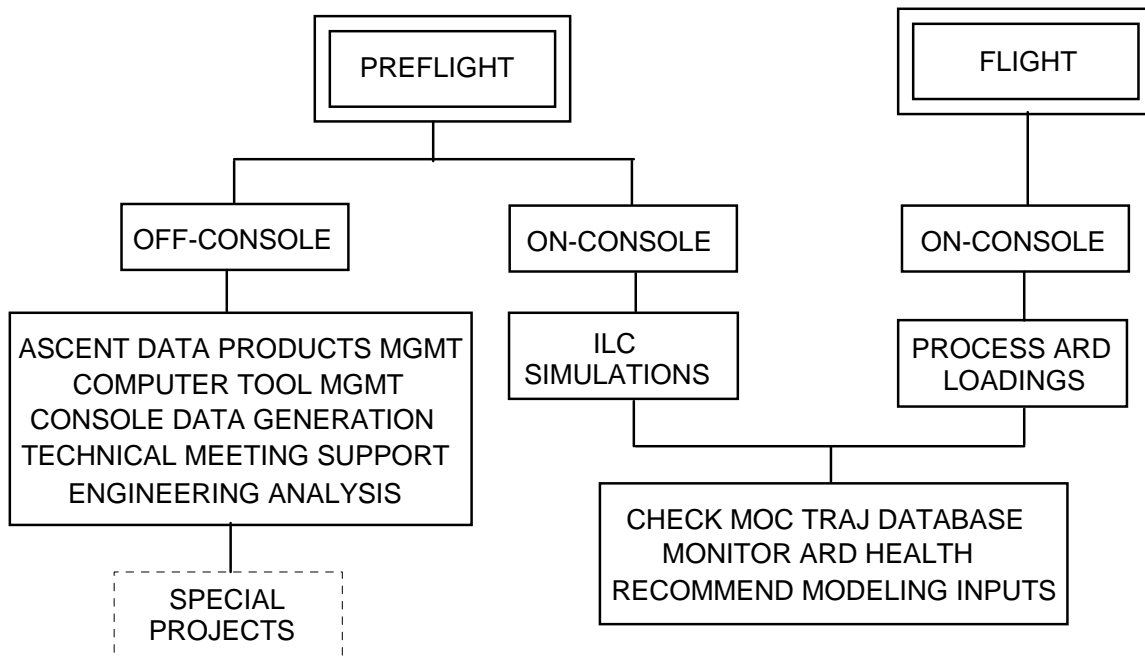


Figure 1-1. ARD Support duties and responsibilities

Figure 1-2 shows a typical task chronology required of the ARD Support Officer. Refer to Sections 2 and 3 for a more detailed description of all the ARD Support's off-console and on-console duties.

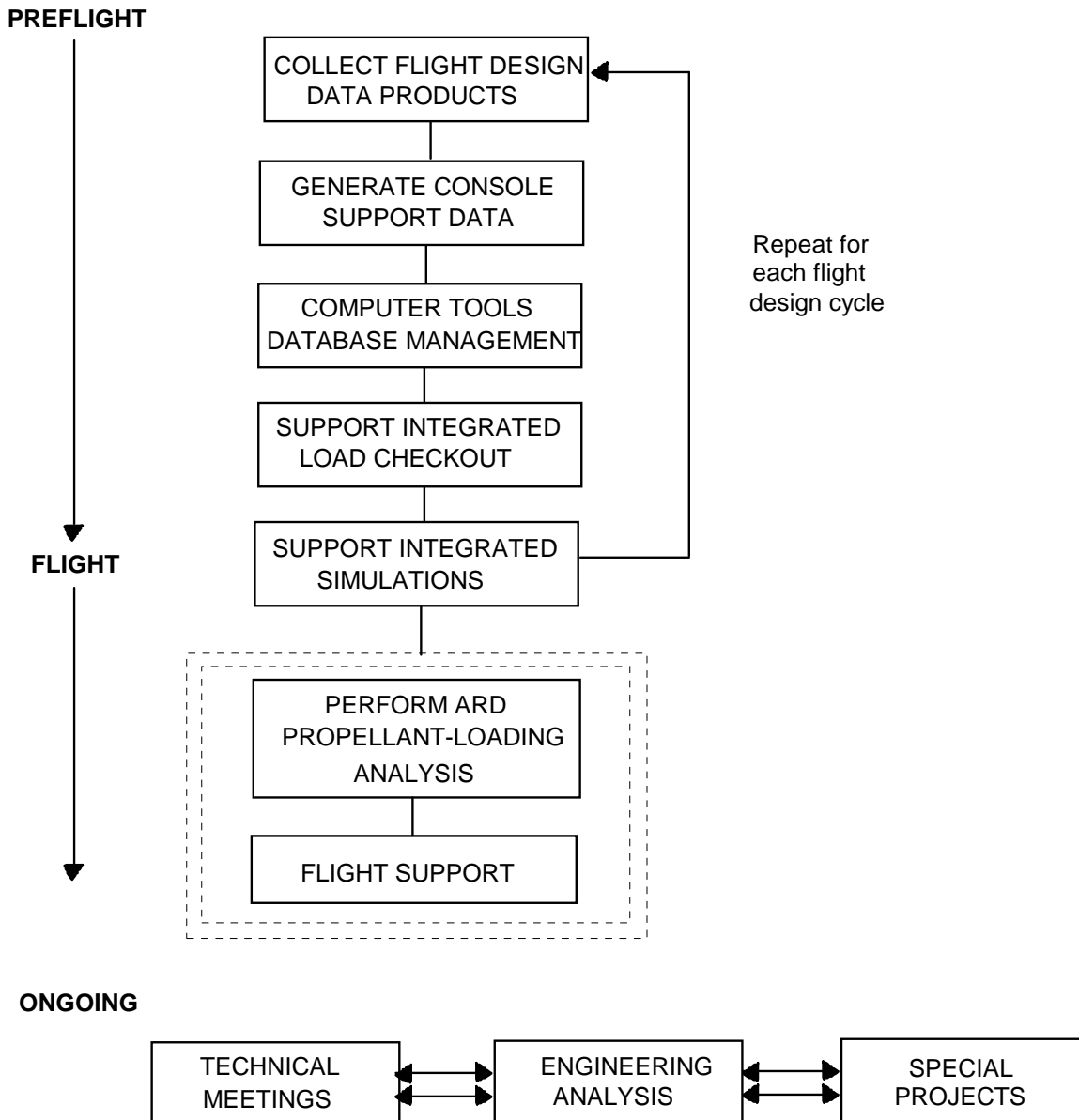


Figure 1-2. Typical ARD Support task chronology

1.2 SUMMARY OF DUTIES

1.2.1 Off Console

The ARD Support Officer is responsible for collecting and organizing the ascent/entry Flight Design products required by the Flight Dynamics team. He is also responsible for producing data packs and console products for the ascent FDO and TRAJ. This task includes developing a list of last minute changes to the Trajectory Server (TRS) ARD/Abort Maneuver Evaluator (AME) database to account for flight re-manifests, mass properties updates, and performance changes. Another responsibility is maintaining the databases used for the FDO/Guidance and Procedures Officer (GPO) Ascent Entry Trainer system.

The ARD Support Officer is often called upon to perform ascent performance analysis. This usually deals with some off-nominal scenario and is required to support Ascent Flight Techniques Panel actions, evaluation of new flight rules, or development of new MCC capabilities.

The ARD Support's off-console duties include:

- Maintenance and reconfiguration of ascent computational tools (scripts, ARDTools application, and Ascent/Entry Trainer). These tools are used for ascent/abort trajectory analyses, console data generation, and console support.
- Prelaunch compilation and distribution of flight-specific console operations data (e.g., booster data for off-nominal engine performance). These data are used by the FDO, TRAJ, and ARD Support for realtime console operations.
- Attendance at technical meetings (e.g., Ascent/Entry Flight Techniques Panel) to provide ARD expertise if needed. The ARD Support engineer is sometimes required to give presentations at these meetings.
- Perform special trajectory analyses at the request of a FDO or Flight Director (FD).

1.2.2 On Console

The ARD Support engineer participates in all MCC ascent integrated simulations and flights. This includes approximately five flight-specific simulations per mission, generic ascent simulations, and Integrated Load Checkouts (ILC) of the TRS ascent database and processors. The ARD Support engineer also supports final updates to the TRS ARD and AME database, which occur on the day before launch (launch minus 1 day (L-1)).

The ARD Support engineer's on-console duties include:

- Verifying the integrity of the TRS database during ILC sessions and prior to each simulation (sim) and flight.
- Calculating Day-of-Launch (DOL) ARD updates based on actual propellant loading measurements to ensure correct Flight Performance Reserve (FPR) protection.
- Assisting the FDO in realtime assessment of ARD accuracy/health, mass track quality and recommendations for modeling inputs during ascent simulation, and the ascent phase of real flights.
- Monitoring all realtime inputs to the ARD for correctness and completeness.

In summary, ARD Support assists the ascent FDOs in both preflight preparation and actual flight operations. The engineer must be knowledgeable about the products delivered by Flight Design, be familiar with ARD software requirements and limitations, and perform analyses for off-nominal ascent performance studies. Finally, the ARD

Support engineer should be proficient in realtime console operations in order to provide timely ARD input recommendations to the FDO and TRAJ during powered flight.

1.3 PERSONNEL INTERFACES

The Flight Dynamics team, as far as the ARD is concerned, consists of four different console positions. These include the FDO and TRAJ in the Flight Control Room (FCR) and their MPSR support personnel, ARD Support and DYNAMICS. Also in the MPSR with ARD are Abort Support, Targeting, and Entry Support. The ARD Support also coordinates with these people back in the office to keep up to date on the latest data and issues concerning the flight.

Figure 1-3. MPSR and FCR on second floor (Deleted)

Figure 1-4. FCR console layout (rooms 231 and 331) (Deleted)

Figure 1-5. Second floor MPSR console layout (room 210) (Deleted)

1.4 DATA FLOW INTERFACES

Figure 1-6 is a diagram of the Flight Dynamics team interfaces with the TRS and ARD. The single arrows signify the flow of data and the double arrows signify voice communication.

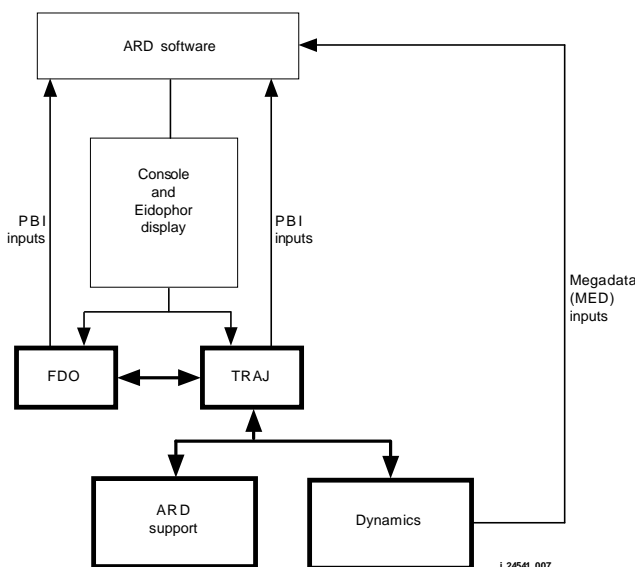


Figure 1-6. Flight Dynamics personnel interfaces with the ARD

Although the FDO is responsible for all ascent flight performance decisions, it is the responsibility of TRAJ to maintain the ARD in the proper and current configuration

during powered flight. TRAJ relies heavily on ARD Support for pre-mission ARD configuration and for realtime analysis of the ARD. When needed, the TRAJ or FDO will make adjustments to the ARD by way of their console displays (e.g. using pushbutton indicators (PBI)) or by directing DYNAMICS or ARD to make ARD Manual Entry Device (MED) inputs to the TRS. DYNAMICS also has the responsibility of being the trajectory software application specialist, the point of contact between the trajectory operations personnel (FDO, TRAJ, etc.) and the TRS software design personnel. Occasionally, the FDO or TRAJ will give the ARD Support permission to talk directly to DYNAMICS. This is usually the case during the pre-sim or pre-ILC database checkout. Sometimes in a dynamic sim run, the TRAJ is busy talking to another front room position, and the ARD Support has to talk directly to DYNAMICS in the interest of time.

1.5 MCC ARD OVERVIEW

This section of the console handbook presents an overview of the ARD software architecture. Reading USA's Flight Design and Dynamics Abort Region Determinator Overview (FDD-ADFD-T-ARD-001) before proceeding to this section is recommended.

The ARD Support engineer should be familiar with ARD software on at least a task level (i.e., be familiar with the algorithms that perform specific ARD functions). Although knowledge of the ARD implementation (coding) is not technically required, one should learn as much of the design requirements as possible for several reasons.

First of all, rationale for console procedures, driven by software requirements (or sometimes limitations), is better understood when those requirements are known. In addition, troubleshooting occasional discrepancies requires knowledge of ARD theory and formulation. Finally, preparing new requirements for periodic ARD upgrades is accomplished more efficiently when current requirements are understood.

This section describes overall functions of the ARD modules (fundamental groups of algorithms that perform a specific ARD purpose) as well as some tasks. The reader should refer to the ARD Level C Requirements Document for more detailed treatment of this subject. Another source of information is the Ascent FDO Console Handbook, volume V.

1.5.1 ARD Concept and Usage

Starting with the current State Vector (SV), the ARD calculates velocity changes (ΔV) required to achieve various trajectories (nominal, ATO, AOA, TAL, and RTLS). This is compared to current ΔV available based on calculated External Tank (ET) propellant remaining and SSME status. This excess capability is expressed in terms of SSME propellant equivalent velocity margin and is displayed digitally on the ARD OUTPUT display and graphically on the ΔV MARGIN display. These functions are performed for the Actual Mode (AM), which reflects the actual SSME status of the orbiter, and two Hypothetical Modes (HM), in which the SSMEs are configured for the abort boundary call being made (e.g., one SSME out in the first HM given three real engines running for the two-engine TAL call). Output is updated every 2 seconds regardless of whether the Selected Source (SS) of the state vectors is the tracking filter (FLT or FLTR) or

telemetry (TLM). (To make ground-based trajectory processing as versatile as possible and independent of the onboard TLM vector if the downlist is lost, the FDO has the ability to select either a TLM vector or a ground-processed Kalman FLTR tracking vector as the SS for the ARD).

The ARD OUTPUT display shows this data for all three modes simultaneously, enabling the FDO to monitor current trajectory capabilities as well as capabilities for certain levels of failure. Orbiter system anomalies may also be modeled as they occur, such as SSME performance cases (hydraulic lockup, Pc shift, etc.), Orbital Maneuvering System (OMS) leaks, or SSMEs stuck in the throttle bucket. In the event of an actual SSME failure, the FDO presses the applicable SSME-out PBI, which causes the engine throttle to be set to zero in the appropriate ARD throttle table. (A throttle table is a tabular list of throttle settings (both AM and HM), Mixture Ratio (MR), and Specific Impulse (ISP) versus Mission Elapsed Time (MET).) The SSME-out velocity is stored in the ARD Abort Proceed Table, which is used for determining dump times after abort selection. If an abort is selected onboard, the ARD is moded to the same abort (via abort select PBI) to continue monitoring the trajectory and/or evaluate further failures and boundaries.

SSME performance cases are input into the ARD by MED to alter the ARD Throttle Tables. Affected elements may include throttle settings, MR, and/or ISP, depending on the type and severity of the SSME malfunction. Calculations are performed by the ARD to keep track of liquid oxygen (LOX) or liquid hydrogen (LH2) imbalance (due to the engine burning at an off-nominal MR) during such cases. This results in unusable propellant at MECO which the ARD excludes from use in the ΔV available calculations.

RTLS selection in the ARD initiates processing of the Event Predictor (EP). This yields predicted times of Powered Pitcharound (PPA) and Powered Pitchdown (PPD).

1.5.2 ARD Architecture Overview

Note: Information in this section is not necessarily current (last updated in September 1995), but is retained for ARD training and historical purposes.

The ARD module “invoking hierarchy” is illustrated in Figure 1-7.

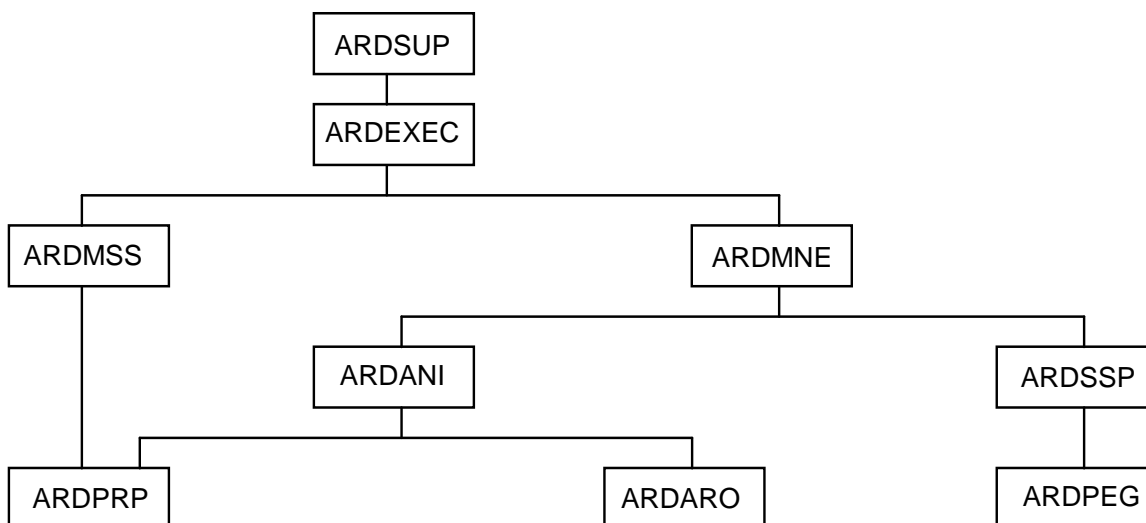


Figure 1-7. ARD module hierarchy

The ARD Supervisor (ARDSUP) controls overall program execution by invoking the ARD Executive sequencing module (ARDEXC). ARDEXC schedules input tasks for each cycle and sets flags for AM, HM, and abort mode computations. It also executes the current mass model module (ARDMSS) and principal model sequencing control module (ARDMNE). ARDMSS performs ET, Solid Rocket Booster (SRB), Orbital Maneuvering System (OMS), and Reaction Control System (RCS) propellant remaining calculations. It also executes the propulsion model, which performs more detailed thrust and mass calculations. ARDMNE schedules OMS and RCS dumps and determines proper throttle settings for the particular abort mode being evaluated. It executes the first and second stage models, ARD ascent numerical integrator (ARDANI) and ARD second stage predictor (ARDSSP), respectively.

ARDANI utilizes Runge-Kutta (RK) numerical integration to propagate the state vector from lift-off to staging. The aerodynamic module (ARDARO) provides inputs for calculation of aerodynamic forces and pitching moments. ARDSSP predicts second stage performance with analytic projection. It calls the powered explicit guidance module (ARDPEG) to emulate onboard closed-loop guidance for calculation of Velocity-To-Be-Gained (VGO) for each abort mode. ARDSSP also calculates the velocity margins.

Now that you have been introduced to overall ARD organization, let us take a more detailed look at module and task functions. Refer to Figure 1-8 for a flowchart of software elements.

The majority of the following material is taken directly from the ARD 2 Level C Requirements Document, May 1993, document JSC-12513. ARD 3 formulation has some differences, but the details of the modules discussed below are not significantly changed. A description of the functional flow by module follows.

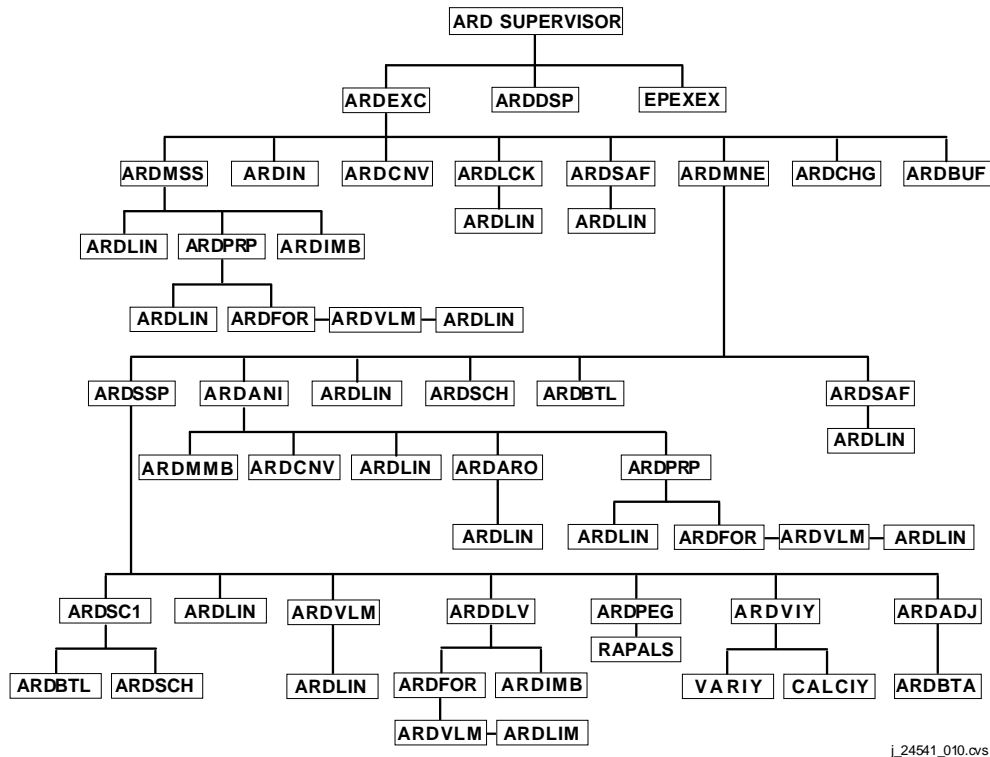


Figure 1-8. ARD module and task hierarchy

1.5.2.1 ARD Supervisor (ARDSUP)

ARDSUP controls overall ARD processing by executing the ARDEXC module and by scheduling the RTLS event predictor (RAPALS) when an RTLS abort has been selected. The supervisor also controls output from the ARD to a display device via the ARD output task (ARDDSP).

1.5.2.2 ARD Executive Sequencing (ARDEXC)

The modules, tasks, and subtasks sequenced by ARDEXC are as follows:

- ARD input task (ARDIN). Must be performed once each cycle prior to the execution of any other tasks or models. The purpose is to lock the current values in the Ascent Constraints Table (ACT) for the duration of the cycle and provide a consistent data set for the other tasks and modules.
- Vehicle-sensed acceleration calculation task. The value of vehicle-sensed acceleration (ASEN) is now calculated for later use. This checks for 3g throttling.
- SSME lock task for throttles (ARDLCK). This task must be performed when there is a MED to change the lock value of an SSME throttle or to change the time at which the SSME's throttle value was locked.
- Selected source Earth-fixed velocity magnitude task. Utilizes the M50 to Earth-fixed conversion subtask (ARDCNV) using the selected source state vector.

Position and velocity vectors are obtained, as well as Earth-fixed and inertial velocity magnitudes.

- Interim SSME-out velocity and time determination task. This task must be performed upon each selection of an SSME-out PBI. For the first PBI, the Earth-fixed velocity magnitude and current source time are used as initial interim estimates for SSME-out velocity and time. For the second PBI, the current source time is used as the initial estimate of the engine-out time, but no update is made to VMEOU. Any re-input of a failed engine PBI is ignored, and any final PBI input that would cause three engines out in the AM is rejected.
- SSME-out Identification (ID) determination task. This task is executed once upon selection of the first and second SSME-out PBI.
- SSME-out safing task (ARDSAF). This task is performed upon selection of either an SSME-out PBI or a MED adjustment to the SSME-out time. Throttle lag for shutdown and throttle-ups is accounted for. The task sets the failed engine's throttle to zero and sets the remaining operating, non-locked engines' throttle(s) to Maximum Throttle Level (KMAX) for all times greater than TMEOUT. In other words, the throttle tables are set up for the failed engine to be out and the remaining engine(s) to throttle up if not locked or failed.
- SSME lock task for MR and ISP (ARDLCK). This task is executed if there is an MR or ISP MED present (indicated by the flag IVLM = 1). The ARDLCK task is executed again to lock the appropriate SSME's MR and ISP history tables.
- Adaptive guidance weight calculation task. This task is executed to compute the adaptive weight adjustment (DWTAGT) based on the adaptive guidance delta time from the PASS, BFS, or filter data. If telemetry is available, the onboard T_DEL is used by the ARD. However, if the downlisted T_DEL is not available, the ARD uses its own calculated value. The ARD T_DEL is less accurate than the telemetry T_DEL (because the ARD executes only once every 2 seconds). If telemetry is lost and later regained, the ARD calculated T_DEL will be overridden by the downlisted T_DEL. DWTAGT calculations are inhibited until the adaptive guidance velocity threshold (at approximately 20 seconds MET) is achieved. After DWTAGT is completed, a flag is set to inhibit subsequent execution. DWTAGT can also be input via MED, which overwrites any calculation performed by this task.
- Start of active guidance time calculation task. The time for the start of active guidance must be computed based on the input start of SRB separation sequence initiation and the attitude hold duration. This controls the ARD stage flag (ISTAGE).
- AM sequencing tasks (ARDMNE, ARDANI, ARDSSP, ARDADI). The AM computations are executed when the control flag IARDCY = 0.
 - The ARDMNE module provides all AM nominal and abort outputs, such as vehicle properties, AM throttle settings, and OMS dump timers.

- ARDANI is then executed when in first stage (ISTAGE = 1). It extrapolates the SS state vector conditions to the conditions at start of second stage guidance.
- ARDSSP is performed once for AM to predict second stage active guidance performance to MECO and calculate velocity margins for nominal and each abort mode.
- ARDADI is executed last. It calculates the AM vehicle attitude as it would show on the onboard Attitude Direction Indicators (ADI).
- AM ARD output-saving task (ARDBUF). The results of the ARD computations are saved for later output by the ARD output task.
- Time-to-go task. The purpose of this task is to set the output time remaining to MECO according to the proper AM prediction. That time selection is based on the abort mode selected, controlled by the abort proceed flag IABPRD = 0 = nominal, 1 = ATO, 2 = AOA, 3 = unavailable (RTLS), and 4 = TAL.
- HM sequencing tasks (ARDANI, ARDSSP). The HM computations are executed when the control flag IARDCY = 1. First, the HM SSME throttle setting task is performed. It uses linear interpolation (via Linear Interpolation Function (ARDLIN)) on each of the HM SSME throttle table histories. If first stage, ARDANI is again executed, and ARDSSP is again called.
- HM ARD ARDBUF. This task is performed again for the HM outputs.
- VMEOU save task. Finally, the SSME-out velocity is saved as the previous value for subsequent cycles.

1.5.2.3 ARDIN

This module has an input task that performs a processor input parameter initialization of all input variables that reside in either the Ascent Constraints Table (ACT) or in the systems parameters. This is done only once per launch during the first ARD cycle.

ARDIN also interfaces the ARD with the SS, the system parameters, and the ACT. This interface inhibits any changes in ARD input parameter values during subsequent ARD execution of this cycle.

The SS state vector and time are extrapolated forward to the current MCC time to compensate for input source state staleness.

The MED throttle setting is converted from percent to a simple fraction.

Input Earth-fixed IY vectors are converted to the M50 coordinate system for use in subsequent ARD computations.

1.5.2.4 ARDLCK

This task is used to modify a given SSME throttle, mixture ratio, or ISP history. The task takes into account the SSME response time.

1.5.2.5 ARDSAF

This task performs AM throttle table history adjustments as required to affect an SSME failure or a three-SSME RTLS selection and the subsequent auto-safing of the remaining SSMEs. The task accounts for SSME response time and uses ARDLIN to fix the location in the throttle table at which adjustments are to commence.

1.5.2.6 ARDBUF

TBS

1.5.2.7 ARDMNE

The principal models and tasks sequenced by the ARDMNE are as follows:

- Abort proceed flag determination task. This sets the abort proceed flag that is used throughout the models and tasks to initiate post-abort mode selection logic. The controller must set this flag to the proper value based on abort mode PBI selection. IABPRD = 0 = Nominal, 1 = ATO, AOA & TAL flag is 0, = 2, AOA & TAL flag is not 0, = 4, 3 = RTLS.
- Automatic HM contingency dump determination task. This task checks the value of VPRESS to turn the automatic HM contingency dump flag on or off.
- Current SSME throttle setting task. The purpose of this task is to ascertain current SSME throttle settings to be used in other ARD tasks and for output to display. It uses linear interpolation (via ARDLIN) on the throttle table histories.
- Abort event task. This task is performed in order to set flags necessary in determining the following events:
 - Is an ITEM 9 ATO in progress? In other words, has the quantity of OMS fuel to be burned been changed via a MED input?
 - Determine the status of the selected abort. That is, see if this is a new abort selection, not a reselection, and determine if the abort is legal. Also see if there is a change in the abort and set the first pass contingency dump flag.
- Post-abort mode selection time and velocity at engine-out initialization task. This task sets the correct values for the time of abort proceed and engine-out velocity.
- Post-abort mode selection 3 SSME RTLS safing task. Used to set the throttles of non-locked engines to the correct RTLS fuel dissipation setting.

- Post-abort mode selection variable IY calculation task. Executes the variable IY logic, if called for; determines the correct target plane to target for based on the engine-out velocity.
- Automatic OMS/RCS dump scheduling task. Executed every cycle. Calculates the OMS and RCS dump times.
- Contingency OMS/RCS dump scheduling task. This is performed only if the dump MED parameter is on. If it is, the appropriate flags are set and the burns are calculated.
- Previous value reset task. Resets four parameters for the next pass.
- ARDMSS. Once per ARD cycle this task is executed to provide current vehicle mass properties to be used in the AM and HM nominal and abort margin predictions.
- Three-g throttle limiting task. Sets the throttles as needed to maintain 3g acceleration.

1.5.2.8 ARDMSS

The current mass model is used throughout the launch to keep track of current vehicle mass properties such as: total vehicle mass, current SSME fuel remaining in the ET, current OMS prop onboard, and current RCS onboard. The mass model makes extensive use of the propulsion module (ARDPRP) as needed. In addition ARDMSS performs calculations of ΔV available from usable OMS and RCS propellant. It has the capability to recalculate ET prop remaining through the mass recycle subtask, allowing mass corrections for an improved engine-out time, for example. The model can be broken down into a series of tasks.

- Initial ET fuel MED task. This task must be performed when a MED has been made to the initial ET prop weight. This is indicated by the initial weight of ET fuel not being equal to the first weight point in the ET fuel remaining table.
- ET fuel remaining task. Keeps track of current SSME fuel remaining in the ET throughout the launch. It has many steps. The major sections are:
 - Mass track recycle subtask. The purpose of this subtask is to repeat ET fuel remaining calculations over a specified time interval to correct for erroneous mass model inputs. Must be performed whenever the recycle flag has been set and the recycle time is less than the current selected source time.
 - Current ET fuel remaining look-up subtask. The purpose of this subtask is to ascertain the current value of ET fuel remaining based on a stored table of information. This must be executed whenever the current selected source time is not increasing. The ET fuel remaining is calculated by

applying an SSME fuel adjustment and an adaptive guidance weight adjustment.

- ET fuel remaining table generation and control subtask. This function controls the execution of the ET fuel remaining table generation, generates the ET fuel remaining vs. time table, and assigns a value for current weight of ET fuel remaining.
- ET prop remaining adjustment task. This task adjusts the ET prop remaining by subtracting out the current value of ARD FPR.
- Imbalance task (via ARDIMB). This must be performed whenever the thrust limiting flag is enabled (IVLENG = 1). It uses the imbalance model to calculate the current imbalance and set the mass track imbalance flag (LH2 or LOX) for display. The imbalance amount is also corrected for the fuel bias in this task.
- Vehicle base dry weight calculation task. This task determines the correct vehicle current dry weight to be used in the vehicle total weight calculation task. The dry weight at lift-off is adjusted for FPR and the losses at SRB SEP.
- SRB prop remaining task. This task decrements for SRB prop burned in first stage.
- OMS flowrate determination task (via OMSFLO). The flowrate of the OMS and RCS engines are determined for use in the next subtask.
- OMS/RCS fuel remaining task. The current quantity of OMS fuel remaining is obtained by decrementing the initial weight of the OMS fuel by the OMS fuel burned. The aft and forward RCS fuel remaining are handled in a similar way.
- Vehicle mass properties MED adjustment task. Any OMS and RCS MED adjustments are taken into account here.
- Vehicle total weight calculation task. The various components of the mass buildup are summed here. Note that all mass properties adjustments will be zero in the processor initialization. Some MED action is required to effect non-zero mass properties adjustments.
- Usable OMS/RCS fuel calculation task. The purpose of this task is to calculate the usable amounts of OMS and RCS fuel for display purposes. It must be performed for each execution of the mass model.

1.5.2.9 ARDLIN

Linear interpolation function. This is a general purpose function for obtaining a dependent variable value from a table of discrete independent/dependent parameter pairs based on a given parameter value. This function is used extensively throughout the ARD modules. For a detailed description, see the Level C documentation.

1.5.2.10 OMSFLO

The purpose of this task is to determine the total mass flowrate and +X thrust for each OMS/RCS dump engine configuration. There are three configurations: OMS only, OMS for ATO, and OMS plus 24 RCS jets. Manifold valve failures are modeled here, as well as the number of OMS engines failed. Individual RCS jets, AFT or NULL, can also be failed.

1.5.2.11 ARDPRP

Propulsion Model. The function of this model is to calculate the thrust and mass flowrates of the various engines on the shuttle. The subtasks are

- SSME throttle subtask. The throttle setting of each SSME at the time the propulsion model is executed is determined. These settings are used later in calculating the thrusts and fuel flowrates of the SSME. The model operates for both the AM and HM. It uses linear interpolation on the throttle table histories. The throttle setting necessary to maintain 3g using non-locked engines is computed here.
- SSME thrust subtask. The thrust for each SSME is computed by multiplying the desired throttle setting by the thrust of one engine (FNSME or "NOMMETH").
- SSME fuel flowrate subtask. To calculate the fuel flowrate of each engine, it is first necessary to determine the ISP of each engine. ARDLIN is used on a table of ISP vs. throttle setting (SPIM) if thrust limiting is not set. If thrust limiting is set, (IVLENG = 1), then ARDLIN is used on a table of ISP vs. time (the throttle tables). The fuel flowrates are then calculated by dividing the thrust by the ISP times gravity. The flowrates are then combined to yield a total for the three SSMEs.
- OMS and RCS fuel flowrate subtask.
- SRB thrust and weight subtask. The ARD assumes that each SRB operates nominally. A table of SRB weight remaining vs. time and thrust vs. time is generated before the actual launch. ARDLIN is used on these tables to compute weight and thrust during first stage. If in second stage, the weight and thrust are set to 0.

1.5.2.12 ARDANI

Ascent Numerical Integrator Module. ARDANI extrapolates the state vector during first stage to the start of closed-loop guidance just after staging. Vehicle weight and ET propellant remaining at SRB separation are also calculated. The first task performed is the table of body axis command selection function. This selects the appropriate body axis table based upon the number of active SSMEs, enabling the ARD to model nominal as well as engine-out first stage. Various integration initialization tasks are performed for each execution. These tasks include initial SV identification and conversion to Earth-fixed coordinates (using ARDCNV), propellant and dry weights initialization,

calculation of altitude and flight path angle, and determination of the proper integration time step.

ARDANI is one of two main models used by ARDMNE to derive abort margin predictions for both the AM and HM from the selected source vector. It performs all tasks and executes all models required to extrapolate the selected source state vector conditions to conditions at the start of second stage active guidance. The integrator performs the following integration control functions:

- Table of body axis commands selection function. Accesses/selects the appropriate table of pitch and yaw body axis commands based on the number of SSMEs running, and whether the center or a side engine is out.
- Integration initialization function. During each cycle, this function initializes the integration parameters that are to be extrapolated to staging from the proper current values. For a list of the parameters, see the Level C document. The input state vector is converted to an Earth-fixed state vector via ARDCNV. Position and velocity vectors are computed, as well as flight path angle and altitude.
- Integration phasing function. This function determines if the current source time is before or after staging.
- Integration time step schedule function. See the Level Cs for details.
- Integration task and model sequencing.
- Transformation to inertial coordinates function. When the state has been extrapolated to the start of second stage, the state must be converted back to inertial coordinates. This function does this.

The models sequenced by the integrator module are:

- Propulsion model. Provides thrusts and fuel flowrates of the SSMEs, and thrust and weight of SRB prop remaining.
- Aerodynamic model. Provides the aerodynamic forces and pitch moments on the vehicle.

The integration tasks performed by the module are:

- Time step adjustment task. This adjusts the time step, as required, to fall exactly on the time of staging and at the start of the second stage for proper integration phasing, while also decrementing the weight for staging.
- M50 to Earth-fixed conversion task.
- Propulsion system vacuum thrust correction task. The vacuum thrusts obtained from ARDPRP are now corrected for atmospheric pressure by ARDANI.

- Open loop primary thrust vector control task. The cant angles of the SSMEs are used in calculating the acceleration of the vehicle. The cant angles in the pitch and yaw are computed via ARDLIN on a table of angles vs. time. Failed engines are accounted for.
- Aerodynamic and thrust pitch moment balancing task (ARDMMB). The aerodynamic moments and thrust moments of the vehicle are balanced in the pitch plane only (roll and yaw are assumed negligible for the ARD) by adjusting the cant angle of the SRBs. The SRB cant angle is used later to determine the acceleration of the vehicle. The moments necessary to control the attitude of the vehicle are negligible for the purpose of the ARD, as are the moments outside the pitch plane. As thrust tails off near staging, moment balancing is no longer performed.
- Weights and acceleration calculation task.
- Body orientation task. This task obtains the body axis commands and calculates the angle of attack.
- RK numerical integration task. A fourth order RK integrator equation is used to compute the acceleration for the vehicle at the beginning, middle, and end of time step. See the Level Cs for details.
- Re-initialization task. Some of the variables are re-initialized for the next time step.

1.5.2.13 ARDARO

Aerodynamic model. The function of this model is to calculate the aerodynamic forces and moments using the 1962 U.S. Standard Atmosphere. It has the following subtasks:

- Atmospheric properties subtask. The static pressure and speed of sound are determined based on altitude.
- Mach number and dynamic pressure subtask. Calculates Mach number and q -bar.
- Aerodynamic coefficients subtask. A variety of aero coefficients are necessary to calculate the aero forces and moments on the vehicle. These are determined via ARDLIN. For a list of the coefficients, see the Level Cs.
- Pitching moment coefficient adjustment subtask. The coefficients relating to the pitching moment refer to a moment about the aerodynamic reference point (0, 0, 0) in the body axis system. It is the purpose of this subtask to adjust the coefficients to refer to a moment about the vehicle center of gravity (c.g.). The c.g. is computed from the c.g.'s of the vehicle components, and the pitching moment is computed using this and the aero coefficients.
- Aerodynamic forces and moments subtask. The lift, drag, and pitching moment are computed here.

1.5.2.14 ARDMMB

Moment Balancing Task. The purpose of this task is to provide primary vehicle thrust vector control in the pitch plane for predicting vehicle performance and trajectory at the start of active guidance by balancing moments in the pitch plane. The SRB thrust is used to balance moments by varying the cant angle of the SRBs in the pitch plane. The Newton-Raphson (N-R) numerical method is used to obtain an approximate solution for primary thrust vector orientation (SRB cant angle) at any point in the trajectory, based on c.g., SSME cant angles, engine locations, and aero moments. The N-R technique is well behaved and converges rapidly. The vehicle body axis system is used in all calculations of this task. It has the following subtasks:

- Conversion of degrees to radians subtask. The input degree angles are converted and the number of cycles is initialized at 1.
- Accuracy control subtask. Controls the execution of the moment balancing subtask. It ensures that the SRB cant angle correction term falls below a certain allowed value.
- Moment balancing subtask. The moments on the vehicle are computed and summed. The required SRB cant angle correction is then computed.
- Conversion of radians to degrees subtask. The internal radian values are converted for output.

1.5.2.15 ARDCNV

M50 to Earth-fixed conversion subtask. This is an external subtask and is not detailed in this document.

1.5.2.16 ARDSSP

Second Stage Predictor. Performs all tasks and models necessary to predict second stage active guidance performance to MECO and calculate velocity margins for nominal and each abort mode. It supports two types of operation: Type 1 operations are the normal pre-abort selection margin predictions, and Type 2 operations are the second stage post-abort selection monitor and margin predictions. The tasks sequenced by ARDSSP depend on whether Type 1 or Type 2 operations are being performed. Those required to support both types of operation are:

- Prediction mode determination task. This must be executed each cycle before any action is taken by the SSP. This task ascertains which type of predictor operation is required of the SSP.
- PEG launch phase initialization task. The proper parameters are initialized for PEG depending on whether it is first or second stage. The state vector and vehicle weights are set to the appropriate values, depending on whether the data came from ARDANI propagation (first stage flight) or selected source and ARDMSS (second stage).

- PEG SSME parameters input task. The purpose of this task is to assign all PEG SSME related inputs to their value prior to executing PEG. It accounts for AM or HM operation, RTLS flight, and 3g constraints. This includes throttle setting, ISP, flowrate, and thrust.
- OMS/RCS dump definition task. Initializes the various parameters required to define the OMS dump for each SSP mode and dump configuration.
 - Dump parameter initialization task.
 - AM OMS dump definition task.
 - HM Type 2 OMS definition task.
 - PEG engine phase task.
 - Vehicle characteristics save task. The AM thrust and mass parameters are saved for later use by the extrapolation sequencer and for staleness state compensation.
- Nominal PEG mode and abort mode definition task. Sets the PEG guidance mode flag for standard ascent execution of PEG and sets the abort mode indicator to indicate nominal.
 - PEG targets inputs task. The nominal PEG MECO target values are assigned to the general PEG input parameters. This includes first guesses to ensure PEG convergence with minimum CPU requirements.
 - Nominal extrapolation sequencer task.
 - Nominal OMS/RCS burn sequencing task.
 - PEG nominal execution task.
 - PEG parameters save task. PEG output parameters must be saved for staleness compensation, decision delay, and variable IY extrapolation for the next PEG cycle.
 - Nominal velocity margin calculation task (ARDDLTV). Provides the SSME velocity margin prediction for nominal based on the nominal PEG VGO prediction.
 - Nominal post-MECO DV adjustment task. Computes the available post-MECO ΔV for nominal and computes the total velocity margin.
- ATO PEG mode and abort mode definition task. Sets the PEG guidance mode flag for standard execution of PEG and sets the abort mode indicator to indicate ATO.
 - PEG ATO inputs task. This includes first guesses to ensure PEG convergence with minimum CPU requirements.

- ATO extrapolation sequencer task. Checks to see if variable IY is being executed, among other things.
- PEG ATO velocity dependent target inputs task. The PEG general input parameters are set to the appropriate ATO abort MECO targets.
- ATO OMS/RCS burn sequencing task.
- PEG ATO execution task. The PEG module must now be executed for an ATO second stage guidance performance prediction.
- PEG parameters save task. The PEG output must be saved for subsequent use on this ARD cycle and for the next ARD cycle.
- ATO velocity margin calculation task. Provides the SSME velocity margin prediction for AOA based on the AOA PEG prediction.
- ATO post-MECO ΔV adjustment task. Computes the available post-MECO ΔV for ATO and computes the total ATO velocity margin.

Section f sequencing is basically repeated for AOA, TAL, and RTLS. There are some fairly detailed differences on the RTLS task sequence. See the Level Cs for details.

- ARDADI vehicle state reset task.

Two internal procedures are sequenced by the ARDSSP:

- OMS/RCS burn sequencing task. This is executed once per each abort mode when the CALDMP flag is off. This task determines the OMS dump start and stop times, the dump contribution to the thrust and mass flowrate, and the length of the first PEG burn phase.
- SSP velocity margin subtask. This task determines the velocity margins for each abort mode. If it is a TAL abort, the extrapolation for minimum droop altitude and VGO correction is also performed.

1.5.2.17 OMSPHA

OMS phasing task. Calculates the time average thrust and mass flowrate of the remainder of the OMS/RCS dump. It also calculates the time of the end of the dump. See the Level Cs for more detail.

1.5.2.18 OMSMDL

OMS modeling task. This task establishes the start and stop times of the OMS and RCS engines for both automatic and contingency dumps. It is called from both ARDMNE and ARDSSP. See the Level Cs for more detail.

1.5.2.19 ARDDL

General velocity margin subtask. Computes SSME velocity margins based on PEG outputs. Imbalance quantities and fuel bias are accounted for. The ΔV s for four thrust phases are summed. MCC1DL and MCC2DL are applied here as correction terms.

1.5.2.20 ARDADJ

Post-MECO DV adjustment task. Calculates the ΔV available post-MECO from any excess OMS fuel that may be remaining at MECO. This post-MECO ΔV and the sum of this and the pre-MECO SSME ΔV margin are displayed cyclically on ARD OUTPUT for abort decisions.

1.5.2.21 OMSBRN

OMS Burn Task. Calculates the OMS fuel burned up to TMCALL, first during the automatic dump, then during the contingency dump. This model also validates MED inputs, modifies the timers for the automatic dumps, and calculates the time remaining in the OMS dump. This routine is called by ARDMSS every pass. Single engine roll control is accounted for.

1.5.2.22 ARDVIY

Variable IY determination task. Determines the correct IY vector to be used in making an AOA or ATO abort prediction. The SSP calls this task if variable IY execution is desired. The vectors are extrapolated to account for decision delay.

1.5.2.23 VARIY

Variable IY extrapolation subtask. Performs a linear interpolation of the state vectors used in calculating the IY vector that will be used in ARDPEG based on the time and on the velocity, position, and acceleration vectors currently in ARDSSP. This extrapolation accounts for the delay between the time of engine failure and the time an abort is actually selected in the variable IY calculations. Note that this task is only invoked when the decision delay extrapolation sequencer option is not being used.

1.5.2.24 ARDXTP

ARD extrapolation sequencer. Handles all decision delay and tail off modeling for the ARD. The input state is the current state used by ARDSSP. The output state, used by PEG in ARDSSP to determine the abort margins, is compensated for engine-out tail off and any decision delay required. The delays modeled are:

- Engine-out tail off, modeled as a very short ramp function rather than a step function or protracted tail off.
- Abort declaration decision delay or abort downmoding decision delay (ATO to TAL).
- TAL or RTLS target reselect decision delay.

- Throttle-up decision delay.

The tasks sequenced by the ARDXTP are:

- First pass setup subtask. Turns the AM and HM first pass flags on or off.
- AM initial pass operations subtask. This task is executed if the AM first pass flag was turned on above. Otherwise, proceed to next subtask.
- AM extrapolation sequencing subtask. This task performs the AM decision delay extrapolations for both type 1 and type 2. This subtask is executed if this is the actual mode and the AM decision delay flag has been set.
- HM initial pass operations subtask. The purpose of this subtask is to determine the number of active engines in the HM and determine if the decision delay is required in the HM. If the HM first pass flag is set, execute this subtask. Otherwise, proceed to the next subtask. The task checks to see if constant thrust or constant acceleration equations should be used.
- HM extrapolation sequencing subtask. Sequences the HM tail off and decision delay extrapolations. If the HM first pass flag is not set, exit this subtask.

The third and fifth subtasks are generic utilities.

1.5.2.25 EXTRAP

ARD extrapolator utility. The function of the extrapolator model is to propagate an input vehicle state forward through a given delta time to a new output state. This model can also extrapolate a state backwards from an initial state by inputting a negative delta time. The model assumes a constant thrust direction during the propagation. It has several parts:

- Thrust integrals determination
- Thrust vector direction
- Position and velocity gained due to thrust calculation
- Position and velocity gained due to gravity calculation
- Final state calculation

For further details of this standard utility, see the Level Cs.

1.5.2.26 ARDDRP

ARD TAL Droop model. This task is called from ARDSSP in the TAL channel. It determines whether or not the conditions are such that a minimum droop prediction or VGO correction is necessary. The altitude and time of minimum droop are predicted based on this propagation. It has the following subtasks:

- ARD TAL droop activation subtask. A matrix of rules determines whether or not to execute further.
- ARD droop initialization subtask. Initialize parameters.
- Droop altitude loop initialization subtask.
- Droop altitude determination subtask. The vehicle state is propagated forward in time to get a prediction of the minimum droop altitude and time of minimum droop. Either the droop control task or PEG is called once each pass to determine the thrust direction parameters for the propagated state. This model has the following sections, which are executed in sequence:
 - Thrust attitude determination subtask. The task may determine the commanded thrust attitude, and will determine whether it should continue to determine the thrust attitude or hand control over to ARDPEG.
 - State extrapolation subtask. Calls EXTRAP.
 - Aero force compensation subtask. Modifies the vehicle position and velocity to account for aero forces if necessary.
 - Vehicle state update subtask. Updates the MPS weight, vehicle weight, guidance phase flag, acceleration, VGO, and altitude.
 - Minimum altitude check subtask. Will set the minimum altitude found flag. See Level Cs.
 - Exit subtask. End the task if certain conditions are met. See Level Cs for the exact conditions.
 - PEG execution subtask. Set the PEG TAL targets to their low energy values if required.
- Solution output task.
- PEG reset subtask. Reset the value of the PEG initialization input flag, turn initialization of ARDPEG back on, and reset the PEG convergence criteria.

1.5.2.27 DRPCTL

Droop control task. The main task of this section is to modify the commanded thrust direction, trading velocity for altitude in order to stay above a target altitude. It has four subtasks.

- First pass initialization subtask. Self-explanatory.
- State parameters subtask. Determines the various state parameters and engine performance parameters required by the droop predictor subtask. It is executed only if the minimum altitude reached indicator (SMNALT) is off.

- Control loop subtask. Is executed as a loop. This task is executed only if the minimum altitude found indicator is off.
 - Control determination. Determines the predicted minimum droop altitude for the current thrust attitude, then determines if the minimum altitude has been reached and if this task should change the vehicle thrust attitude.
 - Steering parameters. Changes the PEG steering parameters as required to reach or remain above the desired altitude. This task is performed only if the command droop flag is on.
- Droop predictor subtask. Predicts the minimum altitude and the time when it will be reached given a predetermined thrust, thrust attitude, and vehicle state. It uses an N-R iteration loop.

1.5.2.28 FHRALT

Fischer altitude task. The task returns an altitude above the Fischer Ellipsoid. The only input is an inertial position vector.

1.5.2.29 ARDFOR

Fuel-oxidizer ratio model. Normally, the ARD keeps track of only the total propellant flowrate. However, if there is a known MR upset, this task is used to calculate the LOX and LH2 flowrates separately. It then sums the difference of LOX or LH2 burned with the mixture ratio imbalance. It calls ARDVLM to look up the ISP, and MR for each engine at the given time.

1.5.2.30 ARDIMB

ARD imbalance model. This task takes the change in the LOX burned, the change in the LH2 burned, factors in the fuel bias, and comes out with a number representing the unusable propellant caused by the MR dispersion. In a changing MR situation, in which both a LOX and an LH2 unusable can build up, a portion of one can be burned with the other until it depletes. The task accounts for all of this.

1.5.2.31 ARDVLM

ARD valve limit MED model. This is used to look up the MR and ISP from the input MR and ISP vs. time tables for each SSME at the time passed by the calling routine. These tables and this task are used only when thrust limiting is enabled. Three MRs and ISPs are returned using ARDLIN.

1.5.2.32 ARDPEG

ARD powered explicit guidance. ARDPEG is the ARD version of the onboard PEG, a general purpose guidance task that computes the reference thrust vector, desired thrust turning rate vector, reference thrust vector time, velocity to be gained, and TGO to target conditions for explicitly guided SSV exoatmospheric maneuvers. The purpose of PEG is to provide iterative steering and throttle commands so that the shuttle will

achieve MECO targets with minimal propellant usage. (For more on PEG, consult Ascent Guidance and Flight Control Training Manual ASC G&C 2102). ARDPEG emulates onboard computations to compute VGO. VGO is then compared with current ΔV capability in the velocity margin subtask to calculate the margins.

ARD uses PEG in its one-call predictor mode to analytically predict second-stage performance to MECO or to PPD for RTLS. ARDPEG is sequenced by the SSP. There are two modes:

- Mode 1 - Standard ascent. This mode is intended for use during the second-stage ascent phase. This covers nominal, ATO, AOA, and TAL. Target conditions are specified preflight and defined by a desired terminal velocity (or range-velocity target line for TAL), flight path angle, radius (altitude), IY vector, and TAL crossrange. The inclination and node constraints are implicitly specified by the IY vector, which is a unit vector normal to the desired orbital plane. Thus, all components of the terminal state are specified except the downrange component of position; this is computed such that the VGO is minimized. An equivalent way to state this is that propellant usage is minimized.
- Mode 5 - RTLS. For use during an ascent that will become an RTLS profile. The target conditions at PPD are a preflight specified radius (altitude), a desired terminal velocity which is a function of range (target line), a desired terminal flight path angle, a desired terminal mass, and a bias to move the return flight heading for ET impact considerations. The return flight heading is specified by a unit vector normal to the plane defined by the burnout position and launch site position vectors.

Major differences exist between onboard PEG and ARDPEG. The onboard PEG is not allowed to iterate (i.e., cycle through the PEG logic multiple times during one call) to achieve a converged PEG solution. The ARDPEG iterates until a converged solution has been reached or until a maximum number of iterations has occurred. Both PEGs assume three burn phases for the time-to-go and thrust integrals calculations. These are two constant thrust phases and one constant acceleration phase (3g limiting). However, the ARDPEG uses the first constant thrust phase to account for the pre-MECO OMS/RCS dumps on the aborts and does not have the same three-phase PEG capability that the onboard PEG has. The onboard PEG is set unconverged if the turning rate limit is exceeded, but the ARDPEG does not do this. The ARDPEG does not output steering commands, so it does not need a steering inputs update task. The ARDPEG does not compute RTLS flyback throttle settings that the onboard PEG does. This results in the ARD operators (ARD SUPPORT and TRAJ) having to “chase throttles” for proper mass track during flyback. In addition, ARDPEG models pre-MECO OMS/RCS dumps more accurately than onboard guidance. Onboard assumes the extra thrust from the dump occurs continuously from dump start to MECO, while ARDPEG models the thrust over the actual dump time span, which is more realistic. This results in ARD versus onboard MECO time predictions not comparing well during dumps. The complexity of ARDPEG is beyond the scope of this section. For a detailed

description of the functional flow of ARDPEG, see the Level Cs. This includes the description of the precise predictor.

1.5.2.33 ACCEL

Acceleration function. This function is called by the precise predictor. It determines the gravitational potential model to be used. The ARD does not use the J2 term.

1.5.2.34 Earth-Fixed-to-M50 Function

Provides a transformation matrix from Aries M50 coordinates to Earth-fixed coordinates that accounts for the nutation and precession motion of the Earth. See the Level Cs for the exact formulation.

1.5.2.35 RAPALS

RTLS/TAL approach and landing selection task. The purpose of this task is to compute the appropriate landing site parameters for RTLS and TAL. For TAL, the landing site position is calculated based on the runway selected; no other calculations are required. For RTLS, the HAC position, distance around the HAC, and a parameter indicating which HAC was selected are computed based on the runway selected and on the Overhead TAEM Targeting (OTT) selection flag. The complexity of RAPALS is beyond the scope of this section. For a detailed description of the functional flow of RAPALS, see the Level Cs. This includes the description of the precise predictor.

1.5.2.36 ARDADI

Attitude direction indicator task. This is executed once each cycle for the AM only. The commanded vehicle attitude for the currently selected abort or nominal mode is determined. This attitude is displayed in a yaw-pitch-roll sequence in LH coordinates, based on the nominal IY I-loads. The calculated yaw attitude represents commanded yaw with respect to the desired insertion plane, and is the attitude that should be flown on the onboard HSI. The pitch and roll are the desired attitudes that should be flown on the onboard ADI, since it drives the yaw to zero for ascent, RTLS, and entry modes. ARDADI should be called by ARDEXC in the AM after ARDMNE and prior to ARDBUF. ARDADI has the following subtasks, which are self-explanatory:

- Initialization task.
- Total vehicle c.g. determination task.
 - Remaining fuel and oxidizer subtask
 - ET c.g. determination task
 - Vehicle c.g. determination task
- Body-frame average thrust direction task. Computes an average thrust direction unit vector, expressed in the body-centered axis frame, based on the gimbal position vectors and the calculated vehicle c.g.

- M50-frame thrust direction task. Uses PEG parameters or RTLS event predictor parameters or TAL droop parameters to calculate a thrust direction vector in the orbiter coordinate system.
- Vehicle orientation task. Determines the commanded roll attitude as heads-up or heads-down depending upon the currently selected abort mode, the current time, and the current velocity. No indication is given for any attitude between heads-up and heads-down. It has the following subtasks:
 - Relative velocity determination subtask. Calculates the relative velocity of the vehicle with respect to the rotating Earth, expressed in M50 inertial coordinates.
 - Roll command initialization subtask. Initializes the right wing commanded roll attitude flag to heads-down. This value is retained for nominal, ATO, and AOA.
 - TAL subtask. Checks to see whether a roll to heads-up should be performed if a TAL has been selected.
 - RTLS subtask. Checks to see whether a roll to heads-up should be performed, if an RTLS has been selected. Basically, before PPA, command heads-down. After PPA, command heads-up.
 - Roll reference vector determination subtask. Calculates a unit vector perpendicular to the plane of travel of the vehicle in the outward right wing direction.
- Matrix determination task. Forms a commanded-body to LH transformation matrix from which the Euler angles for a pitch-yaw-roll sequence can be extracted for the desired body attitude. It has the following subtasks:
 - Inertial matrix subtask
 - Body matrix subtask
 - Commanded body to inertial matrix subtask
 - Inertial to LH matrix subtask
 - Commanded body to LH matrix subtask
- Euler angle determination task. Extracts the commanded Euler angles from the body-to-LH matrix in a yaw-pitch-roll sequence.

1.5.2.37 MECO PRED

MECO state predictor. This task determines the MECO state for each abort mode in both the HM and the AM, with the exception of RTLS. The output of this task is a table of MECO conditions for each mode. This task must be executed immediately after each

execution of the ARDDL task, except for the RTLS modes. It has the following subtasks:

- Guided MECO mass subtask. Calculates the final mass of the vehicle and ET propellant remaining at the PEG guided MECO state. Note that the FPR is considered usable propellant for these subroutine computations.
- Low-level MECO subtask. This task adjusts the MECO state back to the point of low-level cutoff if necessary. This task is executed only if the guided MECO remaining propellant is less than the minimum propellant for low-level cutoff.
 - G-limited trajectory. If there is a constant acceleration burn phase, then extrapolate the state backward to either the low-level cutoff point or to the constant thrust phase, whichever comes first.
 - Constant thrust trajectory. This task extrapolates the state backward through the remaining constant thrust phase.
- State output subtask. Outputs the predicted MECO state and related parameters in a table as a function of abort mode and ARD cycle.

1.5.2.38 ARDDSP

ARD output task. This task is responsible for the maintenance and provision of an output display device and of the ARD AM and HM parameters. Once per ARD cycle, the output task must provide the output display with a complete set of parameters. The throttle settings must be converted from simple fractions to percents for display purposes. Once per launch, a subset of parameters must be output to the AME. This transfer must be affected upon selection of the MECO PBI. This task also suppresses the display of the other computation channels when a particular abort mode is chosen via PBI.

1.5.3 Tracking Data and Telemetry

The ARD only requires an accurate shuttle SV position and velocity data for trajectory evaluation. It does not require any downlisted SSME, SRB, ET, OMS, or flight control parameters to operate. The SV can be provided by either ground radar tracking or Onboard (O/B) TLM downlist. The FDO may select (via PBI) either of these; the one in use is referred to as the SS, and an indicator is displayed on the ARD OUTPUT display. The ARD was intentionally designed this way so that the MCC could retain abort mode evaluation even if part or all of the telemetry stream was lost during flight.

The on-board telemetry state vector is used by various trajectory processors that utilize several front-end processors in the server. As the telemetry stream is routed into the server, the onboard state vector is stripped out and routed to the Telemetry-to-Trajectory Interface Table (TTIT), which is used as a buffer for all trajectory related telemetry, and is made available to any trajectory processor that needs the data. The onboard vectors are stored in the TTIT at the rate of one every second. The ground-based tracking site data, which include C-band skin track radar and S-band telemetry tracking data (antenna pointing angles), are routed into the server via the launch and landing interface unit (LLIU) at the rate of 10 observations per second, per site. The data are then gathered together by the high-speed input processor (HSIP) that performs data verification and conversions. The HSIP then queues the next trajectory processor at the rate of once per second. The launch and landing trajectory determination processor (LLTD) has the task of taking the C-band and S-band tracking observations from the HSIP and applying them to the Kalman filter algorithm so that a best estimate of the current state of the Space Shuttle, the FLTR vector, may be calculated. The LLTD also calculates standard deviations (σ) that reflect the accuracy of the incoming tracking data, an important device for determining the validity of the FLTR vector and whether it or the TLM vector should be used as the selected source for the ARD. Either of these vectors can be made available to the ARD as the source for ARD computations. Since telemetry data is supplied to the ARD every 6 seconds, the filter is usually selected, since it is updated more often. Refer to Figure 1-9 for a diagram of ARD data flow.

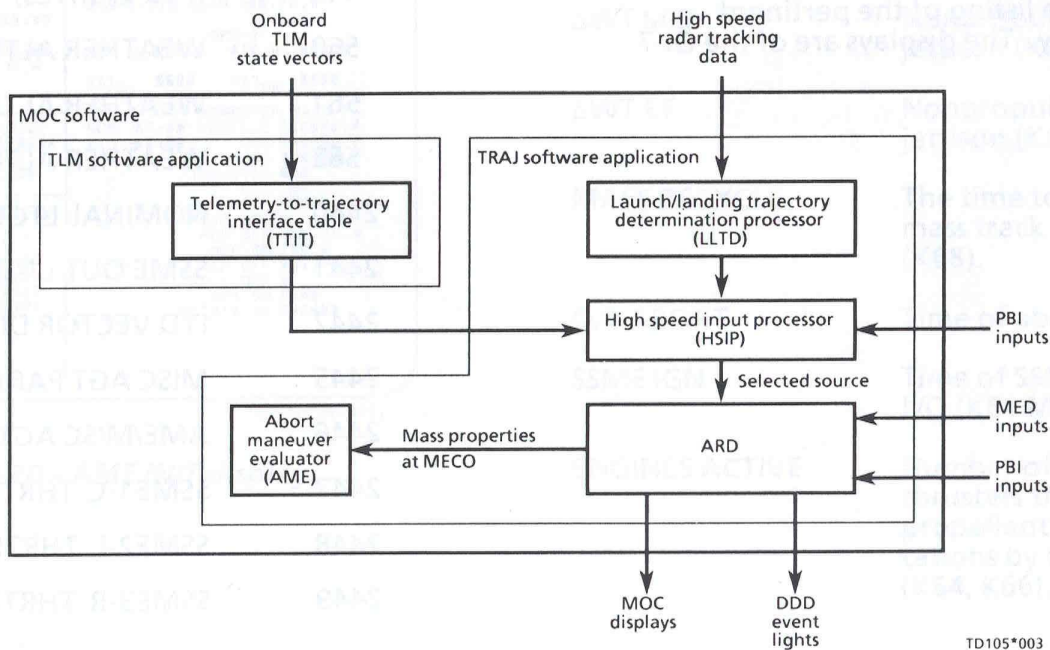


Figure 1-9. ARD data flow

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2 OFF CONSOLE ACTIVITIES

2.1 ASCENT/ENTRY DATA PRODUCTS MANAGEMENT

Many different products from Flight Design are required for the FDOs (ascent, orbit, and entry) to be able to perform their on-console tasks. Other products are required for ARD maintenance tasks or for ascent/entry trainer database configuration. It is the job of the ARD Support engineer (referred to as ARD Support from now on) to verify that all the products have been retrieved from the Flight Analysis and Design System (FADS) system, and to notify the Ascent FDOs that they are available.

2.1.1 Product Descriptions and Delivery Schedules

The United Space Alliance (USA) Flight Design Department delivers a set of data products for each flight design cycle. The ARD Support staff is on “electronic distribution” to receive mail through the FADS system to PC mail, notifying them when many of these products have been electronically delivered to the master storage area on FADS. Along with notification, specific products documented in the “Ascent FDO Electronic Datapack” in Appendix D.15 are also mailed to designated ARD Supports. The products are grouped in categories of mission phase (i.e., ascent, on-orbit, and descent). The ascent products (and some of the descent products) are used by the Ascent FDOs on console and by ARD Support to produce other console data products for ARD Support and the ascent FDO’s use. Some of the products are used to verify that the Trajectory Server (TRS) database is loaded correctly, and others are used to make “calls” or provide “heads-up” information for the ascent phase of a mission.

Figure 2-1 provides an overall picture of the ARD Support Ascent/Entry Data Products Management Task. The diagram shows the source of the products and what the ARD Support does with them. The pentagon-shaped polygons signify a data product source, and the square boxes indicate some action performed by the ARD Support.

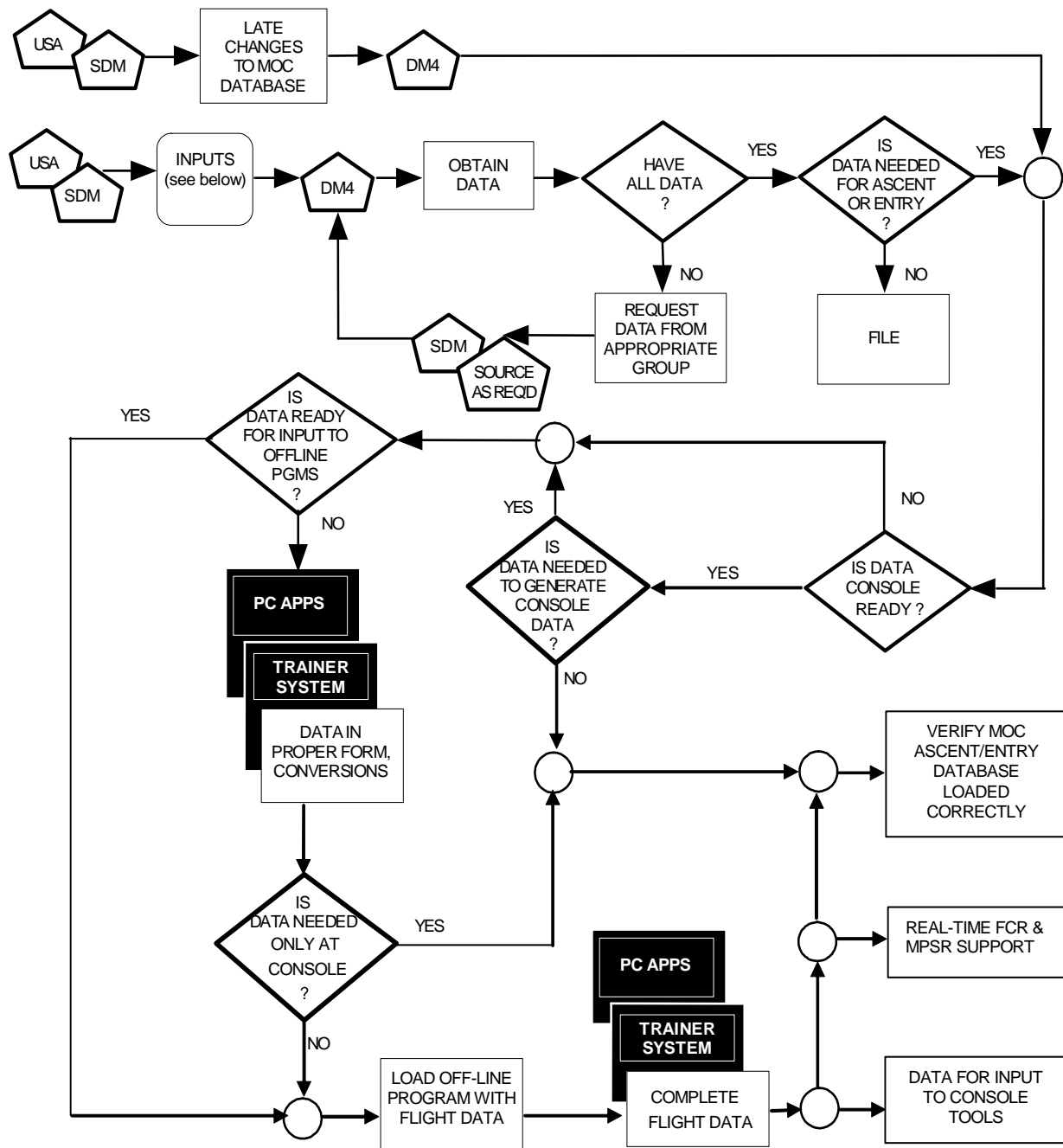
ARD Support should be familiar with all the products and what they contain. A complete list of the products collected from FADS can be found in Appendix D.15.

Table 2-1 lists and describes all the pertinent data products that the ARD Support receives. When a product is delivered, it is stored electronically in

S:\Divisions\DM\Private\DM46\ARDSTUFF\PROD.

Each flight and cycle has its own directory. The following abbreviations are used to reference products:

- ASAB: Ascent/Abort
- DATA: Schedule & Data Management
- ASCT: Ascent
- DSCT: Descent



INPUTS						OUTPUTS
ASAB 20	ASAB 43	ASCT 22A	DATA 40	DSCT 23	TDDP	Console Support: • Ascent Events • Reformatted data • Inputs for computer tools both on console & off-line
ASAB 23	ASCT 06	ASCT 47	DATA 41	DSCT 26	SRB performance data element	
ASAB 25	ASCT 08	DATA 12	DSCT 05	DSCT 28	I-Load element	
ASAB 28	ASCT 17A	DATA 22 A&B	DSCT 06	DSCT 30		
ASAB 30	ASCT 21	DATA 39	DSCT 13	DSCT 41		

Figure 2-1. Ascent/entry data products management task overview

Table 2-1. FDO/ARD support data products

Product name	Name	Description
ASAB 16	Abort Mode Boundary Bar Chart	A graphical display of the abort mode boundaries for RTLS, TAL, Press-to-ATO (PTA), and Press-to-MECO (PTM).
ASAB 20	FDF - OMS Crew Charts (All Sites)	Contains inputs for the Flight Data File (FDF) and the Ascent Checklist. The crew chart product consists of the OMS and aft RCS AOA budget sheets, the post-MECO options sheet, the AOA/ATO zone target chart, the expected OMS-1/OMS-2 delta Vs for MECO underspeeds, and the mission-unique underspeed graphs. The crew chart also provides OMS-2 performance data for the target cue cards.
ASAB 20A	Rendezvous Recovery Chart	Rendezvous Recovery Chart
ASAB 23	FDF - Ascent Mode Boundary Velocities	A flight-critical product used for crew training, ARD Support, and in the FDF/Ascent Checklist. It contains a table of velocities and times in MET of various abort mode boundaries.
ASAB 25	ARD Bias Tables	Contains tables of ARD bias values used in making MCC abort calls.
ASAB 28	FDF - Stuck Throttle Performance	Contains a graph that shows engine failure capability and commanded throttle setting for another engine having a stuck throttle. The capability is supplied for both RTLS and TAL aborts.
ASAB 30	FDF - OMS TGT Table for AOA to All Sites	Consists of all post-MECO OMS Targets (TGTs), their corresponding delta Vs, apogee ranges, and location both onboard and in the AME for the prime landing site.
ASAB 32B	AME MCC Support Tables	Mass properties data sheet. Includes WCGNOM, WCGATO, WCGAOA, and WCGSH.
ASCT 03	Ascent/Entry Trainer Inputs	Contains ascent data for the Trainer ARD and Spacecraft Trajectory and Mission Planning System (STAMPS) simulation (sim).

Product name	Name	Description
ASCT 06	Nominal (NOM) Delta Vs & State Vector	Consists of event summary tables that display Earth relative and Mean of 1950 (M50) orbital parameters from MECO through major mode 106 (post-OMS-2).
ASCT 08	ILOADS - Nominal and Abort	Consists of initialization load (I-load) parameter values. It consists of categories and occurrences organized by discipline.
ASCT 17A	Nominal Ascent Data (Pre-MECO)	ASCT 17A contains the nominal aerodynamic display data and the nominal trajectory display data.
ASCT 21	Ascent Limit Lines	Contains ascent limit lines (range safety boundaries) in tabular format.
ASCT 22A	ARD MCC TRAJ Inputs & Support Tables	Consists of Adaptive Guidance Throttling (AGT) table, ICD data (subset of DATA-22A/B) listing throttle tables, system parameters, landing site information, zero margin weights, ISP reserve, thrust reserve, and FPR buildups for both AOA and RTLS, mainstage weights, ARD loading summary, & nominal margin.
ASCT 44	DOL Uplink I-Loads	DOL Uplink I-Loads
ASCT 47	Final ARD MCC TRAJ Inputs & Support Tables	DOL version of ASCT 22A
ASCT 99	OMS Assist – ATO Update	DOL OMS Assist Iloads
DATA 12	Shuttle Mission Simulator (SMS) Datapack	Contains vehicle summary weight statement, weights at critical mission points, ascent wind reference, SRB ignition time, launch pad ID, ascent aero wind reference, EI-20/10 state vector display, descent aero reference, and gimbal angles.
DATA 22A & 22B	MCC SERS Data (System Parameters & MEDCVs)	A merged set of existing data products (ASCT 22A, ASCT 22B, DSCT 24, DATA 20) that have been successfully accepted by Shuttle Equipment Record System (SERS).
DATA 39	Trajectory Array Report	Consists of a printout of the trajectory parameters that are used by the MCC trajectory processors.

Product name	Name	Description
DATA 40	Old/New Compare Report	Contains a report of all MCC parameters that have changed value between old and new versions of the TRS software.
DATA 41	System Parameters	Consists of a printout that contains current baseline and specific flight system parameter updates.
DSCT 04	Approach and Landing ILoad	Consists of approach and landing Iloads.
DSCT 05	Maximum Crossrange	Consists of a table of maximum entry crossrange capability for different approach directions.
DSCT 13	Deorbit Targets (EOM)	Contains data used to verify and check out the EOM deorbit targets. This product contains L - 100, time of ignition (TIG), EI - 5 and EI state vectors, deorbit target parameters, prime and backup solution displays, DMT and General Attitude and Pointing (GAP) displays, first guess ENG cycle and FLT cycle, and range.
DSCT 17	DDS LST	Contains the DDS LST used in EDS
DSCT 28	Recovery PreBank	Contains recovery prebank curves and tables.
DSCT 30	Target Summary Sheet	Contains EOM, Day 1 and ATO delta Vs, and deorbit targeting parameters.
DSCT 35	Ascent/Entry Trainer Data	Contains descent data.
DSCT 36	EOM Groundtrack Data	Contains EOM groundtrack data.
DSCT 41	LAST TAL Boundaries	Contains the last TAL site for use in the Ascent Events Summary.
DSCT 66	EDS Element File	Contains the EDS elements file
NAVO 10	Landing Site Table	Contains landing site table information.
NAVO 16	SAIL Nav Data Pack	Contains SAIL nav data pack.

Product name	Name	Description
NAVO 16a	SPOC Inputs	Contains SPOC inputs.
NAVO 16b	GPO Command Off the MCC (COTM) Data	Contains GPO Command Off the MCC (COTM) data.
ONOR 29A	Rendezvous Init State Vectors	Contains target state vectors used to generate RNDZ01B.
PROP 02	Sequential Mass Properties	OMS/RCS Prop systems analysis.
PROP 05	MCC Initialization Data Points	Consists of vehicle component weights and c.g.'s.
PROP 31	ARD Data	Contains L-7 vehicle weights, c.g.'s, and loadings.
PROP 34	MCC Data	Consists of vehicle weights, c.g.'s, moments of inertia, and products of inertia at critical mission points.
RNDZ 01B	Rendezvous and Proximity Operations	Consists of phase angle limits for rendezvous and proximity operations.

Note that all product delivery due dates follow one of two generic schedules. For first non-ISS flights, and ISS flights with a new OI, the BASE schedule is used. For ISS flights flying an OI that has flown before, the ISS schedule is used. Note that in the ISS schedule several products have planned redelivery dates. This is all intended to “standardize” ISS flights. Regardless of the schedule used, the cycle is usually referred to as OCF (“One Cycle to Flight”).

Schedules for specific flights can be found at

\\Usahouu4\data\Shared\SDMSCHEM\StsXXX

where XXX is the flight number.

2.1.2 Product Retrieval from the FADS System

A FADS UNIX script has been created to help ARD Support in determining if any new products from the “Ascent FDO Electronic Datapack” list have been delivered. The script also emails new products to PC mail for a designated person or persons. The script is run as a cron job and there is usually no need to run it manually. However, if necessary the script can be obtained from an experienced ARD Support.

Additionally, there is an automated product retrieval system on FADS called MEDIA. It makes product retrieval almost as easy as clicking a button. However, the ARD Support is expected to know the basics of navigating on the FADS system. This is useful in searching for products, working around MEDIA problems, and other things. If you do not have a FADS account, call the Help Desk at 281-282-2841. The developer of MEDIA, USA/Bill Bass, can also offer classes on how to use it (with advanced notice). Follow the steps listed below to retrieve products.

- 1) Once in FADS, start the MEDIA application. See an experienced ARD Support for instructions on how to set up a UNIX alias to execute MEDIA. It is also useful to have a window open to the directory below. Using the UNIX commands "ls" or "ll" in your window, check each of the flight directories to see what products have been delivered. The available directories under any particular flight may be: CFP, ENG, FLT, FRR, LDP, PATCH and OCF, OCFR1, OCFR2, etc.

`/fads/msn/mds/mastdyn/fltcyc`

- 2) Figure 2-2 shows the MEDIA menu. Fill in the "Flight" and "Cycle" boxes at the top of the menu. To list all products under this path, press the "Get Products from Directory" button on the right side. A scrollable list of delivered products will appear. If you already know which product you want, you can fill in the "Product Name" box at the top.
- 3) Either way, the next step is to press the "Get File Information" button. MEDIA will then retrieve all the different files that may make up one particular product and display that list in the box below the button.
- 4) To print the entire product, including the Product Tracking Form (PTF), press the "Write Files to Paper" button. The product should appear at the printer specified under "Set Defaults." You may change the printer if you wish. MEDIA will also display a message box to inform you of the status of the print request. If MEDIA and FADS are working correctly, this is all you have to do to retrieve a product.
- 5) Repeat for each product you need. If you have problems, check with another ARD Support or call the Help Desk.
- 6) When finished, choose Exit from the File pull down menu. Then log off of FADS.

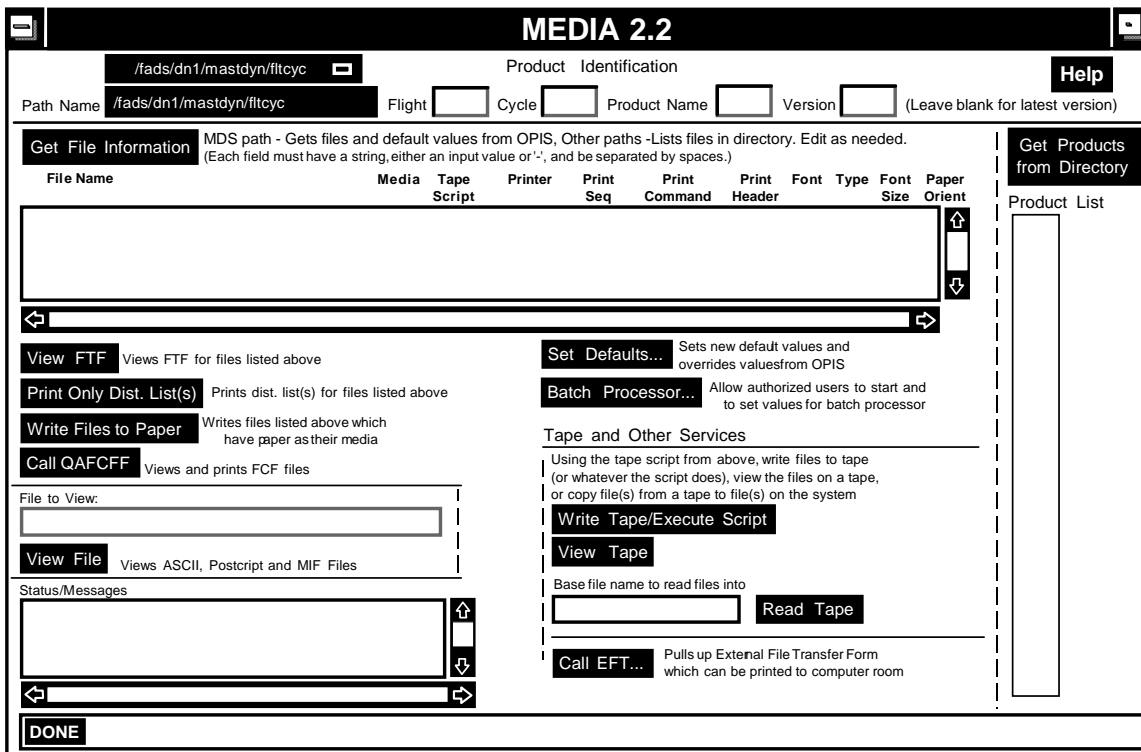


Figure 2-2. MEDIA 2.2 Menu

2.1.3 FDO Data Packs

Leading up to the Integrated Load Checkout (ILC) or day-of-launch (DOL), all products listed in the Ascent FDO Electronic Datapack (see Appendix D.15) should exist in the S:\...\ARDSTUFF directory. Finally, the OMS propellant and Main Engine data are obtained from the PROP and BOOSTER officers. This data is not available on FADS. This data should be available to the Ascent FDO and TRAJ in advance of the ILC or DOL.

2.1.4 Trajectory Matrix Update

The Trajectory Matrix Update is a table published in the mission-specific Flight Rules Annex. The ARDs help the Orbit FDOs fill it out. The Orbit FDOs will provide the version they want filled out (there seem to be several floating around). Get help from FDO, Targeting, or PROP, if you need it.

This task is a low priority for ARD Support; it often comes very early in the product/sim flow. All the products are not in, and the numbers are not firm yet. The driver is an Annex publication deadline, which is usually very early. A completed matrix is shown in Figure 2-3.

NASA - JOHNSON SPACE CENTER		
FLIGHT RULES		
<u>TRAJECTORY AND GUIDANCE</u>		
X4.1.2-1 <u>SHUTTLE TRAJECTORY AND GUIDANCE PARAMETERS</u>		
STS-101 FLIGHT SPECIFIC TRAJECTORY AND GUIDANCE PARAMETERS AS THEY RELATE TO THE GENERIC FLIGHTS RULES ARE LISTED IN THE FOLLOWING TABLE:		
RULE REFERENCE	PARAMETER	VALUE
ALL	NOMINAL THROTTLE	104.5%
ALL	ABORT THROTTLE	104.5%
ALL	MAX THROTTLE	109%
ALL	THRUST BUCKET	72%
{A4.1.2-6}	DELTA V ABOVE AFT PRESS QTY	77 FPS
{A4.1.1-1A}	2 SIGMA + MEAN INFLT FPR	2527 LB
{A4.1.1-1B}	3 SIGMA + MEAN INFLT FPR	3783 LB
{A2.1.2-2}, {A4.1.2-6}	MINIMUM HP	85 NM
{A4.1.2-6}	DESIGN MECO UNDERSPEED	265 FPS
{A4.1.2-6}	CRITICAL MECO UNDERSPEED 1 ENGINE OUT	691 FPS
	CRITICAL MECO UNDERSPEED 2 ENGINES OUT	673 FPS
{A4.1.2-8}	NOMINAL	40 FPS
{A2.1.4-5B}	UNDISPERSED CROSSRANGE:	
	ASCENDING/LEFT	837 NM
	ASCENDING/RIGHT *	N/A
	DESCENDING/LEFT	836 NM
{A4.1.3-7E}	DISPERSED CROSSRANGE:	
	ASCENDING/LEFT	775 NM
	ASCENDING/RIGHT *	N/A
	DESCENDING/LEFT	774 NM
	DESCENDING/RIGHT *	N/A
{A4.1.4-9}	CONTINGENCY PAYLOAD RETURN AFTER ORBIT 3	N/A

* ALL RIGHT TURN APPROACHES TO CONUS SITES ARE WITHIN CROSSRANGE CAPABILITY.

Figure 2-3. Trajectory Matrix

The source of each piece of information is as follows:

- Nominal Throttle: Maximum SSME throttle setting during nominal powered flight. Found in the Level A Groundrules and Constraints (G&C), delivered throttle tables, asct08.iloads (THROTT(4)), etc. Usually 104 or 104.5 percent.
- Abort Throttle: Maximum SSME throttle setting during intact aborts. G&C, asct08.iloads (KMAX). Usually 104 or 104.5 percent.
- Max Throttle: Maximum SSME throttle setting for contingency aborts. G&C, asct08.iloads (KMAX2). Usually 109 percent.
- Thrust Bucket: Self-explanatory. G&C, asct08.iloads (THROTT(3))
- ΔV available above Aft Press Quantity: Aft RCS ΔV that is assumed to be usable in making “press” calls. Protects either AOA steep or ATO/MIN HP with a FD 1 shallow deorbit. The correct value to use can be found as follows:
 - Determine Press Trajectory by looking in asab20.ccht.asc notes page for the trajectory upon which the ATO OMS dump is based (usually first page, line 5).

- If the Press Trajectory is OPT/ST or ATO/ST, turn to the “AFT RCS PROPELLANT BUDGET” page of ASAB-20 and extract the “DELTA-V CAPABILITY” value for the “AOA STEEP” column. Stop here.
- OR if the Press Trajectory is ATO/MIN-HP continue with these remaining steps:
 - Determine the Deorbit REV for that trajectory from the ASAB-20 notes page (usually line 3). It should be either REV 3 or REV 7. If the notes page does not indicate the ATO/MIN-HP Deorbit REV, consult the OMS PROPELLANT BUDGET sheet for ATO/MIN-HP. In the upper left-hand corner of the page, there should be text similar to “ATO/MIN” with the text “ARCS: PQ SH REV #” directly below it, where # is the deorbit rev number.
 - Now turn to the “AFT RCS PROPELLANT BUDGET” page. If the ATO/MIN-HP is based on REV 7 deorbit, extract the “DELTA-V CAPABILITY” value from the column labeled with text “PRESS QUANTITY” directly above “REV 7 SHALLOW”. If the ATO/MIN-HP is based on REV 3 deorbit, extract the “DELTA-V CAPABILITY” value from the column labeled with text “PRESS QUANTITY” directly above “REV 3 SHALLOW”.
- 2 sigma + mean FPR: Flight Performance Reserve that protects 2σ MPS dispersions. From the Nominal Buildup in the Trajectory Design Data Package (TDDP, MPS PROPELLANT INVENTORY DATA - NO FAIL). Get TDDPs from the following link (call Robert Bardwell @ 281-226-5782 for password). Since this is not an ARD quantity, we use the Nominal, not AOA/TAL Buildup. See the equation below. After confirming that the given 3σ number is correct, compute the 2σ value.

<https://rp.boeing.com/>

- 3 sigma + mean FPR: Flight Performance Reserve that protects 3σ MPS dispersions. From the Nominal Buildup in the TDDP (MPS PROPELLANT INVENTORY DATA - NO FAIL). Since this is not an ARD quantity, we use the Nominal, not AOA/TAL Buildup. This quantity is computed for you. This is computed from the standard FPR equation below. It does not hurt to check that the TDDP numbers are correct. The means and sigmas are there in the buildup

$$FPR = \mu_{6:1} + \mu_{NON\ 6:1} + \text{sigma protection level} \times [\text{SQRT}(\sigma_{6:1}^2 + \sigma_{NON\ 6:1}^2)]$$

- Minimum HP: Minimum perigee that will ensure orbital lifetime for at least two orbits beyond the FD 1 PLS. This perigee provides the cheapest option (OMS-1 and 2 plus deorbit) for a FD 1 shallow deorbit. ASAB-20. The currently used values are 85 nmi for low inclination missions and 90 nmi for high inclinations. The actual value from ASAB-20 should be checked by consulting the ASAB-20 notes page (page 1, normally line 3). If the actual value is not found on the notes

page, it can be found on the ASAB-20 “OMS 1/2 TGTING” cue card (ASAB20.zontrg.prt) for the ATO/MIN-HP region. This will be displayed as the following three text strings, each on top of the next “ATO”, “MIN HP”, “(##NM)”, where ## will be the minimum altitude.

- Design MECO Underspeed: Maximum underspeed that protects ET impact constraints, minimum performance capability (either an AOA steep, an ATO/MIN HP FD 1 with shallow deorbit, or an ATO/ATO FD 2 with shallow deorbit), Net Positive Suction Pressure (NPSP), a minimum altitude of 55 nmi and a CG within the contingency limits. Assumes no dump. Found on the notes page of ASAB-20; CCHT (page 1, line 5).
- Critical MECO Underspeed: Same requirements as Design Underspeed, but without ET impact constraints or flight software MECO prep for NPSP constraints. Assumes no abort dump. Found in ASAB-20; CCHT. The single engine case protects OMS prop for single-engine roll control (SERC).
 - 1 SSME Out (2 SSMEs running): Review the ASAB-20 “OMS PROPELLANT BUDGET” sheets, “MAX MECO UNDERSPEED” values for the column labeled as “Maximum Capability” above “ARCS”. For flights with OMS Assist use the column labeled as “Maximum Capability” above “ARCS” above “NO DUMP” above “OMS ASSIST”. Get this value for each of the following trajectories (trajectory labels found at the upper left-hand corner of page): ATO/MIN-HP, ATO/ST, OPT/ST. Enter the greatest underspeed value from these trajectories on the flight rule. Note that the OPT/ST value should rarely be used --- typically only 39.0 degree inclination missions might be designed to the OPT/ST trajectory. See your Ascent FDO if clarification is needed.
 - 2 SSME OUT (1 SSME running with SERC): Similar to the “1 SSME Out” procedure, but SERC must be accounted for. To do this, follow the “1 SSME Out” procedure, with the exception of using the underspeeds from the column labeled as “Maximum Capability” above “ARCS, SERC” for nominal flights, and from the column labeled as “Maximum Capability” above “ARCS, SERC” above “NO DUMP” above “OMS ASSIST” for OMS Assist flights. Here again, the maximum under-speed value from the specified column should be chosen from the three trajectories listed earlier.
- Nominal: Maximum underspeed at which the nominal OMS-2 targets will be executed. GENERIC FLIGHT RULES A4.1.2-8A. Unless indicated otherwise by Ascent FDO, the maximum nominal underspeed should be listed as 40 fps to reflect the Generic Flight Rule A4.1.2-8A. This Flight Rule deals with acceptable NAV down-track velocity errors. Mission-specific requirements (such as ground-up rendezvous) may cause this value to be lower than 40 fps.

- Undispersed Crossrange: The Entry FDO will fill in this item. OR ARD Support can get the data from dsct05, "EOM MAXIMUM CROSSRANGE CAPABILITY" table, "UNDISPERSED" column.
- Dispersed Crossrange: The Entry FDO will fill in this item. OR ARD Support can get the data from dsct05, "EOM MAXIMUM CROSSRANGE CAPABILITY" table, "DISPERSED" column.
- Contingency Payload Return After Orbit 3: Not Applicable (leave as "N/A").

2.2 CONSOLE DATA GENERATION

ARD Support is currently responsible for generating several products. The first of these is an Ascent Events Summary. It is used on console by Flight Dynamics personnel (FDO/TRAJ/ARD) and others such as the Flight Director (FLIGHT) and Public Affairs Officer (PAO) on DOL. This data is a subset of data supplied by Flight Design. Since the data is mission specific, it changes with every flight. The Flight Design data is received far enough in advance that it can be used to compile the Ascent Events Summary for training and simulations.

Other important products generated by ARD Support are the initialization (init) pads. These are the instructions to the Mission Engineers on updates to be made to the TRS configuration, and/or to the GAs on updates to be made to the Trajectory Applications. There is at least one init pad required to be built by ARD Support for each flight cycle. This data is mission- and flight cycle-specific and is taken mainly from the Flight Design products. Additionally there are typically three standard init pads that are used (standard ARD data, sim engine data, and launch pad data).

It must be understood that the ARD Support does not generate flight design data; but merely receives it, reformats it, and presents it in a form that can be easily understood.

Procedures for generating these products are described in the following section. It is assumed that the ARD Support is familiar with Microsoft Word.

2.2.1 Ascent Events Summary

The Ascent Event Summary (ASEV) is a listing of all major events and abort mode boundaries for a nominal ascent trajectory. Each event is referenced by a MET and inertial velocity (V_i). This data is compiled from information contained mainly in the ASCENT MODE BOUNDARY VELOCITIES (ASAB 23), NOMINAL ASCENT DATA (ASCT 17A), NOMINAL DELTA-Vs AND STATE VECTOR (ASCT 06) flight design data products, and Level A G&C. Other data sources have to be referenced for some of the inputs to this summary.

Refer to the example Ascent Event Summary in Figure 2-4, and to Table 2-2 for the data sources of each line entry. Each line in the example is numbered for reference. However, actual Ascent Event Summary sheets are not numbered as such. The actual calls that FDO makes are in bold.

A tool has been developed that generates the ASEV automatically on the FADS platform. It is described in detail in Section 5.2.3. The script uses these products: asct08.iloads, asct17a.trajsumm, asct17a.aerosumm, asab23.nocommdg, prop02.fopchart, onor09.landopts, and asct06.nav. If a product is redelivered with the same name, the script is re-run. However, if a product is redelivered as a “special” delivery and its name is changed, then the script does not pick up the new product and is not run correctly. In this case, the Script owner would need to be notified so the script’s product input file could be edited and re-run to pick up the correct file. The ARD Support should verify that the resulting product is correct before releasing it to the public. Additionally, the ARD Support is required to complete the “LAST TAL” line using DSCT41, and correct the “SINGLE ENGINE OPS 3” line with the correct data from the GPO officer. The runway names and 3-letter identifiers are listed in the G&C document, landing site tables. The resulting product is an “.asc” file that needs to be reformatted into a Microsoft Word file for the users. The directions for reformatting the file are given in the next section.

2.2.1.1 Reformatting an ASEV

- 1) Use Microsoft Word to open the document.
- 2) Go to File > Page Setup to change all the margins to 0.5”, except left to 0.7”. Be sure to check that the “Apply To” box is set to Whole Document.
- 3) Next, go to Tools > Templates & Add-ins. Click on the “Attach” button and choose ASEV_Summary.dot. It is located in the directory below. Be sure to check the box that says “Automatically update document styles”. Click “OK”.

S:\...\ARDSTUFF\PROD\ASEV\Format

- 4) Now, highlight each line/section in the document and apply the appropriate Style in the Formatting toolbar as follows. (You can also go Format -> Style, then choose the style and click “Apply.”)
 - a) For the top two lines (flight & ASEV), use “Top Lines”. Then click on “centering” tool until centered.
 - b) For the next 2 lines [L/O time, orbiter vehicle (OV) #], use “Heading 2”.
 - c) For the data top line, use “Header Row”.
 - d) For the general data, use “Normal, Data”.
 - e) For the bottom info (bucket, inclination, etc.), use “Bottom Data”.
 - f) For the footer information, use “Name, Etc.”. You’ll probably have to enter carriage returns to make it into 3 lines.
- 5) Check the page to be sure the single engine TAL information is spaced correctly. Enter the appropriate data for “Last TAL” and delete the note to “See DSCT41”.

- 6) You have to manually insert the Mission Operations Directorate (MOD) logo. A file called "MOD_logo" is in the above directory, and you can just open it, copy the picture, and then paste it into the bottom left corner of the page.
- 7) Also, you need to manually bold the calls the FDO makes. See Figure 2-4.
- 8) You may have to delete leading tabs and insert some carriage returns to clean up the document and get the format corrected. Use your judgment.
- 9) Finally, use Save As to save the file to Microsoft Word format (with a ".doc" extension). An example file would be: Asce59.doc, standing for "Ascent Events, STS-59." Following this naming convention will help keep the directory orderly. Save official version in:

S:\...\ARDSTUFF\PRODVASEV

STS-110 OCF PATCH ASCENT EVENT SUMMARY	
2	ASSUMES WINDOW OPEN L/O 2002:017:07:10:13.000 GMT (JANUARY 17, 2002)
3	ORBITER: ATLANTIS
	MET EVENT VI
4	0:10 START ROLL MANEUVER..... 1350
5	0:18 END ROLL MANEUVER..... 1490
6	0:38 START THROTTLE DOWN (72%)..... 1930
7	0:52 START THROTTLE UP (104.5%)..... 2190
8	1:00 MAX Q (693 psf)..... 2370
9	2:05 SRB STAGING..... 5360
10	2:15 START OMS ASSIST (1:16 duration)..... 5500
11	2:17 2-ENGINE TAL MORON (104.5%, 2s)..... 5600
12	2:18 2-ENGINE TAL BEN GUERIR (104.5%, 2s)..... 5600
13	2:21 2-ENGINE TAL ZARAGOZA (104.5%, 2s)..... 5700
14	3:53 NEGATIVE RETURN (104.5%, 3s)..... 8100
15	4:43 PRESS-TO-ATO (104.5%, 2s, 160 w/s)..... 10100
16	5:23 DROOP ZARAGOZA (109%, 0s)..... 12000
17	5:26 SINGLE ENGINE OPS-3 ZARAGOZA (109%, 0s, 2EO SIMO)..... 12100
18	5:47 ROLL TO HEADSUP..... 13200
19	6:04 SINGLE ENGINE TAL ZARAGOZA (104.5%, 2s, 2EO SIMO)..... 14300
20	6:32 PRESS-TO-MECO (104.5%, 2s, 160 w/s)..... 16100
21	---- SINGLE ENGINE TAL MORON
22	(109%, 0s, 2EO SEQ, 1st EO @ 5580 VI)..... 16200
23	---- SINGLE ENGINE TAL BEN GUERIR
24	(109%, 0s, 2EO SEQ, 1st EO @ 5600 VI)..... 16200
25	7:03 NEGATIVE BEN GUERIR (2@67%)..... 19900
26	7:05 SINGLE ENGINE PRESS-TO-MECO (104.5%, 2s, 610 w/s)..... 18600
27	7:20 NEGATIVE MORON (2@67%)..... 19900
28	7:22 3G LIMITING..... 20100
29	7:41 LAST 2 ENG PRE-MECO TAL ZARAGOZA (67%)..... 21800
30	7:47 LAST SINGLE ENG PRE-MECO TAL ZARAGOZA (104.5%)..... 22500
31	7:53 23K..... 23000
32	7:53 LAST 3 ENG PRE-MECO TAL ZARAGOZA (67%)..... 23000
33	8:17 LAST TAL DIEGO GARCIA..... 25200
34	8:23 MECO COMMANDED..... 25800
35	8:29 ZERO THRUST..... 25821
36	THROTTLEBUCKET: 104.5, 72, 104.5
37	MECO INCLINATION: 51.60 deg
38	MECO Ha/HP: 119/31 mm
39	OMS-2 C/O Ha/HP: 123/105 mm
40	
41	Name: E. B. Mroczki
42	Phone: (301)483-1042
	Date: December 19, 2001



Figure 2-4. Ascent Event Summary

Table 2-2. Ascent Event Summary Inputs

Line	Data Source	Comment
1	N/A	Title banner with applicable cycle noted.
2	ONOR09	Lift-off time in Greenwich Mean Time (GMT), including normal calendar reference for the day.
3	PROP02	Orbiter Name (useful for trapped fluids, lift weights, etc.).
4	ASCT 17A	Trajectory Summary (Traj Sum), ROLL ANGLE; when roll angle becomes nonzero.
5	ASCT 17A	Traj Sum, ROLL ANGLE; when roll angle reaches max, near 180°.
6	ASCT 17A	Traj Sum, THRT LEVEL; when throttle level decreases from 104 (or 104.5) percent. Use the data for the last line at this throttle level.
7	ASCT 17A	Traj Sum, THRT LEVEL; when throttle level increases from minimum throttle setting. Use the data for the last line at this throttle level.
8	ASCT 17A	Aerodynamic Summary (Aero Sum), DYN PRESS; when it reaches its maximum value.
9	ASCT 17A	Traj Sum; it is printed right on the display.
10	ASCT 08	Start of OMS Assist; JOMSA=ON or OFF, OMSADL = start time delay from SRB separation (sec), DTOMSA = duration (sec).
11-13	ASAB 23	NOCOMMDG; earliest two-engine TAL to prime, secondary, and alternate sites, 2-sigma.
14	ASAB 23	Negative return to KSC at 104 (or 104.5) percent throttle.
15	ASAB 23	Press to ATO, 104 (or 104.5) percent, 2-sigma.
16	ASAB 23	Droop to inplane TAL site; list site with earliest capability. 109 percent throttle, 0-sigma.
17	GPO	The script automatically inserts a value of 12100 fps; confirm with GPO that this is the correct value.

Line	Data Source	Comment
18	ASCT 17A/ ASCT 08	RTHU; From ASCT-08: PHI2ND = 0 for RTHU, VRHOPH = relative velocity to start roll, TVROLL = 0 for RTHU; Interpolate Vi and time using VRHOPH and asct17a.trajsumm.
19	ASAB 23	Simo EO TAL to prime site, 104 (or 104.5) percent, 2-sigma.
20	ASAB 23	Press to MECO, 104 (or 104.5) percent, 2-sigma.
21-24	ASAB 23	TAL site capability for sequential EO. First EO velocity at first capability. Second EO at the indicated velocity. There are no time tags for these. Check closely - sigma may be 0 or 2, throttles may be 104 (or 104.5) or 109 percent
25	ASAB 23	Last TAL to alternate site. (2@67%)
26	ASAB 23	Single engine Press to MECO, 104 (or 104.5) percent, 2-sigma.
27	ASAB 23	Last TAL to secondary site. (2@67%)
28	ASCT 17A	Traj Sum, when THRT LEVEL decreases due to SENSED ACC = 3.0g. Use the data for the last line at 104.5 throttle level .
29, 30, 32	ASAB 23	Last TAL to prime site, two or three engines at 67 percent, single engine at 104 (or 104.5) percent.
31	ASCT 17A	Time when Vi reaches 23,000 fps.
33	DSCT 41	Last TAL opportunity to Emergency Landing Site (ELS). Get Vi and Site from DSCT 41, then time from asct17a.trajsumm. DON'T USE asab16.abrtchrt, which is for normal TALs.
34	ASCT 17A	Traj Sum, when SENSED ACC drops off sharply. Use the data for the last line at this large (>1.5g) level.
35	ASCT 08	6 seconds after MECO command. Do not use the ASCT 17A Vi; use the I-LOAD-ed target: VDNOM in asct08.iloads.
36	ASCT 08	I-LOAD-ed throttle values (THROTT). 104 values in asct08 really equal 104.5.
37	PROP02 or G&C	From the flight overview.
38	ASCT 06	HA & HP at MECO.

Line	Data Source	Comment
39	ASCT 06	HA & HP at OMS-2 cutoff.
40-42	N/A	Name, mail code, phone number, and date of creation or update.

2.2.2 OMS Dump Plot

Having declared an ATO abort, FDO may ask you for the quantity of OMS propellant to be dumped pre-MECO, given the Earth-relative velocity at ATO selection (i.e., dump start velocity). The amount of OMS to be dumped is assumed to be a linear function of relative velocity (i.e., a “ramped” dump). ARD Support may or may not have to generate a paper chart of the OMS dump, depending on that flight’s Ascent FDO --- ask yours if he/she want this paper console product generated. Regardless, the following parameters, which are needed to generate this chart, are also required as inputs to the ARDTools OMS Dump computation.

- Useable OMS from data22b.ame (asab32b.medcv if L-1 Week), K73, Item 2
- VLIN from data22b.ltt (asct47.icddata if L-1 Week), K88
- VZERO from data22b.ltt (asct47.icddata if L-1 Week), K88
- Max Dump from one of the following sources:
 - Targeting Officer
 - (ILC Only) asab20.ccht. Search for “Pre-MECO Dump” in asab20.asc file, and use values for the type of trajectory the dump is based on. Subtract the OMS Assist amount. (ex: ATO/ATO MAX Dump – OMS Assist).
 - data22b.mit (asct47.icddata if L-1 Week), K87, Item 2. Compute the max dump amount via the ATO INH OMS Dump Timer (K87, item2).
 - If the dump is straight-fed then Max Dump = [ATO INH OMS Dump Timer] x 39.12 lb/sec
 - Else, if the dump is interconnected, use time from first line of “ATO DUMP TABLE” from Prop: Max Dump = [ATO ENA OMS DUMP Timer-3] x 100.77 lb/sec + 3 x 39.12 lb/sec.

An example of an OMS dump chart is shown in Figure 2-5. The generation of this chart may not be required by your Ascent FDO, but if it is desired this chart can be generated using this file:

S:\...\ARDSTUFF\PROD\OMS_dump\dump.xls

The associated chart and macro files will open automatically.

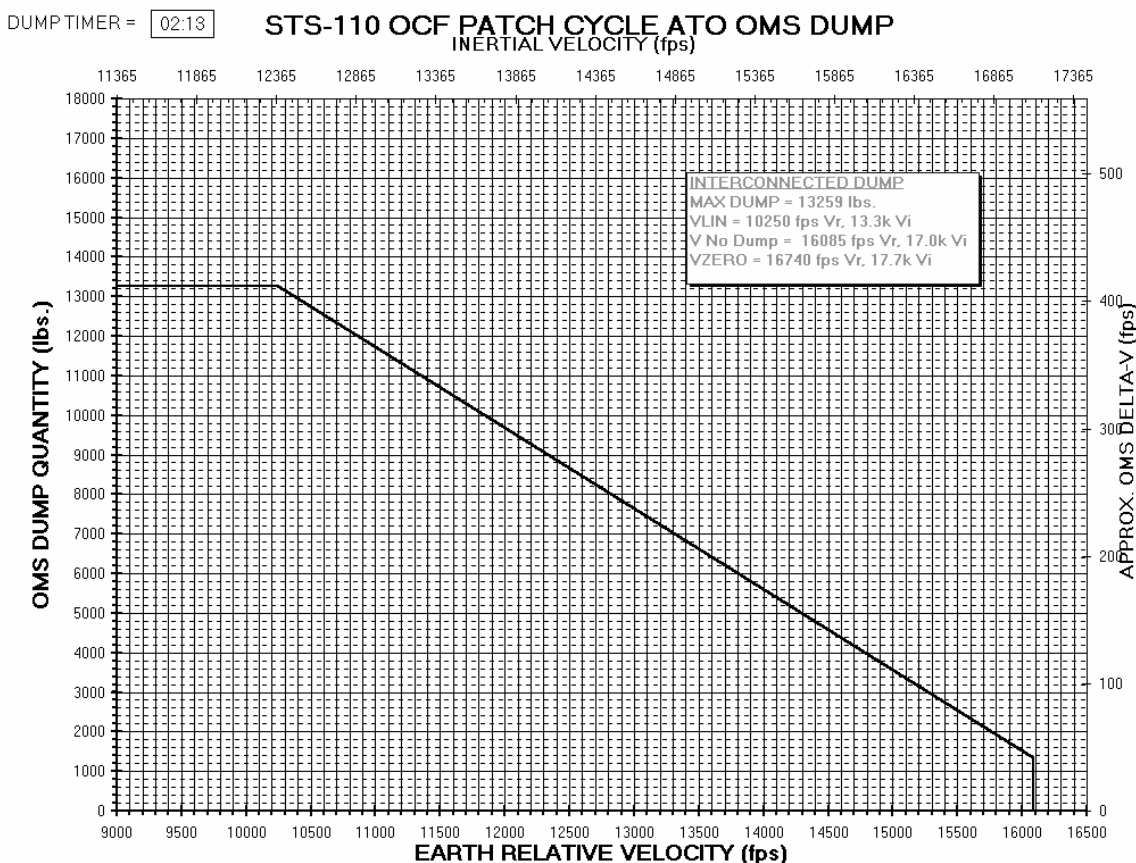


Figure 2-5. Example of ATO OMS Dump chart

2.2.3 Initialization Pad Preparation

Init pads are the official method used to submit data to the Navigation Mission Engineer (ME) for incorporation into the TRS databases, and to the GAs for incorporation into the Trajectory Applications. Here we address the ME inputs; we address the GA inputs in Section 2.2.4. The Init Pad template is located at:

S:\Divisions\DM\Shared\FDDNav\Init Pad Template.doc

It is critical that ARD Support/ME configure the TRS ARD properly. The pads provide a clear set of instructions to the ME, as well as documentation for reference. For these reasons, pads are preferred over voice agreements. Init pads are submitted to reflect changes in data that do not automatically occur through the standard flight design process. Examples of init pads can be found in:

S:\...\ARDSTUFF\DOCS\PADS

Pads are submitted for each flight and cycle combination for the orbit ILC, the ascent ILC, and for launch week. All the data should be submitted to both the lead and backup

(lead for the next flight) MEs (or all MEs for a generic pad) no later than 7 business days prior to an orbit ILC, or 3 business days before an ascent ILC or launch, after the Ascent FDO has reviewed them and concurs with the changes. Figure 2-6 shows a typical pad submitted for simulations using a given flight/cycle combination. The number and type of init pads are different for the DOL configuration. This will be described in Section 4.1.1 and Appendix D.8. Following the example pad shown below is a description of what the data is used for and what the source of each item is.

2.2.3.1 Typical Flight/Cycle Pad

Figure 2-6 shows a typical flight/cycle init pad. Each line in the example is numbered for reference; actual init pads are not. Each item and its source are described in Table 2-3 and in Section 2.2.4. See an experienced ARD Support for additional assistance.

Note that either the ME can generate group MEDs per the init pad instructions, or the ARD Support can generate the group MEDs using the Auto Group MED (AGM) Application. However, the MEs have requested that ARD Support generate the CRP, THR, SYSP, and US group MEDS for orbit ILC, ascent ILC, L-7 day changes, and other updates that are required. Regardless of who generates the MEDs, ARD Support needs to QA them against the init pad. Also, regardless of who generates the MEDs, the init pad still needs to show all the data that will be in the MEDs, so that others can tell what was done by the pad rather than simply seeing a file name. Procedures to use AGM are in Appendices D.3 and D.8, also see Figure 2-7.

01 Flight Controller	Marc J. Abadie	06 Program:	SSP
02 Mail Code	DM44	07 Baseline:	<input type="checkbox"/> Generic <input checked="" type="checkbox"/> Flight Specific: STS-121
03 Phone	281-244-5434	08 FD Cycle	OCFR1
04 Date	2/22/2006	09 MCC Cycle	C
05 Need By Date	2/27/2005	10 System	<input checked="" type="checkbox"/> TSA <input checked="" type="checkbox"/> TRS <input type="checkbox"/> Other:
11 Saved in	S:\Divisions\DM\Shared\FDDNav\Open\121_OCFR1_NEWOV_PAD1.doc		

Description of Change

12 This init pad provides configuration for the upcoming Ascent ILC on the 12103 load. Although the 12103 is based off of 121OCFR1 (like 12102), the OV has been updated, which made a new ILC necessary.

ME Miscellaneous Inputs

13 Apply To: ALL SIM MIS TST

14 Please set the following non-standard data. Update the DAE coefficients with the following :

B73,1STR,18000.0,1STO,25000.0,1VLH,22800.0\$
 B73,2STR,18000.0,2STO,25000.0,2VLH,22800.0\$
 B73,3STR,18000.0,3STO,25000.0,3VLH,22800.0\$
 B73,C41,3.45002E-07,C42,-2.4535342822E-02,C43,582.0876455149,C44,-4604285.50\$
 B73,C45,3.45002E-07,C46,-2.4535342822E-02,C47,582.0876455149,C48,-4604285.50\$
 B73,C49,2.438712E-07,C4A,-1.71219551321E-02,C4B,401.1833778395,C4C,-3133898.24\$
 B73,C4D,-9.19409E-08,C4E,6.6753725616E-03,C4F,-161.5115032632,C4G,1302732.90\$
 B73,C61,3.45002E-07,C62,-2.4535342822E-02,C63,582.0876455149,C64,-4604285.50\$
 B73,C65,3.45002E-07,C66,-2.4535342822E-02,C67,582.0876455149,C68,-4604285.50\$
 B73,C69,2.438712E-07,C6A,-1.71219551321E-02,C6B,401.1833778395,C6C,-3133898.24\$
 B73,C6D,-9.19409E-08,C6E,6.6753725616E-03,C6F,-161.5115032632,C6G,1302732.90\$

15 Please transfer the following group MEDS to the OPS environment for use with the 121 OCFR1 (12103) load. Their location on the IPS is specified:

/fads/fd10a/ARD_SUPPORT/AGM/V1.0/OUTPUT/121ocfr1_newov/S121CRP
 /fads/fd10a/ARD_SUPPORT/AGM/V1.0/OUTPUT/121ocfr1_newov/S121THR

16 Please update the Group MED Table to indicate Launch Pad B will be loaded if necessary:
 11-28-94 DM46/ARDSTUFF/DOCS/PADS/MASTERS/LPAD39/LC39B.doc

17 Orbiter is OV-103 (Discovery), Inclination is 51.6 degrees.

----- INFORMATION ONLY -----

18 The following data are incorporated into the group MEDS:

19 The standard parameter initialization pads:

01-22-04 DM46/ARDSTUFF/DOCS/PADS/MASTERS/Std Init Pad.doc (core pad)
 11-27-02 DM46/ARDSTUFF/DOCS/PADS/MASTERS/StdEngineData9802 TRS.doc

20 D65 L/O: 2005:191:20:51:00.0 GMT (July 10, 2005) (Window Open)

21 K83 L/O: 2005:191:20:56:00.0 GMT (July 10, 2005) (Rendezvous) (In-Plane)

22 The left and right OMS thrust and flowrate are set per the ECT table below.

23 The following are required to set the initial weight in the Orbiter ephemerides and the AME:

Change the K73 vehicle weight to 254938.6 lbs
 Put an M51 total vehicle weight of 254938.6 lbs on ephemerides 1, 2, and 4
 M51 Ephemeris 3 data: Init Weight = 423000.0 lbs, Area = 4000 sq. ft.
 KCON = 1.0, Integrator Options = DM

Figure 2-6. "Standard" Init Pad – Example Only

24 The following non-standard changes are also included. K90 and K91 should be set as follows in order to retain the BEN targets and low crossrange BEN targets:

```
K90,TAL,X5,LZA30,LMN20,LBN36,BEN36$
K91,BEN,A,11811.980,.0013576645,-0.495315E-10,0.642150E-
18,.0041015572,21259848.,2728124.,25000.,22500., 14000.,10000.$
K91,LBN,A,11811.980,.0013576645,-0.495315E-10,0.642150E-
18,.0041015572,21259848.,2728124.,25000.,22500., 14000.,10000.$
K91,LBN,M,X9,2430446,X12,30000,30000$
```

25 K69 throttle table for ALL THREE SSMEs (All three engines are Block II) should be set as follows:

```
452.520,-0:04.616,6.0500,-0:04.616,1,000.0,-0:04.616
452.520,00:00.000,6.0500,00:00.000,2,100.0,00:00.000
452.520,00:03.860,6.0500,00:03.860,3,100.0,00:03.860
452.620,00:04.310,6.0500,00:04.310,4,104.0,00:04.310
452.620,00:33.570,6.0500,00:33.570,5,104.0,00:33.570
452.030,00:36.880,6.0500,00:36.880,6,072.0,00:36.880
452.030,00:49.620,6.0500,00:49.620,7,072.0,00:49.620
452.620,00:52.850,6.0500,00:52.850,8,104.0,00:52.850
452.620,16:40.000,6.0500,16:40.000,9,104.0,16:40.000
...
452.620,16:40.000,6.0500,16:40.000,30,104.0,16:40.000
```

26 HM Throttles are to be set to 0 on the left and 104.0 on the right & center SSMEs.

27 2HM Throttles are to be set to 109.0 on the right and 0 on the left & center SSMEs.

GA Miscellaneous Inputs

28 Please set the engine characteristics per the ECT table below.

29 Please set the deorbit constraints per the DCT table below.

30 Please set the F10 and Kp per the flux values below.

31 Please populate the server with the miscellaneous files specified below.

File Name	
-----------	--

TSA/TRS Engine Characteristics Table (ECT)

Item	Effective Thrust (lbs)	Flowrate (lbs/sec)	Pitch	Yaw	Comment
32 Left OMS	6060.0	19.24	N/A	N/A	N/A
33 Right OMS	6120.0	19.29	N/A	N/A	N/A
34 M1	57.5	0.3290	0.0	0.0	Config 3
35 M2	15.0	0.1057	0.0	0.0	Config 4
36 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/ECT.DIT				

Figure 2-6. Continued

TSA Deorbit Constraints Table (DCT)

Column	Primary/Backup Thruster	Site/Rsite	ATMID	Ncycles	D23C	Elevon Schedule	Miscellaneous
37 1	OBP/OL	EDW22/04	AT5	8	27.2	-3	
38 2	PX4/PX4	EDW22/04	AT5	8	27.2	-3	
39 3	OBP/OL	EDW22/04	AT5	8	27.2	-3	C1 = 19000.0 C2 = -0.75 REI = 5100.0 PHI = -90.0
40 4	OBP/OL	KSC33/15	AT7	8	27.6	-3	
41 5	PX4/PX4	KSC33/15	AT7	8	27.6	-3	
42 6	OBP/OL	KSC33/15	AT7	8	27.6	-3	C1 = 19000.0 C2 = -0.75 REI = 5100.0 PHI = -90.0
43 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/DCT.dit						

TSA/TRS Flux Values

44 F10.7 80 KP 2.4	
45 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/FLUX.DIT

TSA Landing Site Table

File Name	
-----------	--

DDS Landing Site Table

File Name	
-----------	--

DDS Element File

File Name	
-----------	--

EDS Selection Files

FDO Dir	
NAV Dir	

Miscellaneous File Populating

46 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asab23.nocommdg.asc
47 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asab23.reslctdg.asc
48 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asab28.stthrtgdg.asc
49 File Name	users/fdo/Data/SSP121/Ard1.0/TSA/asct17a.aerosumm.asc
50 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asct17a.trajsumm.asc
51 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asct21.tabularA.asc
52 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asct21.tabularB.asc
53 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/dsct23.limitline.asc
54 File Name	/users/fdo/Data/SSP121/Ard1.0/TSA/asct03.mrbil.asc
File Name	

55 Flight Controller Signature	<u>Marc J. Abadie</u>	Date: <u>2/22/2006</u>
56 Approving FDO Signature	<u>Ron Spencer</u>	Date: <u>2/23/2006</u>
57 GA Signature (TSA)	<u>Karen Barnes</u>	Date: <u>2/27/2006</u>
58 ME Signature (TRS)	<u>Toni Deboeck</u>	Date: <u>2/24/2006</u>
59 Flight Controller Verification Signature	<u>Marc J. Abadie</u>	Date: <u>2/28/2006</u>

Figure 2-6. Continued

Table 2-3. Init Pad Inputs

Item	Data Source	Comment
01-04	N/A	Name, mail code, phone number, and date of creation or update.
05	N/A	Date that changes are needed to be complete by.
06	N/A	Pull-down box with SSP ISS Other options. Select SSP.
07	N/A	TSA baseline option. ARD Support will typically select "Flight Specific", then select STS from the pull-down box with STS INCR options, then fill in the flight number.
08	N/A	Pull-down box with N/A LDP OCF OCFRX FLT ENG FRR options. Select option according to the Flight Design TRS cycle.
09	DM/Charles Barrett	Pull-down box with N/A A B (etc.) options. Select option according to the MCC cycle found in the link below. Note: for L-1 Week preps, use the MCC cycle for the latest OCF rev. S:\Divisions\DM\Private\DM32\USERS\Barrett\TSI\SSP MCC Load Matrix.xls
10	N/A	Select which system(s) this Init Pad applies to. If Other, specify.
11	N/A	Enter the name & location of the init pad for easy retrieval. It should be in the standard location (see example).
12	N/A	Provide an overview of the purpose of the pad, e.g. "This init pad provides configuration for the upcoming Ascent ILC."
13	N/A	Applies only to ME inputs for the TRS, and identifies when this init pad is to be used. For the pads generated for the ILC, select "SIM". For the launch init pads, select "MIS".
14	N/A	If required, clearly identify anything non-standard or other helpful information at the top of the "ME Miscellaneous Inputs" section, and repeat in GA Misc. Inputs, Line 28, if needed. For normal configurations, this section is omitted.
15	N/A	Tell the ME which group MEDS you created and where they are located on the IPS.
16	prop02.fopchart	Have the standard launch pad init pad loaded. The ME can also use this to check the correct limit lines.

Item	Data Source	Comment
17	prop02. fopchart	Including the orbiter and inclination is not required, but they are commonly asked questions.
18	N/A	Include this line. Everything below this line is data included in group MEDS you are providing or data included in standard group MEDS. Including this data as "Information Only" avoids confusion for the MEs.
19	N/A	<p>Identify all generic standard init pads for this flight. These can be found in the standard directory:</p> <p style="text-align: center;">S:\...\ARDSTUFF\DOCS\PADS\MASTERS</p> <p>The correct pads may vary flight to flight, so be sure you are using the correct ones. They should be clearly labeled for appropriate use. For sims, you'll at least need these: Std Init Pad.doc, Generic_ETphoto_pad.doc, StdEngineData9802 TRS.doc. For launch, you'll at least need these: Std Init Pad.doc, Generic_ETphoto_pad.doc, asct47.chg, asab32b.medcv (where all init pad values take precedence).</p>
20	G&C or ONOR09. landopts, onor37b	Format is YYYY:DDD:HH:MM:SS.SSS. Lift-off time is always at the open of the launch window, and GMT is always used. The three digit day of the year must be looked up on a calendar, or from the FDO tool "HipToK". It is input via the D65 MED.
21	Data22B/ tt, K83, onor37b	Format is YYYY:DDD:HH:MM:SS.SSS. Lift-off time is always in-plane, and GMT is always used. The three digit day of the year must be looked up on a calendar, or from the FDO tool "HipToK". It is input via the K83 MED.
22	PROP Web site, Orbit FDO	See Section 2.2.4, Item 4.a.

Item	Data Source	Comment
23	PROP34, asct47 Ascent or Lead FDO	<p>M51 total vehicle weight & K73 lines perform the changes required to set the initial weight in the Orbiter ephemerides & AME. Use the Orbiter Pre-OMS2 Burn weight from the abbrvrep file in PROP34. Verify in asct22b.ame (asct47.icddata if L-1 Week); don't use M51 in data22b.mpt (See the Generic Standard Init Pad.) For Line 23: Set ephemerides 1-4 for non-RNDZ flights; for RNDZ flights, set all but 3. Check if your Orbit FDO want to set more.</p> <p>M51 Ephemeris 3 data: For rendezvous flights, this is set to the target's mass properties. For non-rendezvous flights, add ephemerides 3 to the above M51 MED & delete this line. Get data from you Lead FDO early.</p>
24	N/A	Non-standard data that is also included in the group MEDS goes here.
25	DATA-22B, mit, asct47	<p>The purpose of this section is to set the TRS ARD throttle table ISP values to those values used in the SMS for sims. On actual DOL, the delivered ISPs are retained through including the asct47.chg file in your init pad (see D.8 step 14). It can also be used to match up differing configuration engines to their correct positions on the vehicle (the example shows all 3 engines being set identically, however they can be set individually to different sets of values). Be careful to check the line numbers, the bucket throttle, and whether or not there is a two-step throttle bucket. Make sure all the time values match the delivered product. There is a computation tool in</p> <p style="text-align: center;">S:\...\ARDSTUFF\SSME_Comp\Engine_data_98subs.xls</p> <p>to determine the ARD throttle table ISPs; see an experienced ARD Support.</p>
26,27	Ascent FDO, asct47	Set the HM and 2HM throttles as your Ascent FDO wishes. Normally, the engine with the highest Isp is out in HM, and the two highest Isp SSMEs are out in 2HM.
28-31	For 30: Nav Init Pad, data22b.jvt, Lead FDO	<p>Insert directions for your GA here.</p> <p>For 30: See Section 2.2.4, Item 4.c.ii.</p>

Item	Data Source	Comment
32-54	N/A	See Section 2.2.4.
55,56	N/A	<p>You and your Ascent FDO will electronically sign and date here once the pad is complete and approved by your Ascent FDO. Place a copy in the</p> <p style="text-align: center;">S:\Divisions\DM\Shared\FDDNav\Open</p> <p>directory, and e-mail a copy to the TOCSS GAs and/or lead and backup (lead for the next flight) MEs (all MEs if a generic pad), and cc: your Ascent FDO, Entry FDO, and Lead FDO, as appropriate. Do not send this e-mail until after both you and FDO have signed. Note that you may use the AGM script to generate the Group MEDs yourself (see below). After making any necessary manually edits, inform the ME that you used AGM and where the resulting files are located on the FADS system.</p>
57,58	N/A	The GA and/or ME signs the form once the inputs/file moves are complete, and you'll be notified via email.
59	N/A	<p>Once the changes are made/files are moved, ARD Support must verify that the requested changes were made correctly. After verification, sign the form to signify the database change was verified. Re-send to ME/GA and cc: the lead, ascent and entry FDOs, and move the electronic Pad to the appropriate flight specific (XXX) directory(ies) (copies in both TSA and TRS subdirectories (or "Other") if necessary) as selected in Item 10.</p> <p style="text-align: center;">S:\Divisions\DM\Shared\FDDNav\XXX\TSA\ S:\Divisions\DM\Shared\FDDNav\XXX\TRS\</p>



Figure 2-7. AGM Input Screen

2.2.3.2 Throttle Table Pad

This data is now given in the "Standard" Init Pad, which can be found at

S:\...\ARDSTUFF\DOCS\PADS\MASTERS

See Section 2.2.3.1, Item 23.

2.2.3.3 Low Crossrange TAL Pad

This data is now on the Generic Standard Init Pad, which can be found at

S:\...\ARDSTUFF\DOCS\PADS\MASTERS

The rationale and procedures can be found in Section 5.3.6 of the Ascent FDO Console Handbook.

2.2.3.4 AME WX Alternate OMS-2 Targets

This information is no longer necessary.

2.2.3.5 Launch Pad Switch Pad

This information is now referenced on the sim standard mission-specific init pad. See Section 2.2.3.1 of this book and the description of item 17. To switch launch pads in the TRS, several parameters are updated. The init pads for each launch site are available in

S:\...\ARDSTUFF\DOCS\PADS\MASTERS

Updates to the Limit Lines are handled by the FDO.

2.2.4 Procedures to Configure TSA Entry Processors

ARD Support is responsible for configuration of TSA entry processors, as defined in the Trajectory Subsystem Upgrade Project, TSUP-Era Data Recon Ops Concept document authored by C. Edelen. This configuration is done via the "Standard" Init Pad, as described in Section 2.2.3.1 and shown in Figure 2-6. The ARD Support is responsible for configuration of: the Generic TSA Engine Characteristics Table (ECT), DMP Deorbit Constraints Table (DCT), Solar Flux Table (FLUX), Selection Files, and TSA VAT files. ARD Support shall perform the following procedures prior to each ILC and at L-1 Week to configure these files:

- 1) If ILC, verify with GAs that TSA version you are using is the TSA version for the flight. The version number is displayed in the DNAV. (If last week you can skip this step, as step 2 ensures step 1.)
- 2) Go to MCC and log into an activity corresponding to the flight in question (a "no data" activity is fine, call FSM @ 35665 if necessary to set up activity). The activity selected must be an uncert activity. If within 30 days of launch, things will be in cert mode, so contact a GA to determine a good activity to select (usually activity 17) (verify cert mode of selected activity with "Info" button on the Activity Select User Interface, and verify that uncert mode for user software; or use trial and error until typing 'echo \$SCRIPTS' produces the top path below rather than the bottom path (XXX=flight number)

/users/trj/Config/uncert_apps/SSPXXX/ Scripts/

/users/trj/Config/cert_apps/SSPXXX/Scripts/

- 3) Clean up and initialize the local TSA environment by executing:
 - a) /Applications/TSA/Clean Up Local TSA/Yes & dismiss resulting popup window.

b) /Applications/TSA/Initialize Local Trajectory (P80)/Yes & dismiss resulting popup window.

4) Generate necessary files.

a) ECT

i) Open display by executing /Applications/TSA/Maneuver Generation/Engine Char Table/Local.

ii) Update Thrust and Weight Loss Rates for OL, OR, M1, and M2 thrusters. Also update the pitch, yaw, and comments for M1 and M2. M1 and M2 may not be required for non-ISS flights. The Left and Right OMS data is periodically updated based on which OMS pod is mated to the vehicle. Get the official OMS Engine assignments at the top link below. Click on each engine to obtain the OME S/N (serial number) at the top right of the page that comes up. Once you know which two engines are on your vehicle and their S/N's, get thrusts and flowrates from the SODB Vol I table 4.3.3-8 (see bottom link below; add the Oxid and Fuel Flowrates together). M1 and M2 info is obtained from the Orbit FDO.

<http://p51.ksc.nasa.gov/dept/oms/oms.htm> (click Pod/Module link)

<https://opo.jsc.nasa.gov/sodw/>

iii) EXECUTE (f2).

iv) EXIT MENU (f4).

b) DCT

i) Open display by executing /Applications/TSA/Deorbit|Entry Processors/DMP and PADJ/Deorbit Constraints Table/Local.

ii) Update PLSIDs, RLSIDs, D23C, ATMOSs for prime landing opportunity, and NCYCLES for prime landing opportunity.

(1) Set PLSIDs and RLSIDs according to FDO preference.

(2) The parameter D23C can be thought of as the "anchor point" of the entry drag vs. velocity profile. It can be found on the Target Summary Sheet (dsct30.sum) for the deorbit Rev of the appropriate trajectory on which the ATO OMS Dump is based --- see asab20.ccht notes (normally item 5, and see Item 3 if ATO/MIN).

(3) Set ATMOS and NCYCLES appropriately. A chart that shows the available atmospheres & how to select one based on inclination is in Section 5.3.10 of the Ascent FDO Console Handbook (see an experienced ARD Support). The N-cycles can be found in the same manner that the D23C is determined.

- iii) Using data from prop34.abbrevrep (prop31.abbrevrep if LDP): update the elevon schedule. If Xcg on line "Orbiter Entry Interface" is less than or equal to 1092.0 inches then elevon schedule = -3.0; if greater than and not equal to 1100.0 inches then elevon schedule = +7.0; else elevon schedule = 2.0 (per "Trim Aerodynamics Schedule Table (TAST) Elevon data replacement," USH-482L/David A. Kyle, September 04, 2002).
 - iv) EXECUTE (f2).
 - v) Open SUMMARY DCT (f8).
 - vi) Double check ATMOS, PLSID, and RLSID values.
 - vii) Using data from data22b.dct: update Column 3 and 6 PHIs (MM304) to R01, PHI4 value.
 - viii) Update column 3 and 6 with standard initial guess values: C1 = 19000.0, C2 = -0.75, and REI = 5100.0.
 - ix) EXECUTE (f2).
 - x) EXIT MENU (f4).
 - xi) EXIT MENU (f4).
- c) FLUX
- i) Open display by executing /Applications/TSA/Miscellaneous Functions/Solar Flux Updates/Local.
 - ii) Using data from the Nav Init Pad or data22b.jvt.asc (or Nav Init Pad if LDP): Update F10.7 and Kp --- be sure to use the proper year and enter data to bound actual year/day combination, and check with Lead FDO.
 - iii) EXECUTE (f2).
 - iv) EXIT MENU (f4).
- d) DDS LST - ARD Support is no longer responsible for configuring this application based on the dsct17.dds.ls.asc product. This item is now maintained by the Orbit FDO Office.
- e) TSA LST - ARD Support is no longer responsible for configuring this application. This item is now maintained by the Orbit FDO Office based on navo18 and navo16b updates, maintaining the file rwy_extra_info.txt and using the start_gtl script.
- f) DDS Element File - ARD Support is no longer responsible for configuring this file. It is now maintained by the Orbit FDO Office.

- g) Selection Files - ARD Support is no longer responsible for configuring these files. They are now maintained by the Orbit FDO Office.
- h) Miscellaneous File Populating
 - i) For all products shown in the example (Figure 2-6):
 - (1) Open a DECTERM window, create (if not done yet) and move into a working directory.
 - (2) Type 'ftp 130.196.75.1'; enter login id and password.
 - (3) Type

```
get /fads/msn/mds/mastdyn/fltcyc/XXXYYY/filename
```
 - (4) Type 'quit'.
 - ii) Check with lead FDO for any vectors to be included in baseline VAT.
- i) Move all "File(s) Created" listed files to "ARD Move (mv) or Copy (cp -rp) To" location in Summary Table (Figure 2-8) below.
 - i) Can use:
 - (1) /Applications/TSA/Xdir application to move files (select /GOTO/Local ASA in Xdir) OR
 - (2) cp -pr old_file new_file (use -p option to retain time setting in copying, use -r option for copying directories) OR
 - (3) mv old_file new_file (to actually move the files instead of copy)
 - ii) Check times of all files (using 'ls -l') to ensure dates/times of changes are since you started these actions.
- j) Fill out an Init Pad according to procedures in Section 2.2.3.1 for Items 55 – 59 to have these files moved by a GA. Be sure to get your Ascent FDO's signature before submitting to the GA. When GA says they've completed the file moves, double check all files are moved to the proper "GA Final Location" as specified in Figure 2-8. Don't just check the updated dates on the files; do "diff"s on the files to ensure they match the files you stored \$ARD_DB.
 - i) As mentioned above, the DDS Element File, the EDS Selection Files, TSA Landing Site Table, and DDS Landing Site Table are no longer configured by ARD Support. The Orbit FDO Office (DM34/David Mayhew) has agreed to configure these files. When you double check that all the files you've configured have been correctly moved to the "GA Final Location", it's not a bad idea to double check the DDS Element File, EDS Selection Files, TSA Landing Site Table, and the DDS Landing Site Table as well. The GA should

move these files to the following locations, using these variables: XXX = flight ID, Y = cycle ID (A, B, C, etc.), Z.Z = TSA version number:

(1) EDS Selection Files:

(a) /users/trj/Database/SSPXXX/cycleY/TSAZ.Z/DSC/data/nav/seldir/

(b) /users/trj/Database/SSPXXX/cycleY/TSAZ.Z/DSC/data/fdo/seldir/

(2) The DDS LST (dds.ls.asc) and the DDS Element File (dsct66.eds.dds.bnr.dec):

(a) /users/trj/Database/SSPXXX/cycleY/TSAZ.Z/DSC/data/nav/

(b) /users/trj/Database/SSPXXX/cycleY/TSAZ.Z/DSC/data/fdo/

(3) NAVO16B product files (datafile.asc and descript.asc) go into this directory:

(a) /users/trj/Database/SSPXXX/cycleY/

(4) TSA LST (LST.DIT) goes into this directory:

(a) /users/trj/Database/SSPXXX/cycleY/TSA6.0/System/

2.3 .ASCENT/ENTRY TRAINER RECONFIGURATION

Note: A specific ARD Support usually handles this reconfiguration for all ARD Supports for all flights --- you may have no action here, other than checking to be sure this is done for you.

Flight-specific data for the Ascent/Entry trainer must be reconfigured for each flight design delivery. This is to maintain an up-to-date training and analysis capability for FDOs, GPOs, and ARD Supports. Current ascent trainer database reconfiguration is provided via ASCT-03 which includes both STAMPS and ARD flight specific ascent databases, and DSCT-35 which provides descent data. It is ARD Support's responsibility to provide these products to the Ascent/Entry Trainer Caretaker when they are received. These products are forwarded electronically to the Caretaker through PC mail. Using these products and the "Post ASCT-03 Delivery Updates" memo stored in

S:\...\ARDSTUFF\RECORDS\MISC\ASCT-03 Updates.doc,

the Trainer is configured in flight specific simulation mode. To configure the Trainer in true flight specific mode, the simulation data is overwritten with flight specific data.

Figure 2-8. Throttle Table Pad (Deleted)

Application	Product(s) Needed	Parameter(s) Involved	File(s) Created	ARD Moves or Copies to:	GA Final Location
DCT	Ascent FDO, asab20.ccht	PLSIDs RLSIDs D23C ATMOSs NCYCLEs	\$LOCAL/ DMP/ DCT.dit	\$ARD_DB/ TSA/ DCT.dit	\$DB/ DMP/ DCT.dit
	data22b.tast	Elevon Schedule			
	data22b.dct (R01,PHI4)	Col 3 & 6 PHIs			
ECT	http://p51.ksc.nasa. gov/dept/oms/ oms.htm SODB Vol I Table 4.3.3-8	OMEs, M1, & M2 Data	\$LOCAL/ System/ ECT.DIT	\$ARD_DB/ TSA/ ECT.DIT	\$DB/ System/ ECT.DIT
FLUX	Nav Init Pad or data22b.jvt	F10.7 Kp	\$LOCAL/ System/ FLUX.DIT	\$ARD_DB/ TSA/ FLUX.DIT	\$DB/ System/ FLUX.DIT
Misc. File Populating	asab23.nocommdg.asc asab23.reslctdg.asc asab28.stthrtgdg.asc asct17a.aerosumm.asc asct17a.trajsumm.asc asct21.tabularA.asc asct21.tabularB.asc dsct23.limitline.asc asct03.mrbil.asc	N/A	\$WD/ (product name)	\$ARD_DB/ TSA/ (product name)	/users/ trj/ Database/ SSPXXX/ cycleY/ (product name)

Application	Product(s) Needed	Parameter(s) Involved	File(s) Created	ARD Moves or Copies to:	GA Final Location
<p>Notes:</p> <p>1) \$ARD_DB = /users/fdo/Data/SSPXXX/Ard1.0/ 2) \$WD = working directory 3) \$LOCAL = /mcc/rw_local/fdo/TSA(Vers)/ 4) \$DB = /users/trj/Database/SSPXXX/cycleY/TSA(Vers)/</p> <p>where XXX = flight number and Y = MCC cycle number, and 1) is an actual TSA environment variable, 2) thru 4) are not.</p>					

Figure 2-9. TSA Entry Processor Configuration Matrix

3 BASIC CONSOLE PROCEDURES

In this section, office and console pre-simulation database verification procedures are outlined, followed by console initialization steps that are applicable to simulations or actual missions. Console voice communication protocol is also addressed. Special procedures for Trajectory Server (TRS) initialization and database checkout are outlined for both Integrated Load Checkout (ILC) and simulations. An ILC is conducted once each engineering cycle delivery to verify processors, display limit lines and functionality, SMS operation, and MCC/SMS interface. This is performed prior to the start of integrated simulations for that load and is conducted for ascent, orbit, and entry phases. Flight Cycle Checkouts (a.k.a. mass calibrations) are analogous to ILCs, but are performed with the Flight Cycle load for ascent phase only. ARD Support procedures for Flight Cycle Checkouts are identical to those for ILCs.

3.1 ILC AND FLIGHT CYCLE CHECKOUT PREPARATION

3.1.1 Init Pad & Console Product Generation

At 1 week prior to ILC or Flight Cycle Checkout, ARD Support should submit init pads to set up the TRS and TSA databases. Init pads document changes performed by the flight control team to the Flight Design-delivered trajectory database so that an audit trail is available. ARD Support and ME controllers transfer init pad inputs to the ascent Group MED and system parameter file that contain any deltas to trajectory processor databases from what was delivered by Flight Design. See Section 2.2.3 for a detailed description of how to build pre-sim init pads.

Also, prior to ILC or Flight Cycle Checkout, ARD Support should have completed generation of console products. It should be verified that all Flight Design products listed in the FDO data pack (Sections 2.1, 2.2, and Appendix D.15) have been retrieved from FADS and collected in the following directory:

S:\Divisions\DM\Private\DM46\ ARDSTUFF\PROD\(\flt)\(\cycle)

(Note: The assembly of the products in this directory is usually assigned to a specific ARD Support who does this for all flights --- but you must verify that all products for your flight are there.) Also a Console Data notebook should be prepared in similar fashion to previous flights that contains: all init pads and Group MEDs for the load, prop leak level tables, ARD console products, AGT table, Ascent Events Summary, and any desired flight design products or the products script output (see 3.1.2), etc. (details in Appendix D.5).

3.1.2 ARD/AME/DAE Database Verification Tool Preparations

The ARD/AME/DAE Database Verification Tool (AADDVT), also known as “database checker” (DBCHEK), was implemented in April 1999 to automate the manual checking of over 5000 parameters by ARD Support. Manual checking of these parameters used to be done (and still might be necessary if DBCHEK fails on launch day) by comparing product data to that which appears on displays according to Table 3-1. (Note: for

close-to-launch database check, ASCT-47 and ASAB-32B updates override data in DATA 22). Details on how to use the DBCHEK prior to and during the ILC and sims can be found in Section 5.1.4. Also, be sure to check the Operational Notes, located in:

S:\...\ARDSTUFF\DOCS\Cert DB Verif Tool

for any special procedures to be used.

The DBCHEK is configured in the Operations (OPS) platform for each flight. Approximately a week prior to the ILC, ARD Support should notify the Group Administrator (GA) that the appropriate directories (along with others) need to be configured. It is best to ask them to copy the configuration of a flight with the same versions of DBCHEK and the “baseline” spreadsheet. The OPS directory is

/users/fdo/Data/SSPXXX/Ard1.0/AADDVT/

with sub-directories for BASE_REFERENCES, LOCAL_REFERENCES, PRODUCT_REFERENCES, and PLACE_HOLDERS.

Additionally a script, the DBCHEK Product Script (DPS), was written that creates a file with all the Flight Design product data in the order consistent with the DBCHEK. This script also creates the placeholder files needed for DBCHEK. A few days prior to the ILC, ARD Support should transfer the DPS product reference files and placeholder files from the FADS system to the OPS platform. Specific procedures for the DPS and how to complete the file transfer are given in Section 5.2.4. The product and placeholder files are placed in the OPS DBCHEK mission support directories. The print files are not moved to the OPS but are for printing only. These can be placed in the Console Data Book for easy reference.

Table 3-1. Display vs. Product Checklist

Display name	Product	Table name
ARD-AME INIT	DATA-22A	CNST
	DATA-22B	AME, MIT, LTT
	PROP34	
ARD OUTPUT	DATA-22B	√ Thrust Limiting Off (lmb Block shows engine designators in inverse video)
WX Alternates	DATA-22B	GTT
	INIT PAD	Reduced Cross Range (XRNG) Targets

Display name	Product	Table name
Downrange Abort Evaluator (DAE) PARAMETERS TAB 1-5	DATA-22B	DAE
MECO U/S CURVES - STEEP SHALLOW FLAGS	DATA-22B	MIT
MECO U/S CURVES	DATA-22B	MIT
ARD MAINTENANCE	DATA-22B/PAD	MIT (ARD FPR), LTT
TRAJ PROF STATUS	DATA-22B/PAD	MPT
ENGINE CHAR TABLE	DATA-22A/PAD	CNST
ARD/AME SYS PARAMS	ASCT-22A DATA-22A SYS PRM RPT INIT PAD	ICDDATA CNST
ARD SYS PARAMS	ASCT-22A SYS PRM RPT DATA-22A	ICDDATA CNST
TRAJ PARAMS	DATA-22B	SECD, TMTT
ENTRY PARAMETERS	DATA-22B	TMTT
IYD VECTOR DISPLAY	DATA-22B INIT PAD	LTT, MIT √ correct L/O time
AGT OMS 1 TGTS	DATA-22B	LTT
AGT OMS 2 TGTS	DATA-22B	LTT
AME INIT	DATA-22B	AME, LTT

Display name	Product	Table name
MISC PARAMETERS	DATA-22B SYS PRM RPT	TMTT
AME/ETIP AGT MED INP	DATA-22B	AME, LTT, MIT
SSME1-C THRTL/ISP/MR	DATA-22B / PAD	MIT
SSME1-L THRTL/ISP/MR	DATA-22B / PAD	MIT
SSME1-R THRTL/ISP/MR	DATA-22B / PAD	MIT
ARD SSME PARAMS 1	DATA-22B / PAD	TMTT
ARD SSME PARAMS 2	DATA-22B / PAD	TMTT
ARD CONTROL DATA	DATA-22B	MIT, TMTT, CNST
ARD-AME INIT	DATA-22A DATA-22B PROP34	CNST AME, MIT, LTT

3.2 VOICE COMMUNICATIONS

3.2.1 DVIS Logon

Voice communication on console is accomplished with the Digital Voice Intercommunications Subsystem (DVIS). To log onto the system, touch the screen to activate it, then push "SIGN ON" and enter the four-digit keyset ID on the front of the unit. Then press "ENTER" to complete the logon. Page up or down to select the desired communication loops configuration by pressing the "PAGE" area followed by the up and down arrows; another page will have the "2" loops if you need them. You can then select communication loops to monitor by simply pressing them once. Press again to talk on a particular loop if you have talk capability--this is annunciated by a flashing indicator. For more detailed DVIS instructions, reference the DVIS Keyset User's Guide (FAC-UG1432).

3.2.2 Communication Loops

Communication loops are usually recorded; therefore, do not say anything you do not want replayed. The recordings facilitate post-flight reconstruction of events that occur during the mission. Note also that Flight Directors (call sign: FLIGHT) sometimes monitor backroom loops, even during simulations. While communicating on the loops, certain etiquette should be observed. Common sense works well in this area. A few simple rules include:

- When initiating a conversation, call the party's position followed by your position (e.g., TRAJ, ARD). With multiple loops punched up, a person can pick out his/her position call and concentrate on that bit of conversation. Often, a phrase blurted out over the loop without identifying from whom it came or for whom it is intended will be lost in the garble. This general rule sometimes falls to the wayside for routine calls that are made every run. This is dependent on the individuals involved.
- If someone is using the loop, do not "walk" on their conversation. Wait until the conversation is finished unless there is some urgency in your communiqué. If it is necessary to break into a conversation, a "BREAK, BREAK" preceding the call is warranted. If someone is talking on your loop that should not be there, by all means feel free to correct their blunder.
- Hold your conversation when the crew is talking to the ground. There may be something important that affects your discipline. Also, generally do not talk to FDO or TRAJ if FLIGHT is talking to them, except if you are passing them brief, helpful information that pertains to their discussion with FLIGHT.
- Acknowledge all communications. It is important for the initiating position to know you have received their communications, even if you are not ready to respond yet to their question, instructions, etc. Therefore some acknowledgment should be made that is appropriate to the situation; e.g., "copy," "stand by," "that's in work," etc.

ARD Support (call sign "ARD") must monitor the following communication loops:

- FLT DIR - Flight Director loop
- A/G - Communications between the shuttle and the MCC are monitored on air-to-ground (A/G) loops. There are three loops: A/G-1, A/G-2, and A/G UHF. Having all three loops called up at the same time may drown out the rest of the loops. If you are monitoring only one A/G loop, be sure to switch loops if a malfunction disables the loop you are monitoring. It is recommended that A/G 1 and UHF be monitored to protect for this scenario.
- AFD CONF - This loop is used primarily during debriefs after each run during a day of sims. Day of launch, KSC Launch Director loops are tied in on this loop.

- MOCR DYN - This is the FDO's primary loop for communicating with other front room console positions. If another front room position wants to initiate a conversation with the FDO/TRAJ, they will call for them on this loop (e.g., "FDO, PROP, your loop" or "TRAJ, BOOSTER, MOCR DYN").
- NAV SPT - Communications between the FDO and Navigator Support (NAV) occur on this loop. Radar tracking "filter" status is given frequently on this loop, which can give a heads up on noisy ARD output (digital and plot).
- SDP DYN - Prime loop for the FDO/TRAJ/ARD to communicate with DYNAMICS, who perform all MED inputs to trajectory processors. TRAJ voices any ARD/AME updates over this loop to DYNAMICS.
- MPSR DYN A - This is the prime loop for ARD to communicate with FDO and TRAJ. Also communicating with the FDO and TRAJ on this loop are ABORT SUPPORT, TARGETING, ENTRY SUPPORT, and Landing Support Officer (LSO).
- MOCR SPEC - Communications between the BOOSTER and FDO/TRAJ, initiated by FDO/TRAJ, take place on this loop. This is BOOSTER's primary loop for communicating with other front room positions. SSME status and performance case data may be passed to the Flight Dynamics team over this loop.
- MOCR GNC/PROP - Communications between PROP/GNC and FDO/TRAJ, initiated by FDO/TRAJ, take place on this loop. This is PROP's primary loop for communicating with other console positions. OMS dump failures and leak level information may be passed to the Flight Dynamics team over this loop.

Other loops that are useful for DOL include BOOSTER MPSR, where you can hear the status of the main engines. OIS 232 NASA Test Director (NTD) is the main KSC operations loop. The Launch Director will be discussing all major issues there first. He may direct them to another loop later. This is also where all the pre-launch checklist steps are verbally cleared, so it is an excellent source of information and launch status.

3.3 OPERATIONS FOR ILCS AND FLIGHT CYCLE CHECKOUTS

3.3.1 Trajectory Server Initialization

For ILCs and Flight Cycle Checkouts, the trajectory server is initialized with a flight-specific configuration delivered by reconfiguration personnel. ARD Support's Group MED and system parameter files containing deltas to the Flight Design delivery are not loaded until FDO provides a "go"; therefore, the server is "clean" or "cold." After successful console initialization, ARD Support should first check that the correct (most recent) baseline file is being used by DBCHEK, then check the "cold" server with the Flight Design products using DBCHEK and the files generated by DPS.

ARD Support brings up the DBCHECK and selects the appropriate PRODUCT_REFERENCE and PLACE HOLDER files, and then electronically retrieves

the server data. This allows for easy and accurate comparison of the product data to the data in the server. Once this is completed, DYNAMICS loads the Group MEDs and ARD Support confirms that the only changes are the results of the init pads submitted earlier. If a parameter is found to be in error during the database check on console, then a Discrepancy Report (DR) should be submitted and the correct value should be passed to FDO so that DYNAMICS may correct it manually (be sure to use correct units for system parameters).

3.3.2 Database Check

The ascent trajectory database must be checked prior to each ILC, Flight Cycle Checkout, integrated simulation, and actual mission. ARD Support is responsible for ARD, AME, and various miscellaneous database parameters. Though not as exciting as realtime ops, database procedures are extremely important. An erroneous parameter could cause misleading trajectory processor output, causing FDO to make a bad call. Or a wrong parameter could cause a total program crash. Either of these scenarios jeopardizes crew safety and is career limiting as well. A careful ARD Support should have a thorough understanding of database changes for each flight, verify that the changes have been implemented correctly, and double check Flight Design delivered parameters.

Parameters of importance to ARD Support can be divided into two categories: MED-able parameters and system parameters. MED-able parameters can be thought of as realtime changeable parameters. These can be modified using manual keyboard entries (MEDs) individually as well as in groups via Group MEDs. These inputs can generally be performed at all times, except that some MEDs are not accepted in certain phases (ops, launch, landing) or after a processor has already performed its initialization task. System parameters, on the other hand, are much more difficult to modify since they are generally considered static data. The Flight Mode in the TRS must be taken from locked to unlocked in order to change system parameters. Flight Mode updates can only be performed by the Trajectory Application Officer (TAO). Due to risks associated with allowing updates to 'static' data, FDO approval is required. Another drawback to manual system parameter changes is that no limit checking is performed on the entry. System parameters may be updated individually or via Group MED.

After DYNAMICS has loaded the Group MED and system parameter file, ARD Support should verify that ARD/AME database parameters match the previously verified product data. There will be changes due to the flight-specific and generic standard sim init pad Group MED and system parameter file. The DBCHEK and associated checklists are used for this verification (see Section 5.1.4 and Appendix D.6). Additional Entry Phase and other non-ARD-related miscellaneous parameters should also be checked against the product files using DBCHEK. This is a courtesy check only; ARD Support is generally not responsible for this type of data, but only provides a heads-up to FDO if parameters differ from product data. An exception to this is if ARD Support has modified any parameter via the Group MED, then ARD Support is directly responsible for ensuring that correct data has been entered.

Again, be sure to check that all init pad changes have been implemented correctly by verifying the displayed value using the DBCHEK checklists in Appendix D.6. If any system parameters are changed (via init pad) that are not on a display, special procedures outlined in Section 4.1.1.1 must be followed. Once all these activities are complete, save the file in DBCHEK to be used as a future reference file.

Following the ILC activities, any database discrepancies need to be resolved. Once verified, the files generated at the ILC are moved to the BASE_REFERENCES directory by the GA. Once this process is complete, then the DBCHEK BASE_REFERENCES files may be used for TRS database checkouts. The BASE_REFERENCES files become your “bible” for checking the database on console. This allows a much faster pre-simulation database checkout than using a binder full of Flight Design products.

3.3.3 Operational Software Check

During integrated ascent runs, two tasks are accomplished: processors, displays, and analog plots are verified, and a performance match is made between the ARD and the SMS. These checkout tasks are performed simultaneously, with the MCC/SMS performance match usually requiring two to three runs.

During the integrated runs, all displays and plots are checked to ensure that they are updating and plotting correctly. Particular attention should be given to displays that have been modified since the last MCC load. Processor output displays are monitored closely to ensure that they are producing the expected results. FDO tools that are examined include ARD, AME, DAE, Launch Window Launch Target (LWLT) processors (if a ground-up rendezvous is planned), and Entry Design System (EDS). ARD abort boundary times are noted and compared with the pre-mission predictions. The NAVs verify that the high speed filter processor is functioning properly and that they are able to receive tracking data from the SMS. ARD Support should notify FDO of any problems noted during the checkout so these anomalies can be included in his/her paperwork.

3.3.4 SMS Calibration

The main purpose of the ILC, as far as the ARD Support is concerned, is to calibrate the ARD computed performance with the SMS computed performance. The performance match is necessary for accurate training to assure that SMS underspeeds achieved during integrated simulations match realtime ARD predictions. For training, the SMS simulates a real vehicle in flight. The ARD should track the actual nominal performance very closely. “Syncing” these math models for nominal cases ensures that off-nominal cases will exhibit only the actual malfunction being simulated (i.e., thrust limiting) and not some discrepancy inherent in comparing ARD to SMS. This calibration process is performed in two ascent runs. The first run can be thought of as quantifying the weight error. The second run can be thought of as determining how that weight error is distributed between ET propellant (ETP) and dry weight (ETD).

The Δ Time to MECO (TMECO) is the main cue used in the first run to derive the total weight error. This can be thought of as the “dumb” part of the calibration. The main

interest is in this total weight error and not in the specific performance differences. Since the TMECO calculations assume the target cutoff velocity will be reached (the calculation does not care how much prop it will take or how much it has), it follows that a heavier vehicle will take longer to accelerate to the cutoff velocity; hence its TMECO will be higher. Based on such data from the first run, a weight adjustment is made to the SMS.

In the second, or “smart” run, an underspeed performance comparison is used to determine how the total weight error should be divided between ET propellant and dry weight. This is important because making the ARD and SMS “weigh” the same is not enough - it makes a big difference whether the weight added (or subtracted) is propellant. For example, say that the SMS is shown to be “light” in the first run, and weight needs to be added to it to match the ARD. Of course, adding all the weight error as straight dry weight will degrade performance. Adding it as straight propellant will probably make the performance much higher than the ARD. However, adding some dry weight is not bad if some propellant is also supplied to lift it. Therein lies the trick - to determine the proper breakdown of the total weight error into propellant and dry weight. This is the main purpose of the second run. In fact, the propellant is properly broken down between LOX and LH2!

The run sequence for performance calibration between the SMS and the ARD is a function of observed weight errors and performance differences. This is described below. Note that the Thrust Update Method is NOT used for any ILC runs. ARDTools is used on console by ARD Support to aid in calibrating ARD and SMS mass properties (see the ARDTools User’s Guide.) The formulae programmed into ARDTools are based upon the solution of two linear equations. These equations relate inert and propellant mass deltas (Δ) (lb weight error between SMS and ARD) to a delta in performance (fps converted to lb). They are as follows:

$$\Delta ETP + \Delta ETD = \Delta Mass \tag{1}$$

$$(1-\gamma) * \Delta ETP - \gamma * \Delta ETD = \Delta Perf * TF \tag{2}$$

$$\text{with } \gamma = \delta W_{tprop}(req) / \delta WT_{gross}$$

Note that for bookkeeping purposes, all SMS/ARD weight errors are assumed to be either dry (inert) ETD or ETP weight mismatches. This is to avoid modifying Orbiter weights, which could cause problems with the on-orbit phase. Gamma (γ) above is the partial of propellant required with respect to gross weight, which equals 0.95 for the Space Shuttle. This represents the amount of propellant required to lift something to orbit. In other words, 100 extra pounds of inert weight require consumption of an additional 95 pounds of propellant to get to nominal MECO. The same is true for lifting an extra 100 pounds of propellant (i.e., you use up 95 of the 100 pounds just lifting the weight), so 100 - 95 = 5 pounds left over that can be burned for extra performance. Thus the 1- γ (which is 0.05) factor is in front of the ΔETP term. The trade factor (TF) (lb/fps) is used to convert ΔV in fps to lb propellant. For shuttle ascent, the value is

about 22 lb/fps (exact value can be found in ASCT-22A, WTSFPR, AOA FPR build-up calculations, for 3 SSMEs – ISP Dispersion).

Combining these two equations and rearranging yields:

$$\Delta\text{ETP} = 0.95 \Delta\text{Mass} + \Delta\text{Performance} * \text{TF} \quad (3)$$

and rearranging the first equation yields:

$$\Delta\text{ETD} = \Delta\text{Mass} - \Delta\text{ETP} \quad (4)$$

The last two equations relate the observed mass and performance differences between the SMS and ARD to ET inert and propellant weight. The procedure is to determine the Δmass between the SMS and ARD during the first run and then determine Δperf during the second run, after the SMS folks have corrected any weight error found during the first run. The SMS total weight is synced up with total ARD weight after the first run. Then an engine failure is used to invoke a low level cutoff (i.e., underspeed) to determine performance capability of the vehicle. Delta performance between the ARD and SMS is entered in equation (3) with any residual weight error as Δmass (should be zero if the weight updates from the first run were implemented correctly). This provides the value of ΔETP , which, with equation (4), provides ΔETD . These results are added to the initial ΔETD or ΔETP that was applied to the SMS. (Note ARDTools performs this internally; i.e., there is no need to manually add results from the second run to the first.)

The ILC checklist is a procedure for ARD/SMS mass calibration; it contains calculation instructions as a backup ARDTools. It is shown in Appendix D.6. The next subsections describe the process.

3.3.4.1 Run 1: Nominal Ascent

The 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 TRS and SMS. This is done by observing the ARD nominal margin trend. An assessment is made of the weight difference between the ARD and the SMS using ΔTMECO between the ARD and SMS. Differences of 0.1 or 0.2 seconds are okay. Note: For OMS assist flights, the ΔTMECO comparison should be done after the OMS Assist is complete. OMS assist begins 10 seconds after SRB staging and ends approximately 102 seconds later assuming an approximate 4000 lbs. dump. Figure 3.1 is a rough, empirical approximation of overall weight errors and should be used with its limitations in mind. It is not an all inclusive diagnostic “fixit” plot for every case where the times don’t match up. This weight error is used as a starting point for syncing up the performance of the ARD and the SMS. If the SMS appears to be light, dry weight is added to the SMS inert ET model. If the SMS appears heavy in the first run, weight is removed from the SMS ET LOX and LH2 in a 6:1 manner. FDO/GPO Monitor (FiGMo) coordinates the input of these weight deltas to the SMS. This will result in an overall weight match between the ARD and the SMS. You have now made the ARD and SMS “weigh” the same by taking out the total weight error. Now proceed to run 2 to calibrate the performance. ARDTools performs these calculations; reference Section 5.1.1 for operating instructions.

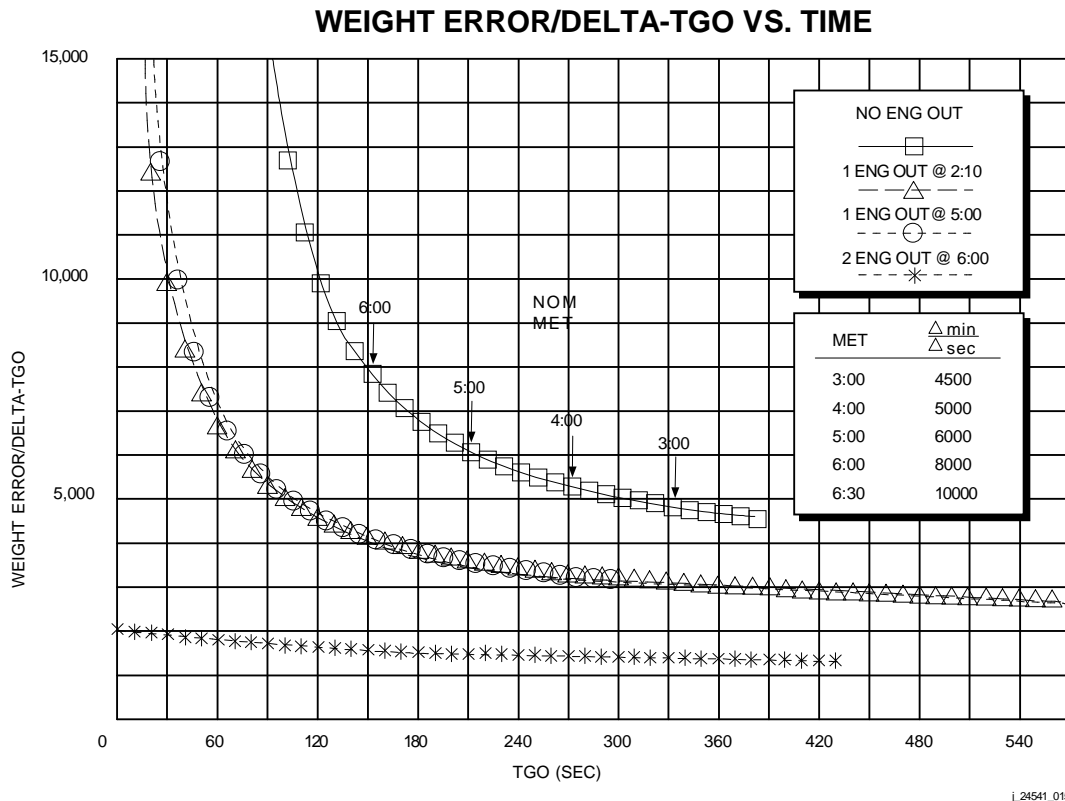


Figure 3-1. Weight error vs. $\Delta TMECO$

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

Note: If a good match is indicated, runs 1 and 2 may be combined.

This run is used to calibrate the distribution of SMS propellant weight and inert weight. An engine is failed just prior to PTM and a predicted underspeed is obtained, once the ARD is updated correctly with the time and velocity of engine failure. Actually, the engine out can be done anytime after PTA, so long as neither the SMS nor the ARD abort ATO. You do not want any dumps to take place, but you do want an underspeed. If the SMS weight adjustment from the first run was accurate, there should not be any significant weight error during the second run. However, if there is, make sure to correct the weight error using a delta ETP input during the ARD run before the engine is failed.

The ARD predicted underspeed should be adjusted to 0σ (since no dispersions are present in the SMS) by adding in the performance value of FPR (about 110 fps) to the predicted MPROP. By recording the underspeed prediction, it is possible to “save” what the ARD predicted performance is, based on what it has for ETP/ETD distribution. The SMS will fly its own way, with performance based on what it has for ETP/ETD distribution. MECO will occur with a low level cutoff. The resulting underspeed will most likely be different from the ARD prediction recorded since the ETP/ETD distributions are probably different. This underspeed is compared to the actual

underspeed achieved. If a good underspeed match is obtained, the SMS weights are correct, assuming no weight adjustment was required. If a weight adjustment or an underspeed mismatch is observed, ARDTools recomputes the appropriate SMS weight updates. These updates are passed to FiGMo in the Sim Control Area for input into the SMS. Note that these final weight updates override any updates made previously from run 1. FiGMo will incorporate the final weights into a data store from which to initialize the SMS for all future ascent runs. This ensures that the ARD and the SMS performances are in sync and minimizes any negative training aspects that can arise from having a performance mismatch.

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

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

3.4 OPERATIONS FOR SIMS AND FLIGHTS

Integrated simulations start approximately 1 to 2 weeks after a successful ILC. These simulations are the primary source of crew and flight controller integrated training. There are few other opportunities for operational crew and flight controller interaction. Training personnel script runs with specific training objectives in mind. The runs are kept as realistic as possible. Integrated simulations continue through the final week prior to launch.

3.4.1 TRS Initialization

For the majority of simulations, a flight control checkpoint, taken during a previous set of integrated simulations or ILC, is used to initialize the server. Flight controller inputs from this set of sims are automatically made. This saves DYNAMICS and other flight controllers from having to load Group MEDs and system parameters. If, however, a checkpoint is not used to bring the server up, it will be brought up cold, and then DYNAMICS will have to be notified to load the Group MEDs and system parameters. Typically, the server is up and clear for inputs about 1 hour prior to the start of integrated runs.

3.4.2 TRS Database

If the server is brought up cold, then the TRS database must be checked over to ensure that what came up is the same database that was checked during the ILC, and that database changes have been entered correctly. FDO should consult with DYNAMICS on the system status and database changes. Post-design cycle changes and database errors must be corrected. These corrections can be stored by DYNAMICS so they can be easily implemented for each integrated sim. If the server was brought up from a checkpoint, then the database can be compared to files saved at that checkpoint.

The DBCHEK application should be used to check the database against references taken at the ILC or appropriate checkpoint. To do this, bring up the application and retrieve the appropriate ILC file from the Base_REFs or checkpoint file from Local_REFs. Once DYNAMICS has loaded the Group MEDs and system parameters,

get current data. Compare any deltas to the init pads or changes submitted after the reference file was saved. Any discrepancies should be brought to the attention of TRAJ.

After the database is checked to ensure correctness, a checkpoint is taken from which all the integrated runs will be initialized for the remainder of the day. Database discrepancies or console configuration errors found after the checkpoint must be corrected prior to each run. If the number of changes is too much of an operational impact, a second checkpoint can be requested. A DBCHEK file should be saved just prior to or immediately following the server checkpoint. This is ARD Support's reference for each run or future sim. The file should be saved as "CP_MMDDYY", where mm is the 2-digit month, dd is the 2-digit day, and yy is the 2-digit year. Also, a list of checkpoints and their general configurations (runways, etc.) should be kept in the front of the ARD Console Databook so future sims can be compared against similar configurations.

For actual flight preparations, detailed procedures for database checkout are documented in Appendix D.

3.4.3 Display Setup

Displays that are used during an ascent run include ARD OUTPUT, FDO LAUNCH DIGITALS, LAUNCH DDDs, ARD MAINTENANCE, DVMARG, THROTTLE TABLES, PROP Dump Log, and sometimes ARD/AME INIT, ARD CONTROL DATA, RTLS DIGITALS, and EOW vs. RGO.

3.4.4 Integrated Simulation Runs

Once lift-off occurs, the sim is supported as if it were an actual flight. Different failure scenarios and procedures are discussed in a checklist format in Section 4. Once the training objectives of a particular run are accomplished, the run is terminated. After the run, a debriefing occurs on the AFD CONF voice loop. Participants include the crew, flight controllers, and the training team. Every anomaly is discussed in detail, and action items are assigned as required. It is important to pay attention to the debriefing. This is where a lot of learning occurs. Be sure to discuss any questions about the run with the FDO or TRAJ prior to the next run. During debriefing, the server and SMS machines are being turned around in preparation for the next run. After the debriefing, the sim supervisor picks a time to start the next run and the process starts over again.

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4 LAUNCH PREPARATION AND ASCENT PROCEDURES

4.1 PROCEDURES FOR NOMINAL FLIGHT

Preparation for flight intensifies about a week prior to launch. All ARD-related data must be collected and incorporated into the TRS database. The day-of-launch (DOL) processors must be configured to support DOL activities. DOL activities include using the loadings function in ARDTools (Section 5.1.1) to compute TRS database updates based on DOL loadings. ARDTools also produces data that must be incorporated into the ARD in the event of a launch hold after drainback has been initiated. Section 4.1 discusses flight-related activities that occur from about L-1 week through post-MECO operations. Specific ARD procedures for different abort modes and anomalous situations are discussed in Section 4.2.

Much of the following discussion goes hand-in-hand with the L-1 Week Checklist in Appendix D.8. It is a vital tool that collects into one checklist all the necessary, important steps to be performed during the last week. The checklist is updated after every flight, so any step numbers referenced here will probably change. If the checklist or this section does not answer all your questions or if something is not clear, ask an experienced ARD Support. Every effort must be made to prevent/eliminate errors during the last week.

4.1.1 L-1 Week to L-1 Day

The week prior to flight is usually hectic. MCC flight support begins as early as 3 days prior to launch for a mission containing a ground-up rendezvous. The TRS is brought up for continuous, 24-hour-a-day support, 36 hours prior to launch. Continuous console operations start about 13 hours prior to launch with the planning team. The ascent team is required to be on console no later than 5 hours prior to launch. All the steps on the L-1 Week Checklist (D.8) need to be completed. Due to available data or other constraints, you may not accomplish the steps in the order they are listed. The sequence of steps listed is representative of the flow events from a typical mission. Read the checklist carefully and make sure you understand the reason for each action. Some of these steps will be detailed in the following subsections.

4.1.1.1 Nonstandard Database Parameters Procedures

OCF 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 goes next to the SPF, which converts the system parameters to TRS 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. Refer to the Ascent FDO Console Handbook Vol. V, Section 4.3 ARD/AME Database Procedures, Standard Update Parameter List.

This may be due to some change in ARD operating procedures or an improvement to modeling accuracy. The nonstandard 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. ARD Support should verify that proper units have been used and that TRS application experts concur with the change.

Parameters that change from ocf to the close-to-launch delivery (ASCT-L47 and ASAB-32B) must be checked against the Standard Update Parameter List. Parameters on the list are standard updates due to mass property tweaks, engine tag assignment, minor I-load CHANGES, etc. ARD Support should determine why every change from OCF to the close-to-launch delivery has occurred and check the new numbers for reasonableness, verifying when possible. Any parameter changed on a close-to-launch product but not listed in this section should not be input into the TRS 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 GA/ME 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 nonstandard parameter change must be verified in the MCC environment during either an integrated simulation or dedicated database checkout run. This should be completed by L-1 day and may require special coordination for the MCC and SMS. Advance planning should be used to identify any nonstandard database change and verify it during a scheduled ascent simulation so that special support is not required.

The ASCT-47 product includes TRS unit conversions for system parameters that require conversion. This is accomplished automatically for the standard delivery and manually for nonstandard updates. System parameters not requiring conversion are labeled N/A. When preparing an Initialization Pad, all system parameter changes should be listed with both external and internal TRS units.

WARNING: System parameters are typed directly into TRS 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 during powered flight.

Special attention should be paid to the units for manual changes outlined on the separate Init pad described above. Since the manual process is more subject to error, proper TRS 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 OCF should be verified during the database checkout to ensure that the correct number has been input in proper units. To do this, hardcopy displays prior to any Group MED or system parameter 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.

4.1.1.2 Final Mass Properties

The OCF data that has been used in sims up to this point does not represent what you will be flying with on launch day. It is the database that everyone has agreed to make decisions on when designing and planning the flight. There will be some difference between this data and what you really fly with on launch day. That is where the L-7 day TDDP and subsequent product deliveries come in. The release of the TDDP gets all the disciplines throughout the program “on the same page” (i.e., up to speed on what are the latest and greatest values for engine tags, mass properties, consumables budget, etc.). Flight Design takes this data and does what amounts to a mini-cycle of product redeliveries. The products you are interested in are PROP-31, ASAB-32B, ASCT-47, ASAB-25, ASCT-99, and DSCT-05.

The Propulsive Consumable section personnel will deliver an LDP cycle PROP-31 on FADS that contains all sorts of mass property data. Included in this package of data is an ARD Loading Worksheet. Sometimes the PROP personnel will not agree with the OMS and/or RCS loadings that are published in the TDDP. Any discrepancies need to be resolved. PROP needs to concur with or provide the following: aft RCS load, forward RCS load, total OMS load, and usable OMS quantity (total OMS load - unusable quantity due to mixture ratio losses).

In addition, ARDTools is also updated, as required, based on the other L-7 products. (The products' due dates are actually about L-3; see Section 2.1.1 for details.) The difference between the total OMS load and the usable OMS quantity may not match the system parameter value for trapped OMS (MCWTOX is usually 798 lb regardless of OV-102). The difference must be recorded as orbiter dry weight. ARDTools takes care of this automatically. You will use the output from ARDTools to confirm that all the data you receive is reasonable and accurate. From this new data, you will carefully write Initialization Pads for the ME to set up the launch database.

Once the data from these product deliveries has been incorporated into the TRS ARD database, you will do a database inspection and checkout run on L-1 day. Sections 4.1.2.2 and 4.1.2.3 discuss these procedures. When they are complete, the only thing that should change your database is changes due to DOLILU and the KSC ET loadings data from actual DOL tanking. Don't worry--that is exactly why the loadings section of ARDTools was created, and that is what you will use it for on DOL.

4.1.1.3 Weather Alternate Group MEDs

This section is no longer applicable.

4.1.1.4 SSME Performance Case Data

Note: The Booster office will recompute their SSME performance case data based on the L-7 TDDP and they will deliver a new set of Main Engine Tables. The performance case data must be updated to match the latest and greatest Booster data. This is done using the Thrust Limiting Delta File Application (TL DFA). The L-1 Week Checklist explains this procedure.

4.1.1.5 Miscellaneous Activities in Preparation for L-1 Day

The L-1 Week Checklist contains all the other steps you need to complete before L-1 day. An important task is getting copies of the latest data to the TRAJ and FDO. You should also check the FADS system thoroughly to make sure no products have been delivered since the OCF cycle but before the LDP cycle of which ARD, TRAJ, and FDO were not aware. The OMS engine data should be checked to make sure the OMS pods have not been changed on your orbiter between the time you created the OCF Init pads and now. This is rare, but it occurred during STS-59. Another item that may change since the OCF cycle is the launch pad. Usually if this happens, it is well publicized and you will receive plenty of notice. There are standard Init pads written in the ARD Office to support a launch pad change. See Section 2.2.3.5.

It is extremely important to verify that the correct units are being used for any parameter being input into the TRS. For example, the system parameters MDSPIM01 through MDSPIM07 have the units of 1/sec, but for input into the TRS, they must be in 1/hr. The ASCT-47 product should make these conversions for you, but always verify that they are correct. The wrong units on certain parameters could cause the ARD to crash or not function properly. This almost happened with a cycle timer on STS-55; the RSLs abort at T-3 seconds caused a 2-week launch delay, during which the error was detected.

Update the Ascent Events Summary with new titles and the actual lift-off time. Include any updates on boundaries or underspeeds from Targeting and Abort Support. There is always high demand for these during the last few days, and they are passed on to upper management, the State Department, TAL sites, NASA Headquarters, etc., for their information.

With all the running around making sure that FDO, TRAJ, and the TRS all have the latest data, take time to carefully update your own console databook. Include the new Main Engine Tables, Prop data, ARD biases, FPR weights, etc. You can do this on L-1 or before, but on DOL it is a distraction you do not want to bother with.

4.1.2 L-1 DAY OPERATIONS

4.1.2.1 TRS and Console Initialization

The TRS is brought up cold for the database check. This is to ensure that no SMS-configuration data is present in the TRS database. After the TRS is initialized and up and clear for inputs, the console is initialized. Console initialization for flight support is identical to the initialization performed during the ILC (see sec. 3.4.1).

4.1.2.2 Database Check

The TRS database must be checked to ensure that what Flight Design delivered (and what you sent to ME/DYNAMICS) is correctly implemented in the TRS. Also, post-OCF cycle changes documented in ASCT-47 must be verified and database errors must be corrected. These corrections are made just as if preparing for an integrated sim, and ME/DYNAMICS may already have the updates stored on file. System parameter and some MEDCV changes are stored on file, and all other MEDCV changes are stored in Group MED files.

When all the data is in, use the DBCHEK to check all the inputs. Retrieve from the Base_REFs the verified data file from the ILC (ex. 111_OCF). After you're sure that DYN has loaded the Group MEDs and system parameters, select "Data: Get Current". Verify all miscompares against the init pads submitted and ASCT47 (see the L-1 Day Checklist in Appendix D.9). When you're happy with the data, "Save as Ref" using the file name format of: XXX_DOL (i.e. 111_DOL). After the Confidence Run, have the GAs move the file to the BASE_REFERENCES directory. This DOL database will be your new reference "bible" until the launch takes place. Therefore, it is critical that you check it carefully against the checkpoint taken during the ILC. Make sure all the new L-7 based numbers are in correctly. Use the flight design data products and calls to the flight designers to resolve discrepancies. After the database is checked to ensure correctness, a checkpoint is taken. The TRS will be reinitialized from this checkpoint in the event that it crashes. Except for changes due to ET loadings data and DOLILU, the TRS database is ready for flight. The next procedure is to run the ARD in this configuration, an exercise that should detect any errors in the database or erroneous MEDs, if they exist.

4.1.2.3 TRS Confidence Run

The TRS Confidence run on L-1 day will involve DOL parameters processing state vectors from an OCF cycle trajectory. This will cause an ARD margin trend due to the mismodeling. There is a spreadsheet to compute what this trend should be. Call up:

S:\Divisions\DM\Private\DM46\ARDSTUFF\CONFRUN\Ardconpr.xls

Fill in the data indicated. Take this with you to L-1; it will help you judge whether the trend you will see is due to the known differences or indicates that something is wrong. See Figure 4-1.

When the checkout run is complete, resolve any problems you might find. Next, a DOLILU transfer test is often done just as it will be on DOL; see Section 4.1.3.2.

On the DOL, the database will be checked again to ensure correctness. The final TRS database updates occur about an hour and a half prior to launch when the ET loading estimates are available. ARD Support uses the loadings section of ARDTools to compute TRS database updates based on the actual ET loading estimates.

TRS Checkout Run: ARD Margin Trend Predictor

File: MOCONPR3.XLS

5/14/02

10:14 AM

Make inputs into purple boxes.

Cell notes exist - check indicators.

There are hidden rows and columns.

Includes FPR and Fuel Bias added wherever Dry is - not in prop.

Tape Number:
Run Date: **3/29/02**
Run Number: **5**
Run Trend: **0**

LOAD DATA

FLIGHT	FLT CYC Configuration	DOL Configuration	Difference
STS-110	(SMS engine data)		from FLT Cycle
Dry Vehicle	669279	671041	1762 lbs.
MEP Weight	1605392	1605314	-78 lbs.
SRB Sep Wt	373251	374838	1587 lbs.
FPR	2322	1721	-601 lbs.
Fuel Bias	679	894	215 lbs.
NOMMETH	469965	471651.333	1686.333 lbs./eng.
Isp at 104%	452.62	452.51	-0.11 sec.
Bucket Start	39.21	34.85	-4.36 secs.
Bucket End	55.93	50.81	-5.12 secs.
Bucket Level	72	72	0 %throttle
Bucket Adjstm	16954	16183	-771 lbs.
Grav	32.17405 ft/sec2		

Note:
Input bucket start, stop, and power level based on how ARD will be set up for confidence run (ref lastweek.doc).

MET	FLT CYC Acceleration (a= F/m)	DOL (104.5%) Acceleration (a= F/m)	Delta-Accel (fps/min) (ARD Margin Trend)	Total Trend incl. observed trend from run	MET
120	31.0	31.1	-9.8	-10	02:00
150	33.1	33.3	-11.2	-17	02:30
180	35.5	35.7	-12.9	-25	03:00
210	38.3	38.5	-15.1	-34	03:30
240	41.6	41.9	-17.9	-45	04:00
270	45.1	45.4	-21.2	-58	04:30
300	49.7	50.1	-25.8	-75	05:00
330	55.4	55.9	-32.2	-96	05:30
360	62.5	63.2	-41.2	-124	06:00
390	71.7	72.6	-54.5	-161	06:30
420	84.1	85.4	-75.4	-215	07:00
450	101.8	103.6	-111.0	-297	07:30

Due to Mass deltas

Total Mass Delta from Flight Cycle (incl. bucket)
2114 lbs.
Total Thrust Delta from Flight Cycle (cluster)
5058.999 lbs.
Change in Bucket length:
0.76 secs.

Figure 4-1. TRS Checkout Run spreadsheet

4.1.3 Day of Launch Operations Through L-9 Minutes

ARD Support is due on console at no later than L-5 hours. The tasks to be accomplished prior to coming out of the final hold at L-9 minutes are covered in the L-1 Week checklist. Complete at least one database check soon after arriving on console. This is to ensure that the database was not somehow corrupted since the checkout. Besides, FDO will ask the status of the database, and if there is a problem, you will need to understand and correct it as soon as possible. When using DBCHEK, be sure to tell FDO or TRAJ when you're getting ready to get data as it may impact the system load. Use as a baseline reference the DOL file you saved at the confidence run.

Make sure ARDTools is properly configured and working correctly. Complete any steps from the checklist that are not yet finished. This may include setting up the stopwatch function on the time module or QA-ing any data that DYNAMICS has returned to you late.

4.1.3.1 MED Delog scan

This section is no longer applicable.

4.1.3.2 DOL I-Load Update (DOLILU) II Procedures

DOLILU II implements DOL uplink of the throttle profile and first-stage steering parameters along with associated wind and atmosphere data. The command loads containing this information are built from a corresponding TRS data table, which is updated on launch day based on offline DOLILU II processing. The required values are transferred from the FADS system to the TRS, from which DYNAMICS builds a Group MED by which the TRS data tables may be updated. Accuracy of ARD processing is affected by DOLILU II updates since the ARD throttle table and AGT mass track update coefficients must be properly aligned with the onboard throttle profile. 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 DOLILU II requirements.

Safety requirements on DOLILU II dictate that ARD parameters must be QA'ed by (at a minimum) independent console positions. The procedures define specific steps and players in the QA process and protocol for resolution of discrepancies. Participants in this process are FDO, TRAJ, ARD Support, DYNAMICS, Ascent Support, and Abort Support. For more information, reference DOLILU II Definition and Requirements Document, DOLILU Operations Support Plan (NSTS 08329, Volume VIII), FCOH (Section 3.2.6.3), and FDO Console Handbook, vol. V (Prelaunch/Ascent). Once again, the FDO Handbook is the final reference; all effort is made to keep this document accurate and in sync.

Upon FDO authorization, DYNAMICS will transfer DOLILU II data from FADS to the TRS. At about L-2:30, a DOLILU II Group MED is built by DYNAMICS, and a hardcopy should be printed. ARD Support should obtain a hardcopy of the Group MED file after it is built and QA it against MEDCV images from the DOLILU II QA package.

Dynamics has a "K69 prep" group med that contains K69 zero throttle values, zero ISP values, and 5.000 MR values, all at times of 16:40 for each line for each table for each engine. These will be used to prepare each throttle table on DOL before the DOLILU II K69 data is loaded. The "K69 prep" will prevent any K69 MED from being rejected in the event that the DOLILU II throttle bucket is shifted earlier in time than the previous throttle bucket stored in the ARD throttle history table. Unisys testing has proven that this method is effective.

Note: This "K69 prep" is generic since DOLILU II will overwrite throttle, ISP, and MR entries with correct values. Thus this "K69 prep" should not require flight-to-flight reconfiguration.

At L-3:00, the "K69 prep" with 16:40 time entries are loaded to prepare each throttle table for DOLILU II entries, then the DOLILU II Group MED is loaded. ARD Support should QA the following displays against the DOLILU II file: TRAJ PARS (F02) (MDMBOD01 & 02, SECDs 2, 5-16), AME/ETIP AGT MED (VLIN, VZERO, VMEOATO), ARD CONTROL DATA (ATO dump time, OMS Assist flag & time, EPSK2, K66 ENA/INHs), C SSME THROT (ARD throttle table, C eng), L SSME THROT (ARD throttle table, L eng), R SSME THROT (ARD throttle table, R eng), ARD/AME SYS PARM (VKMAXU, VKMAXD). When this is completed, inform TRAJ of the result of the QA check. If a discrepancy is found, FDO will ask Ascent Support for a discrepancy explanation. A NO-GO shall be declared until thorough understanding of the problem (and resolution) is demonstrated. FDO will write a DR and submit a Flight Note noting the discrepancy and action taken.

At ~L-2:30, ARD Support should obtain a new AGT weight delta table from Abort Support and distribute this data to FDO and TRAJ. This data should be incorporated into flight databooks to confirm adaptive guidance throttling and check ARD DELWT.

4.1.3.3 ET Loading Updates

4.1.3.3.1 Nominal Procedures

In order to provide accurate abort boundary prediction, the ARD is updated with actual ET load quantities at about L-3.5 hours. Actual loaded liquid oxygen (LOX) and liquid hydrogen (LH2) quantities are input into the loadings processor of ARDTools, which re-computes vehicle mass properties, FPR, and fuel bias for the ARD as well as the launch hold table. In addition to matching overall vehicle mass properties, performing this update enables the ARD to start with the most accurate possible fuel bias, which becomes important in the event of an SSME performance case. FPR updates are based on predicted MECO propellant imbalance, which is sensitive to this initial fuel bias. So inputting the actual fuel bias improves the accuracy of FPR updates, which affect press times and uphill capability appreciably.

PLOAD is the computer program used by Ascent Support to calculate actual ET loadings during the countdown. Tank ullage pressures along with propellant temperatures are used to predict what quantity will be in the tank at End-of-Replenish (EOR), which occurs at about T-5 minutes. (Following EOR is the drainback phase

during which the LOX tank is not replenished, as some is vented out of the SSME overboard lines. Prior to this, LOX tanks are continually topped off to maintain maximum quantity.) PLOAD LOX and LH2 loadings are passed to ARD Support at approximately L-3 hours (see Figure 4-2). EOR LOX and LH2 are input into ARDTools loadings using the DOL propellant loading function. (See ARDTools User's Guide for more information.) ARDTools subtracts the correct drainback amount to obtain propellant quantities at engine start command. From this it computes K67 usable prop (MEP), ET jettison, dry vehicle, and FPR weights which are used by the ARD. K88 ARD Fuel Bias, K88 ET prop low level, and system parameter MCWTET are also computed. ARDTools provides a printout of these results, which should be provided to the FDO and TRAJ. This is shown in Figure 4-3. ARDTools also provides the capability to ship the MEDs that will update the server with the PLOAD data.

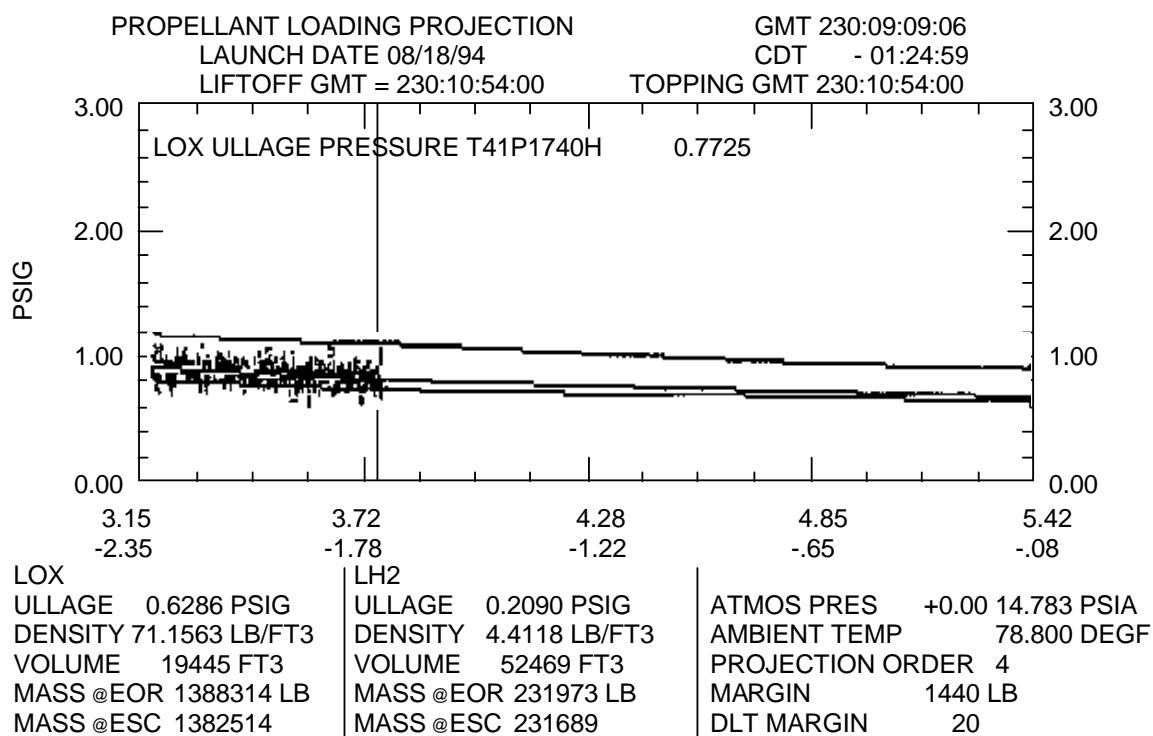


Figure 4-2. Example PLOAD program output

ARD Support is expected to recommend to the FDO which updates should be made to the ARD. A formal chart of criteria is currently in the FDO Console Handbook. In summary, we update for anything >10 lb on Fuel Bias, and >50 lb on everything else. There is an element of FDO-of-the-day. Some FDOs use larger criteria. It is a good idea to know what the 2-sigma values are for the affected parameters. ARDTools may be updated some day to include this for us. That way, you can judge just how relevant the delta is. ARD Support should also closely monitor the updates, obtain hardcopies of affected displays, and recheck the database for any erroneous changes (this happened at L-1 hour on STS-57; the OMS quantity was accidentally changed, but this error was caught by the ARD Support controller).

Note that we do not update MCWTET. System parameter MCWTET is used to compute the center of gravity of the vehicle during first stage, which is used to calculate aerodynamic pitching moment and SRB nozzle cant angles. These calculations are not critical for second stage modeling, and to change this parameter would require the TRS Flight Mode be taken from locked to unlocked so the change to TRS memory can be performed, since it is a system parameter.

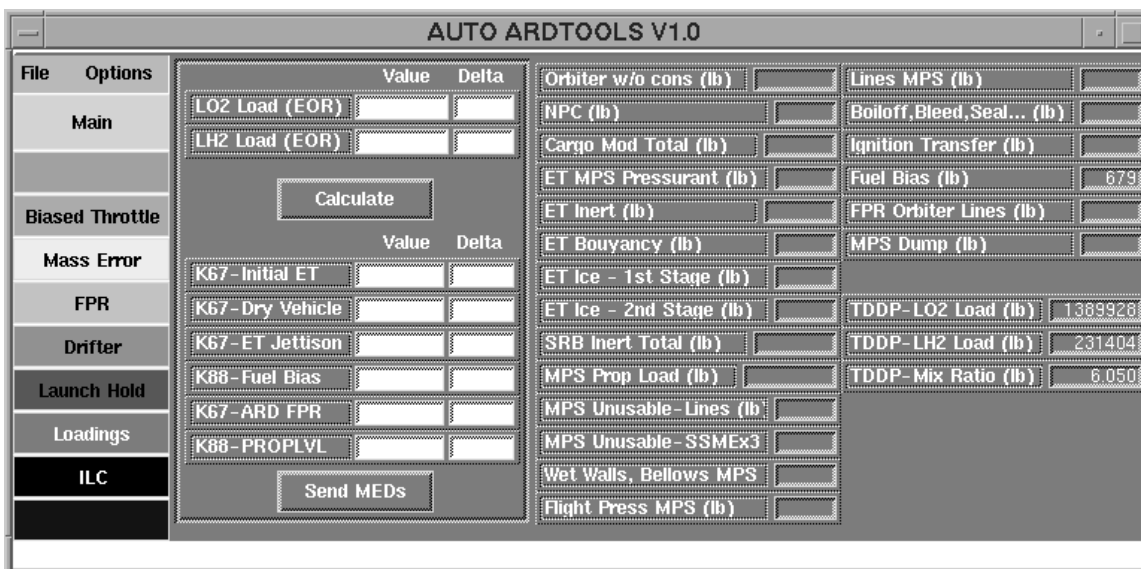


Figure 4-3. ARDTools ET loadings update

If for some reason there is a delay in obtaining ET load data, check with Ascent Support personnel in the trajectory MPSR to see if they have obtained the data yet.

4.1.3.3.2 Off-Nominal Procedures

Problems with the ET propellant loading process can cause a delay in the availability of ET load estimates. 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 is useful, and an additional 10 minutes of data are required to derive a reliable curve; therefore, at least 30 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 hours before lift-off, hence the above time requirements are easily accommodated on the nominal day. However, during the replenish phase, if for any reason LOX is depleted to the point that the 98 percent quantity sensors are uncovered, a revert is performed wherein 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 restarted. It is

assumed that 30 additional minutes are needed (beyond the PLOAD 30-minute data requirement) for transmission to JSC, distribution to and analysis by the operators, briefings to MMT and FD, and count to T-0, which leads to a 1-hour minimum time between start of stable replenish and T-0. Reverts occurring inside about L-1.5 hours (allowing for the additional time to actually refill the tank) may require a launch slip so that required analysis can be performed. This situation occurred on STS-44. These requirements are separate from LCC requirements, which dictate ET loading criteria in terms of 98 percent and 100 percent 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. If all other LCC criteria are met, a launch may occur without stable replenish. If this occurs, the TDDP loading information is used.

If a LOX revert occurs after generation of the L-3:25 hour load report, PLOAD data will be delivered to the MPSR at 37 minutes after resumption of stable replenish (about 30 minutes of this is required for accurate curve-fitting of the ullage pressure data). This is a minimum of 23 minutes before lift-off, so quick coordination between ARD Support and TRAJ may be required to get updates from ARDTools into the TRS. LH2 reverts require only about 5 minutes of stable replenish to ascertain the predicted EOR quantity, and the data will be delivered to the MPSR only 12 minutes after resumption of stable replenish. Once again, launch could be as early as 23 minutes away, so remaining prelaunch activities must be expedited.

For the case of an extended hold before drainback (such as for bad weather) with no revert, predicted loads may be updated periodically. This is to account for the later lift-off time in the ullage pressure curve prediction. Nominally, extra data sets will be taken at 30, 60, 120, etc. minutes past the originally planned lift-off time. These should be delivered to the MPSR at about 37, 67, 127, etc., minutes after the nominal lift-off time. Only the latest data should be used in the ARD if significant changes exist in the data. To avoid any possibility of confusion, care should be taken to destroy old launch hold charts once they have been superseded.

4.1.3.3.3 PLOAD Effects on FPR

Table 4-1 outlines lightweight tank (LWT) and super lightweight tank (SLWT) loading data uncertainties for ARDTools that should be used for various scenarios. NOTE: The actual values to be used should always be verified in SPAD Tables 8.1 and 8.4! For no-PLOAD, the ARD FPR increases slightly based on the increased load uncertainty. For both LWT and SLWT, when both low range sensors fail, use the no-PLOAD uncertainties. To determine the new FPR quantity for these different cases, the 1σ load uncertainties below should be input into ARDTools along with the TDDP load. Coordinate any updates to the ARD FPR with FDO.

- HISTORY: After a PLOAD issue on the reliability of the high range sensors on STS-88 and the PSIG meeting on January 1999, it was decided that the high range transducers would no longer be available for use. The case where both low range transducers were lost would result in a no-PLOAD scenario.

- **BACKGROUND:** The total 3-sigma uncertainty associated with PLOAD estimates of loadings are due to uncertainties in propellant density, tank volume, level control, wave action, and sensor location (reference AFSIG 1/31/92). 1-sigma loading uncertainties in pounds are input into ARDTools and used to compute the 6:1 component of FPR. The higher the uncertainties, the higher the FPR. When we use the PLOAD LOX and LH2 quantities, we must associate with them a PLOAD-derived uncertainty obtained from the SPAD. When the low range sensors are failed, or the low range data line is inoperative, then the No PLOAD procedures must be used. For a no PLOAD case, the ARD FPR must be configured to reflect load uncertainties based on historical differences between reported loadings (PLOAD) and target load (TDDP) root-sum-squared with PLOAD uncertainties above. Note that to commit to flight, managers must be certain that enough propellant is in the tank to meet performance constraints.

**REFERENCE THE SPAD FOR THE MOST CURRENT UNCERTAINTIES!!!
DATA SHOWN HERE ARE TYPICAL EXPECTED VALUES.**

	Low Range Sensors PLOAD available	PLOAD not available
LOX Load	Use reported load	Use TDDP load
LWT: 1 σ uncert (lb)	1376	1742
LWT: 3 σ uncert (%)	0.29	0.37
SLWT: 1 σ uncert (lb) *	1376	1742
SLWT: 3 σ uncert (%) *	0.30	0.38
LH2 Load	Use reported load	Use TDDP load
LWT: 1 σ uncert (lb)	309	309
LWT: 3 σ uncert (%)	0.40	0.40
SLWT: 1 σ uncert (lb) *	309	309
SLWT: 3 σ uncert (%) *	0.40	0.40
How derived	RSS of PLOAD uncerts	RSS of PLOAD uncerts and historical TDDP-PLOAD

NOTE: Data Origin: SPAD, Change No. #47, March 16, 1999; Tables 8.1 and 8.4. □

Table 4-1. PLOAD Loading Uncertainties

4.1.4 L-9 Minutes to Nominal MECO

This portion of the ARD Support Console Handbook addresses the realtime aspect of console support. The procedures for supporting a nominal ascent are presented here; off-nominal procedures (e.g., aborts) are covered in Section 4.2. The procedures contained in this console handbook are written from the point of view of ARD Support. They are intended to describe, in timeline fashion, what occurs. To get a better grasp of the larger picture, read Section 6 of the FDO Console Handbook (vol. V - Ascent). Each procedure is presented in checklist form along with background material. Note that many procedures described in this section are also utilized during aborts and off-

nominal cases, where differences are described in the next section. Some functions performed by FDO and/or TRAJ are included in the checklists in order to provide further explanation of team tasks and ARD responsibilities in particular. Phrases in quotes denote phraseology that should be used verbatim to reduce confusion. The main displays used by ARD Support are ARD OUTPUT; ARD DV Margin; ARD MAINTENANCE; and the throttle tables.

4.1.4.1 Console Checklist

Figure 4-4 is an example console checklist for powered flight. Feel free to create your own personal checklist while training. In fact that's a great way to learn the procedures. By your interim evaluation, you'll have to use the official procedures in Appendix D.12.

ARD SUPPORT CONSOLE CHECKLIST

STS-____/____ ARD OUT____
 RUN#____ DVMARG____
 DATE____ ARD MAINT____
 INITIALS____ Inclination____

MASS ERROR/1 sec.	
TMECO	delta
3:00	4000 lbs.
4:00	5000 lbs.
5:00	6000 lbs.
6:30	10000 lbs.

HOLD TIME ____:____ NEW FB____
 NEW ETP____ NEW ETD____
 NEW FPR____

Prime RILS KSC____
 Prime TAL____
 Initial K73 OMS____
 Nominal Bucket Level ____/____%

IYs: X____
 Y____
 Z____

L/O: ____/____/____ : ____:____
 Bucket ____/____ Tdel____secs____lbs.
 NEW Delwt?____

2 ENG TAL ____:____ PTA ____:____ SEPTM ____:____
 NEG RETURN ____:____ PTM ____:____
 DROOP ____109 ____:____ SE ____:____

SRB SEP: VREL____ 1ST STG PERF:
 NOM LOFT
 HDOT____ LOW DEPR

ABORT ATO TAL RILS
 MSK 463 RV MSK 444 RV
 VEL____ TIME ____:____

Nom MECO VI____
 Actual MECO VI____
 U/S Predict____ Actual____

NOM MARGIN/TMECO/WEIGHT(ARD-O/B)

STG____ Determine Trend on TLM

3:00 ____/____/____
 3:30 ____
 4:00 ____/____/____
 4:30 ____
 5:00 ____/____/____
 Reconfig HYPE after PTM
 6:00 ____/____/____
 7:00 ____/____/____
 8:00 ____/____/____
 9:00 ____/____/____

DRIFTER Level ____ to Level ____
 IMBAL ERROR____ DV ADJUST____ For MINUTE____

BSE SUSPECTS?	NONE	L	C	R
		DATA CMD	DATA CMD	DATA CMD

CASE	LEVEL	ENGINE	THROTTLE	TIME
ELEC/HYD LOCK	____	L C R	____%	____:____
PcS HI Act LO	____	L C R	____%	____:____
PcS LO Act HI	____	L C R	____%	____:____
HPOT EFF	____	L C R	____%	____:____
LPFT	____	L C R	____%	____:____
FLOW HI Act LO	____	L C R	____%	____:____
FLOW LO Act HI	____	L C R	____%	____:____
NOZLEAK	____	L C R	____%	____:____
BACKUP LOCK	____	L C R	____%	____:____

1ST ENG OUT L C R
 TMEO ____:____
 VMEO ____:____

Vstg IF
 EO in 1st
 STAGE

2ND ENG OUT L C R
 TMEO ____:____

OMS L Fuel Ox He
 OMS R Fuel Ox He
 Level____ Blowdown Time____secs.
 ATO DUMPED____ - OMS____
 ATO REMAIN____ + RCS____

THROTTLES	TIME	(-6 SECS.)
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____
____	____:____	____:____

If Table full, expect weight error

MECO RNG____ VEL____

Figure 4-4. Example Console Checklist
 4-14

4.1.4.2 Terminal Countdown Procedures

PURPOSE

To document realtime procedures for supporting countdown from T-9 minutes to lift-off.

PROCEDURE

- L-9 MIN & COUNTING:
 - √ DISPLAY CONFIG
 - √ ARD OUTPUT: TAL SITE, HMCONFIG
 - √ STOPWATCH READY
 - √ DVIS CONFIG
 - √ ARD DATABASE: ARD-AME INIT, Throttle Tables
- L-4:55 & COUNTING:
 - STAND BY FOR LAUNCH HOLD

BACKGROUND

During the hold at L-9 minutes is a good time to tag up with TRAJ and discuss any ARD issues for the coming powered flight phase. This might include landing site selection, HM configuration, timing of calls, or launch hold procedures. Make sure there are no misunderstandings on anything.

Prior to lift-off, the workstation should be configured so that the ARD MAINTENANCE, the ARD OUTPUT, and the DVMARG are displayed. The workstation should also be set up with the three throttle tables.

From L-9 min to L-4:55, it is a good idea to scan the following portions of the database one last time, looking for corrupted values: Throttle tables, ARD-AME INIT data. Note that during an actual countdown the ARD initial OMS quantity was corrupted accidentally during ET loading updates and was found later by the ARD Support during this type of database check. Also verify that the correct TAL site is in the ARD.

From L-4:55 to lift-off, ARD Support is standing by, prepared to support a launch hold. Loop traffic and MPSR noise should be kept to a minimum at this point. By all means notify the MPSR police if proper MPSR noise discipline is not being maintained.

4.1.4.3 Launch Hold Procedures

PURPOSE

To document realtime procedures for configuring the ARD after a launch hold inside drainback.

PROCEDURE

- LAUNCH HOLD INITIATED: START STOPWATCH AND MONITOR LCC LOOPS FOR HEADS UP ON COUNT RESUME TIME
- LAUNCH COUNT RESUMED: STOP STOPWATCH AND NOTE HOLD TIME
- FDO: PASS NEW L/O TIME TO DYN
- COORDINATE W/ TRAJ TO DETERMINE HOLD DURATION, ROUNDING UP TO NEAREST 5 SECONDS
- ARD SUPPORT: SELECT HOLD TIME AND CALCULATE WITH ARDTOOLS. ONCE CALCULATIONS ARE PERFORMED, DOUBLE CLICK SEND MED BUTTON TO SHIP THE FOLLOWING PARAMETERS (CAN BE SHIPPED PRIOR TO L/O):
 - K67 Δ ETD
 - K67 Δ ETP
 - K67 ARD FPR
 - K88 FBIAS
 - K88 PROPLVL
- CONFIRM UPDATES ON ARD OUTPUT, ARD/AME INIT, AND ARD MAINTENANCE; ENSURE NO OTHER VALUES CORRUPTED

NOTE: Since holds at T-31 sec are likely in this case, it is not unusual for the updates to be made during powered flight. Updates must be complete prior to staging.

BACKGROUND

During launch preparations, LOX and LH2 flow through parts of the main engines to provide thermal conditioning. LH2 is returned to the ET, but LOX is drained out of vent lines on the SSME nozzles. Prior to L-4 minutes 55 seconds, LOX lost overboard is replenished via the fill and drain valves so that the proper oxidizer quantities are maintained. However, at L-4:55 the drainback phase starts, during which LOX is no longer replenished. As long as lift-off occurs on time, this is no impact since the propellant inventory accounts for the vented LOX. If a hold does take place, then this results in a decrease in the amount of total usable propellant since LOX continues to be

drained. Decreased LOX results in an increase in Fuel Bias, and an increase in dry weight (unusable LH2 double-book-kept). In addition, FPR decreases due to the increased Fuel Bias since higher bias lowers the chance of a costly LOX imbalance building up due to mixture ratio dispersions. The ARDTools program outputs launch hold data that tabulates Fuel Bias, delta dry weight, delta ET propellant, and FPR as a function of hold time. This data is generated after L-3.5 hour loadings come in. See Figure 4-5.

```

Launch hold updates to ARD for flight: SSP114
File generated on: Wed Mar  2 13:49:45 CST 2005
    
```

Hold	Fuel Bias	DETP	DETD	FPR/PROPLVL
0:00	679	0	0	2322

0:05	697	-124	18	2296
0:10	714	-248	35	2272
0:15	732	-371	53	2249
0:20	749	-495	70	2229
0:25	767	-619	88	2210
0:30	784	-743	105	2192

0:35	802	-867	123	2176
0:40	820	-991	141	2162
0:45	837	-1114	158	2148
0:50	855	-1238	176	2136
0:55	872	-1362	193	2125
1:00	890	-1486	211	2115

1:05	907	-1610	228	2106
1:10	925	-1734	246	2098
1:15	942	-1857	263	2091
1:20	960	-1981	281	2084
1:25	978	-2105	299	2078
1:30	995	-2229	316	2073

1:35	1013	-2353	334	2068
1:40	1030	-2476	351	2064
1:45	1048	-2600	369	2060
1:50	1065	-2724	386	2057
1:55	1083	-2848	404	2054
2:00	1101	-2972	422	2052

Figure 4-5. Sample Launch Hold Data

If a launch hold occurs inside drainback, it is important to know the hold time. This can be accomplished by using a personal stopwatch or by using the PC timer under Start → MCC Menu → E. Flight Items → A. Timer. It is extremely important for ARD Support to record the hold time. In the hectic timeframe of a launch hold inside drainback, there is no guarantee that anyone else will know it. After the count resumes, coordinate with TRAJ to select the proper hold duration, rounding up (conservative) to the nearest 5 seconds. This time is entered into ARDTools and the corresponding update can be shipped from ARDTools as well. These updates must be loaded prior to SRB SEP. A portion of a typical Launch Hold Table from ARDTools is shown in Figure 4-5. The actual table shows data up to an 8:55 hold duration.

4.1.4.4 Lift-off Checks

PURPOSE

Document procedures for verifying ARD lift-off time, recycle time, and IY option in the post-lift-off timeframe.

PROCEDURE

- LIFT-OFF CONFIRMED:
 - √ GRND D65 L/O TIME MATCHES O/B exactly
 - √ GRND K83 L/O TIME MATCHES O/B to within 0.1 sec
 - √ CORRECT IY OPTION
 - √ ARD CYCLING, VERIFY "TL" FLAGS OFF
 - √ ARD mass track recycle time is correct
 - √ ET MASS History
 - START ARDTOOLS
 - SELECT: FILE → OPEN → ALL (can be done before lift-off)
 - SELECT: OPTIONS → RUN

BACKGROUND

When lift-off occurs, the onboard lift-off time appears on ARD MAINTENANCE. The ground value is also displayed on ARD MAINTENANCE for easy comparison with the onboard. ARD Support confirms that the correct lift-off time string, including days, has been entered, although this occurs automatically. The ground D65 time (MET reference time) must match exactly. The K83 lift-off time (IY rotation reference time) may be off by as much as 0.1 sec. A call to the FDO/TRAJ is crucial if the incorrect time gets into the TRS, because this will result in a mismatch between ARD and onboard planar targets since the inertial IY rotation is a function of time.

ARD Support should also confirm a correct IY rotation option (nominal for EF to M50 rotation, or rendezvous for M50 to EF rotation) has been entered into the TRS. This is displayed on ARD MAINTENANCE. If it is incorrect, it must be fixed ASAP. Notify TRAJ immediately if it is incorrect, since this could result in the ARD targeting to the wrong launch plane, thus providing erroneous ΔV margin output.

Prior to L/O, TRAJ and ARD Support ensure that the ARD thrust limiting flags are off and the ARD mass track recycle time and the ARD Mass history are 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 (ARD heavy). This can cause the ARD to be NO-GO. On STS-111, a software problem caused the ET mass to reset to its initial value at lift-off, and resulted in a +23 fps/min trend. To fix either of these, perform a K67 Δ ETP = -11,700 lb. A mass track recycle is automatically performed. A new ARD Mass History display was added after the STS-111 incident.

The workstation based ARDTools application must be started after the ARD is started. This allows the auto-calculation functions in ARDTools to extract the necessary ARD and TLM data to monitor ARD health. Note: "Run" can only be selected after lift-off; opening the data files can be done before lift-off.

4.1.4.5 Adaptive Guidance Monitoring

PURPOSE

To document procedures to predict vehicle throttle bucket profile and verify ARD weight adjustment.

PROCEDURE

- 0:20 MET:
 - NOTE PASS AND BFS DOWNLISTED TDELs ON ARD OUTPUT
 - USING THE PASS TDEL, LOOK UP THROTTLE BUCKET SETTING AND DELWT FROM THE AGT CHART
 - CALL TRAJ W/ BUCKET AND DELTA WT GOOD/BAD
- IF TLM NOT AVAIL:
 - INFORM TRAJ STATIC DATA; STANDBY FOR TDEL CALL
 - CALL WHEN DATA RESTORED
- IF DELWT IS NOT CHART VALUE:
 - RECOMMEND DELWT OVERRIDE FROM CHART
 - VERIFY GOOD INPUT

BACKGROUND

One function of ARD Support is to monitor onboard adaptive guidance output. ARD Support will confirm the throttle and delta-weight parameters that are computed to account for throttle bucket adjustments (load relief) by a call to TRAJ. Upon reaching an I-loaded velocity (V_{ref_adjust} , around 20 seconds MET), onboard guidance compares the current elapsed time to an I-loaded reference time (T_{ref_adjust}) at which V_{ref_adjust} was expected. The difference in these times is $TDEL_adjust$ (operationally referred to as TDEL), which is downlisted for both the primary and backup flight systems.

TDEL is the difference between the time when the vehicle actually achieved V_{ref_adjust} and the time that would nominally be expected. The larger TDEL is, the further off-nominal the initial portion of the ascent is. TDEL represents an acceleration difference that is generally attributed to SRB performance since SRB dispersions are the largest source of trajectory deviations in first stage. Thus, for a negative TDEL, the vehicle has accelerated more quickly than anticipated. This extra acceleration is attributed to the SRBs producing more thrust. High-thrusting SRBs are called hot, while lower-thrusting SRBs that result in a positive TDEL are called cold.

Onboard guidance uses TDEL to adjust the SSME throttle bucket and pitch profile in order to maintain dynamic pressure constraints which are threatened by either excess or low SRB performance. To maintain dynamic pressure (q) constraints, the vehicle generally lofts the first stage trajectory for hot SRBs. The throttle bucket is also lowered to compensate for the SRBs. For example, instead of having a throttle bucket of 104/65 percent, the bucket may be adjusted to 100/65 percent (see Figure 4-6). This bucket modification reduces the max q and, as a side effect, saves main propulsion system (MPS) propellant for use in second stage. To minimize the impact of cold SRBs, the vehicle depresses the trajectory, allowing a more optimum trajectory. The throttle bucket is also adjusted upward to compensate for the lower performance SRBs. For example, instead of flying a 104/65 percent bucket, it may be adjusted to 104/70 percent (see Figure 4-6). In this case, you must still meet the dynamic pressure constraints, and you lose propellant as a by-product.

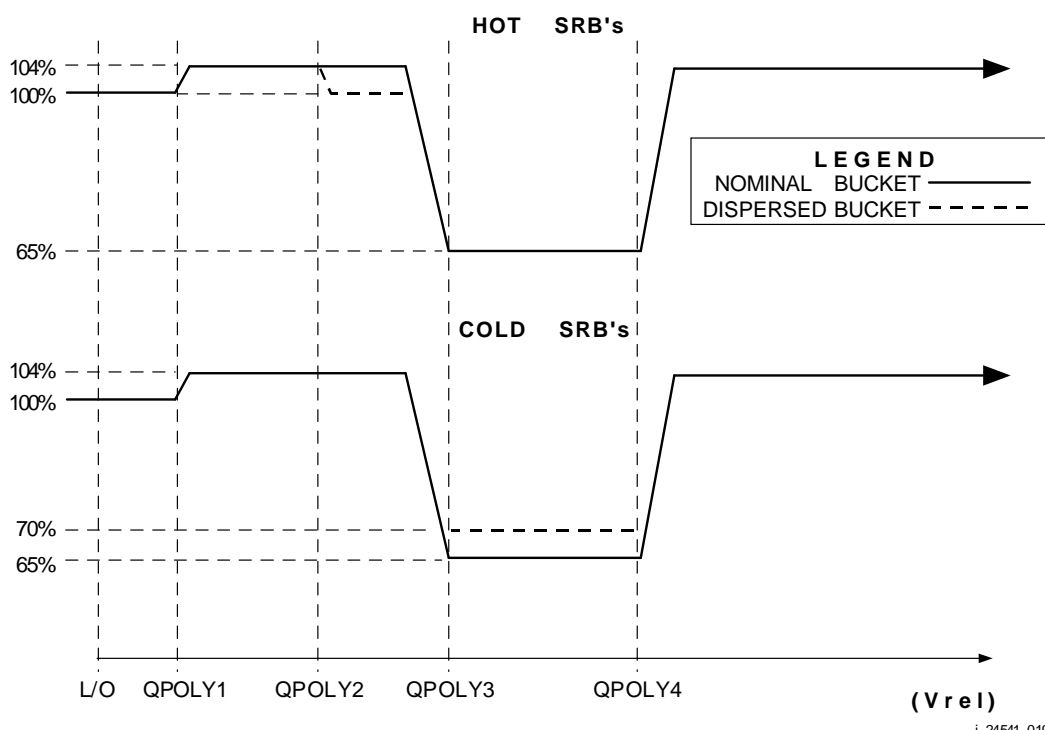


Figure 4-6. Throttle bucket adjustments for hot and cold SRB

The ARD has a built-in nominal bucket that does not change. The ARD uses TDEL to compute a delta weight (DELWT) that is applied to the ARD mass track to account for an off-nominal bucket. This delta weight represents the propellant use difference between the planned throttle bucket (which is given in the ARD throttle table) and the actual bucket. For example, if the real throttle bucket uses less than the planned (e.g., hot SRB example above), a positive delta weight is applied to the ARD mass track.

At approximately 20 seconds MET, TDEL is downlisted for both the primary and backup flight system (BFS). The ARD also computes a TDEL, but it is somewhat inaccurate due to the ARD's 1.92 second cycle rate (velocity snaps are too granular). Therefore, the ARD uses the PASS value if it is available, else the BFS value is used. This is the

ONLY piece of telemetry (other than state vectors when telemetry is the selected source) that can get automatically incorporated into the ARD. The TDELs are displayed along with the DELWT and DELWT OVERRIDE in the lower right-hand area of the ARD OUTPUT display. The DELWT and DELWT OVERRIDE entries are made automatically when based off of the TDEL. ARD Support notes the TDEL and looks up the corresponding throttle bucket profile and delta weight from a flight design delivered Adaptive Guidance Table (AGT) from product ASCT-22A or Abort Support for DOL. ARD Support passes this information to TRAJ, who is also looking it up (e.g., 104, 66; good weight). FDO uses the throttle settings that ARD Support passed to TRAJ to compare with the actual onboard throttles. A good ARD Support should also do this check. Compare the throttle bucket from the chart to that shown by the PASS/BFS commands and the Booster computations. When the vehicle throttles to what ARD Support pulled off the table, the FDO sometimes gives a "TDEL confirms throttles" call to the FD if requested. FDO may also comment on the dispersion level of the SRBs based on TDEL (one sigma TDEL is about ± 0.3 sec). If the vehicle does not throttle to what ARD Support said it would, there is a guidance problem, engine hardware problem, or a mistake by ARD Support.

If telemetry or PASS problems occur, or if the DELWT does not match the AGT table value, it may be necessary for DYN to manually input the DELWT Override. ARD Support should make sure DYNAMICS does this entry correctly and that no other entries are made by mistake. This can happen because the ΔETP and ΔETD entries are adjacent to the DELWT Override entry on the K67 MED.

4.1.4.6 Staging Performance Check and IY Confirmation

PURPOSE

To document procedures to determine staging conditions and verify ARD planar targets after SRB separation.

PROCEDURE

- SRB SEP:
 - RECORD Vrel
 - VERIFY ARD SELECTED IYs = O/B IYs
 - IF PASS
 - IF MATCH → CALL TRAJ IYs CONFIRMED
 - ELSE
 - NOTIFY TRAJ
 - √ GRND L/O TIME MATCHES O/B
 - √ CORRECT IY OPTION
 - IF NO JOY: CALL TRAJ GRAB O/B IYs
 - IF BFS
 - CLOSELY MONITOR MARGINS
 - IF DOWNWARD TREND AND ADI (ARD-PASS) YAW IS CHANGING BY MORE THAN 0.2 DEG/CYCLE AND NO OTHER REASON FOR TREND → RESELECT I-LOADED IYs
 - IF DELAYED SRB SEP
 - NOTIFY TRAJ TO UPDATE OMS ASSIST START TIME

BACKGROUND

ARD Support monitors several parameters at staging. They include relative velocity (Vrel) and the ARD Actual Mode Nominal MPROP margin. A good cue for when staging has occurred is the PC <50 and SRB Sep on the FDO Ascent DDD. When this event light is lit or there is some other indication that SRB SEP has occurred, ARD Support notes the Vrel available on ARD MAINTENANCE.

Vrel at staging is input into the ARD as the engine-out velocity if an engine-out occurs in first stage. This velocity is used by the ARD Event Predictor to determine when pitcharound will occur and what the fuel dissipation attitude should be. This is to emulate what onboard guidance does; it snaps the staging velocity and uses it to set the fuel dissipation attitude. If the actual engine out velocity were used, the ARD solution would not be as accurate as it could be. This would affect the ARD estimated time to pitcharound. FDO uses this time as a backup cue in case guidance has failed or is having trouble converging. If this is the scenario, then an RTLS abort will be executed at 2:30 MET.

The planar targets (IY) that the ARD is using must be checked to ensure that they are the same as those the onboard is using. There has been at least one sim case where an abort was initiated because the ARD did not have the correct planar targets. This was a result of an incorrect vector rotation option being used when the lift-off time was updated (rendezvous was used instead of nominal for a non-rendezvous flight). It is also possible (particularly during sims) that the onboard planar target is not correct. If IYs are wrong, you'll notice it in the form of decreasing DV margins and a negative trend (see 4.1.4.8)

ARD Support notes the ground-computed IYs after confirming TDEL parameters in first stage. These IYs are computed based on the updated lift-off time that DYNAMICS inputs; therefore, it is required to confirm that the correct lift-off time and rotation option have been input into the ARD (K83 MED). The IYs, lift-off time, and rotation option are all on ARD MAINTENANCE. These onboard IY targets are compared to the ground-computed IY targets to confirm that the ARD is flying to the same plane as the shuttle. Once this has been confirmed, ARD Support makes the call to TRAJ: "IYs confirmed." If the IYs do not match, then both the ground lift-off time (D65 MED) and the EF Launch Targeting time (K83 MED) should be checked again, along with the IY rotation option. If these are correct, the vehicle may have incorrect planar targets (e.g., I-load error). If this is the case, FDO and GPO will be working this problem on the Flight loop if serious out-of-plane steering is occurring. It may be necessary to snap the onboard targets with a K84\$, K84P MED series that captures the downlisted IYs and then forces the ARD to use the PASS targets. Another option is to abort ATO in hopes of replacing nominal targets onboard with those for ATO.

If BFS has been engaged, see Section 4.2.14.

If staging is delayed significantly, then the OMS Assist start time in the ARD may need adjustment, which will automatically adjust the stop time as well. It is important to have the stop time correct in the ARD, otherwise the onboard dump will stop sooner than the ARD (by an amount equal to the amount of delay in staging), and cause errors in the ARD until the ARD also stops.

4.1.4.7 ARD Mass Track Assessment

PURPOSE

To document procedures to assess accuracy of ARD mass track.

PROCEDURE

- TO DETERMINE MASS ERROR:
 - TMECO METHOD (DO NOT USE IF NAV ERROR PRESENT):
 - ARDTOOLS: COMPUTES $\Delta\text{TMECO} = \text{ARD TMECO} - \text{O/B TMECO}$
 - ARDTOOLS: COMPUTES WEIGHT ERROR USING NSSME, TGO, AND ΔTMECO .
 - ARD HEAVY IF $\text{ARD TMECO} > \text{O/B TMECO}$
ARD LIGHT IF $\text{ARD TMECO} < \text{O/B TMECO}$
 - VERIFY WT ERROR W/ TREND ($\approx 2.1 \text{ FPS/MIN}/1000 \text{ LB MASS ERROR}$ 2:30 - 4:00)
 - IF SUSPECT MPS WT ERROR, OBTAIN CONCURRENCE FROM FDO AND SHIP $\Delta\text{ETP MED}$ FOR WT UPDATE & RUN DBCHEK POST-OMS-2 & SAVE THE POST-LAUNCH DATA

BACKGROUND

The primary responsibility of ARD Support during powered flight is to assess the ARD mass track and make recommendations on how to improve it, as required. The ARD mass track is really an ET propellant array. The array contains the values for the usable ET propellant at specific time points. This propellant array is controlled by the throttle table, which is initialized to the nominal profile. Changes to the throttle table (engine out, thrust limiting, etc.) are made by DYNAMICS via MED input or by FDO via PBI input. Section 6.3 contains further information on the ARD mass track.

The health of the mass track is evaluated using two cues available to the flight control team. The two cues are MECO time differences and trending ARD margins. Evaluations are made throughout powered flight, with status calls normally occurring at 3, 4, 5, and 6 minutes MET. At 3:00 MET, for example, ARD Support makes the call, "ARD looks good at three." If there is a problem with the mass track, it should be brought to the attention of TRAJ and FDO immediately.

The ARD-computed MECO time can be directly compared to the onboard-computed MECO times. Note that the TGOs cannot be directly compared; there is lag associated with the onboard value. MECO times are computed for both the primary flight system (PASS) and the BFS. If the MECO time of the ARD is earlier than the onboard computed MECO time, the ARD is accelerating faster than the onboard. This means

that the ARD is either light or has higher thrust (or both). Conversely, if the ARD MECO time is later than the onboard MECO time, the ARD is not accelerating as fast as the vehicle. This indicates that the ARD is heavy or has less thrust than the vehicle (or both). The ARDTools workstation application continually performs this computation through second stage.

The onboard computes a parameter called TF (thrust factor - visible on ARD MAINTENANCE). TF is the ratio of the sensed acceleration to expected acceleration. TF not equal to one is an indicator of off-nominal SSME thrust or a weight error.

Prior to lift-off, the ARD is configured with specific mass properties and engine characteristics. This defines a mass and mass flowrate profile that, in turn, defines an acceleration profile. If the real vehicle mass or flowrate differs from what is planned (and loaded into the ARD), the vehicle acceleration profile will differ from the ARD. The acceleration of the vehicle is visible in the state vector. This acceleration profile difference appears as a trend in the ARD nominal margin. An upward trend indicates the vehicle is accelerating faster than the ARD expected. This could be caused by the vehicle being lighter than expected, or having more thrust than anticipated or both. The AM MPROP will trend upward because the greater vehicle acceleration means that not as much ΔV will be required to reach the MECO target. Thus, the ΔV margin will increase since $\Delta V_{\text{margin}} = \Delta V_{\text{available}} - \Delta V_{\text{required}}$. The opposite is true for the downward trend. A downward trend indicates the vehicle is not accelerating as fast as the ARD expected. This indicates the vehicle is heavier than anticipated, or has less thrust or both, or possibly is flying to the wrong planar targets. Thus a mass error detected via TMECO error should be verified against the observed ΔV margin. It should be pointed out that an error in thrust (high or low) will manifest itself as a mass error over a period of time. This is due to a mass flowrate difference that can accompany a thrust difference. (If ISP is constant, then a flowrate error will accompany a thrust error.) Thus the signature for a weight error does not necessarily guarantee that a weight adjustment will fix the problem.

If an ARD mass error is suspected, it should not be corrected unless a likely source of error has been identified. This is due to the fact that an apparent weight error could be due to LOX or LH2 loading errors, vehicle inert weight errors, SSME thrust or ISP dispersions, or onboard navigation problems. For statistical reasons, the thrust update method (Section 4.1.4.8) is normally used to reduce thrust-induced mass errors, correcting the ΔV margin trend in the process. If a likely mass error is present, however, then a MED adjustment to the ARD's mass model is warranted. Examples of this are SSME failure times not being modeled correctly, SSME failure behind a data path (decreases confidence in failure time), suspected RTLS throttle time errors, etc. See Section 4.1.4.8 for why this method is preferred to a thrust update if a mass error is strongly suspected.

HISTORICAL NOTE: On STS-60 the ARD was "no-go" due to a mass error (procedural) at lift-off (the ARD mass track did not model the SSME thrust between ignition and lift-off, and error of approximately 11,000 lb ARD heavy). The same

problem occurred (software error this time) on STS-111, but the ARD was “go”, with a thrust update of +23 fps/min.

4.1.4.8 ARD Thrust Update and No-Go Criteria

PURPOSE

To document realtime procedures for evaluating the ARD solution and performing a thrust update using the Auto-Thrust Update software. These procedures are valid only from 3 to 6 minutes MET, if the same number of OMS engines are burning onboard and in the ARD, no SSMEs are stuck in the bucket, no SSME failure has occurred and no abort has been selected.

PROCEDURE (CLUSTER)

- 2:25 MET (BUT AFTER 2-ENG TAL): INFORM TRAJ: SELECTED SOURCE → TLM
- 2:30 MET: NOTE AM NOM MPROP
- 3:00 MET: EVALUATE MARGIN SLOPE W/ TRAJ ON FDO LAUNCH DIGITALS
 - √ TREND: STABLE & CONSISTENT WITH OBSERVED Δ TMECO (EARLY O/B TMECO, POSITIVE TREND)
- IF TREND > ± 30 FPS/MIN:
 - INFORM TRAJ ARD NO-GO UNLESS OTHER CONFIRMING INDICATIONS OF OFF-NOMINAL PERFORMANCE ARE PRESENT
 - BEGIN REALTIME DATABASE √
- IF TREND < ± 4 FPS/MIN: REPORT ARD IS GO; INSIDE DEADBAND
- IF TREND > ± 4 FPS/MIN and < ± 30 FPS/MIN:
 - CALL TRAJ: "GO FLAG, TREND OF x" WHEN GO FLAG APPEARS
 - COMPARE FRZ THRUST WITH COMP THRUST
 - IF OK → √ SELECTED SOURCE → FLTR
 - ELSE → INFORM TRAJ BAD FREEZE & CALL FOR RE-FREEZE UPON GO FLAG
 - PROMPT TRAJ TO √ WITH BSE: SEEING TREND; IS SSME PERFORMANCE NOM?
 - IF THRUST LIMITING CONFIRMED BY BSE → REQUEST BSE DATA, REMOVE ANY TRENDS SO FAR IF BSE REPORTS A CASE, GO TO SSME PERF CASE (4.2.3)
 - IF NOM → TRAJ: CLICK THE "EXECUTE ALL' PBI

- CONFIRM WITH:
 - “UPDATE” INDICATOR = “ALL”
 - TMECO AGREEMENT IMPROVED
 - MARGIN SHIFT TO NEAR DEADBAND LIMIT
 - IF CONFIRMED → INFORM TRAJ GOOD THRUST UPDATE & SELECT SOURCE → FLTR
 - ELSE → RE-EVALUATE THR UPD OUTPUT & TRAJ: √ BSE
- NOTE: AFTER THRUST UPDATE PERFORMED:
 - IF SSME PERF CASE OCCURS → RESTORE BEFORE ENTERING SSME DATA
 - IF AN ENGINE FAILS, DO NOT RESTORE

BACKGROUND

At 3:00 MET, the Trajectory Officer and ARD Support determine the health of the ARD solution as described in the previous section. The TMECO differences on ARD OUTPUT between the vehicle and ARD should generally be less than 1 second. Differences greater than this indicate presence of anomalies such as:

- significant thrust mismatch (requiring a relatively large thrust update),
- SSME thrust limiting,
- large NAV dispersions or guidance problems,
- non-thrust dispersions beyond flight experience such as a large loading error, inert weight error, or ISP dispersion, and/or
- a ground configuration problem (database or modeling error).

Although TMECO error is often used to provide a quick heads up on ARD modeling health, the nominal ΔV margin slope is used more often for detailed quantitative assessment of modeling errors.

When properly modeling vehicle performance, the ARD prediction of current nominal capability (nominal ΔV margin) does not vary with time. However, when SSME characteristics and/or vehicle mass properties are mismodeled (i.e., when systems dispersions are present), the nominal margin will trend up or down with time. The nominal ΔV margin should trend in a direction consistent with the TMECO discrepancy; e.g., a later O/B TMECO indicates low performance O/B and the ΔV margin should reflect this with a downward trend.

Analysis shows that at the flight-derived 2σ level, an SSME thrust dispersion results in a ΔV margin trend that is approximately three times larger than the trend due to all other performance-related variables combined. Therefore, it is probable that a trend outside this deadband is caused by improper SSME thrust modeling. Abort mode boundary accuracy is heavily dependent on accurate systems modeling; therefore, the ARD thrust value is updated in realtime, using an empirical relationship between thrust error and margin trend rate. The deadband is derived from the ΔV margin trend due to the root sum square (RSS) of 2σ inert weight error and 2σ ET LH2 loading error. It has been determined that ISP and ET LOX loading errors need not be included in the deadband since thrust updates can conservatively correct for these errors via flowrate adjustment. The deadband is equivalent to 3.4 fps/min. The update does not eliminate the trend; it merely reduces it to the deadband region where the remaining trend could be due to other factors for which protection is maintained via the ARD FPR (ref. flight rule 4.1.2-2).

Any ΔV margin trend beyond the deadband is considered to be due to an O/B thrust dispersion since the delta V margin is much more sensitive to thrust dispersions than others (case a above). However, thrust updates are not performed beyond the SSME system specification limit ($\pm 10,392$ lb/cluster or ± 0.74 percent, with a margin slope of ± 30 fps/min) without a confirming indication. In this case it is assumed that a ground configuration problem (last case above) is responsible unless secondary cues are present, such as large O/B TMECO difference from preflight predict or a suspected SSME performance case. The second and third cases 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 the fourth case above, other than obtaining SSME data from Booster in realtime if they can support this.

The auto-thrust update algorithm converts margin slope to thrust error using an empirical relationship. To do this, it requires a set of 10 smooth entries in the ΔV margin array (about 20 seconds) for an accurate curve fit. For smoothness, telemetry (TLM) vectors are much preferred over filter (FLTR) vectors; however, an approximate solution may be obtained using the FLTR. When the array is filled, the algorithm begins to output thrust data on ARD MAINTENANCE and FDO LAUNCH DIGITALS. Another 10 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.) This results in a requirement for 30 seconds of TLM data for the algorithm to function optimally. Therefore, TLM is selected at 2:30 MET (or right after the 2-engine TAL call) to allow thrust updates beginning at 3:00 MET. 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, so FLTR should be reselected during dropouts lasting more than a couple of cycles. 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.

Thrust update output can be examined once the ΔV margin and averaging arrays are filled with telemetry-based data ($\approx 3:00$ MET assuming TLM was selected at 2:30).

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). Note that the displayed slope is a raw slope and does not account for the nominal-expected slope, which may be slightly non-zero. The algorithm strips out the nominal-expected slope from the raw slope internally to come up with an adjusted slope, which is used in thrust error calculations.

Once the standard deviation of thrust error solutions from the averaging routine is below a certain threshold (0.007 percent RPL), 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. (Thrust updates are inhibited only during first stage, if the ΔV margin array is not filled, if in 3g throttling, or if an abort has been selected.) Note that the raw slope (displayed) may exceed the deadband slightly and still not require an update if the nominal-expected slope is non-zero and in the same direction, because the displayed value takes into account the nominal-expected slope (VERIFY!!!). Conversely, a thrust update may be required with a raw slope slightly inside the deadband if the nominal-expected slope is non-zero in the opposite direction. If the trend is greater than the deadband, then the algorithm will divide the cluster thrust dispersion equally among the operating engines and display it on ARD MAINTENANCE as updated tag thrust values for each engine. In addition, the thrust error in pounds per engine will be displayed along with the current standard deviation of the thrust error array.

The Thrust Update Freeze PBI is depressed by FDO 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 at 3:00 MET is, "ARD's GO at 3:00, slope -11, low thrust O/B, stand by for freeze," followed shortly by freeze when the GO flag is set. Note that margin slope output becomes stable well before 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 ARD MAINTENANCE. If the frozen throttle output is stable and matches the updating solution for a couple of cycles, then a good solution has been frozen and TRAJ can reselect FLTR for state vectors if desired. TRAJ should then consult with BOOSTER to determine if an SSME performance case is present. If so, then data should be requested and modeled via SSME Performance Case procedures (Section 4.2.3). If BOOSTER reports three nominal engines, 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. A discontinuous change in the ΔV margin will occur after a thrust update, along with better agreement of onboard and ARD MECO times. The ΔV margin trend should now be at or near the deadband. Once a trend is taken, another should not be taken on top of the original trend, i.e., only take a second trend if the first trend has been restored. (See the historical note below for details.) After the ΔV array has refilled, the algorithm should indicate either no update required or a very small thrust error beyond the deadband. 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 TRS.

The thrust update output should not be used outside of the time span of 3:00 - 6:00 MET. If for some reason it is desired to remove the updated thrust, the Restore PBI can be clicked to set thrust back to the prelaunch tag value. This will also trigger a mass recycle, reset the delta V array, and initialize thrust error output to zero pounds. For an engine out, do not restore the original thrust. See Section 6.2 for further detailed explanations.

Any time a thrust update is performed, FDO should inform FD on the Flight loop.

HISTORICAL NOTE: On STS-111 the ARD mass track did not model the SSME thrust between ignition and lift-off. The ARD was “go”, with a thrust update of +23 fps/min. After taking the +23 fps/min in the ARD, the calculation converged again to a value of -6 fps/min. This was a case where the thrust update did not lead to a shift toward the deadband (the re-converged trend should have been about +3 or +4 fps/min), but rather went past the deadband. This indicates that the problem was at least partially due to a mass error in the ARD, rather than solely a thrust error. Had the issue been a thrust error only, the shift toward the deadband would have worked. Here, the shift was well past the deadband limit because the trend can only fix a mass error at that instantaneous point in time. As time progresses, the taken trend being a thrust correction manifests itself as a “mass” delta that was instantaneously correct, but then proceeds to change with time! Thus, STS-111 then experienced a negative trend (ARD lighter and lighter) after the original +23 fps/min trend was taken. Thus, a second trend should never be taken on top of a first trend, because that second trend would indicate at least partially a mass error, not a thrust error.

PROCEDURE (SINGLE ENGINE)

A thrust update can also be performed on a single engine if Booster believes one engine is behaving anomalously. TRAJ can do this 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 SSME. Again, a restore can be done later if Booster does call a performance case.

4.1.4.9 Abort Boundary Monitoring and Hypothetical Modes Reconfiguration

PURPOSE

To document procedures for recording abort mode boundaries and maintaining proper hypothetical mode (HM) configuration.

PROCEDURE

- AT EACH FDO ABORT BOUNDARY CALL: RECORD MET and VI (Boundary Log on ARD OUTPUT)
- JUST PRIOR TO DROOP 109:√ 2HM 0, 0, 109*
- JUST PRIOR TO SINGLE ENGINE TAL: √ 2HM 0, 0, 104*

* or proper 1 good engine running; config based on DOL engine tags.

BACKGROUND

ARD Support must be cognizant of the mission mode and upcoming abort boundaries throughout powered flight. As the FDO makes mode boundary calls, ARD Support records the time. During ascent use the boundary log in ARD OUTPUT to record the boundary times and velocities. Click the "SNAPSHOT" button whenever a call is made. Once orbit is obtained, FDO will poll the backroom support people (ARD Support, Abort Support, TARGETING) to get a consensus of the boundary times. FDO will use this for his ascent summary that is in the log and is distributed to the FD. ARD Support should also be aware of upcoming boundary calls and provide an extra pair of eyes and ears to ensure that FDO makes the call on time. If there is any doubt concerning a call being late, alert Abort Support. The FDO Console Handbook, vol. 5, should be consulted to learn more about making abort boundary calls. Also, ARD Support should help make sure CAPCOM correctly communicates the abort boundary to the crew after FDO announces it on the FLIGHT loop.

ARD Support should also assist FDO in maintaining a proper Second HM SSME configuration by providing notification if the 2HM is misconfigured. Normally the Droop 109 call is made with the ARD (rather than VIs) if the Droop boundary is not near a higher priority boundary. In this case, the 2HM is set to one SSME at 109 percent and two others at 0 percent prior to Droop. After the Single Engine Limits boundary is reached, the 2HM is normally reconfigured to a single engine at 104% for the Single Engine TAL call.

4.1.4.10 Uphill MECO Assessment

PURPOSE

To document procedures for determining the actual inertial velocity achieved for a nominal or ATO case MECO.

PROCEDURE

- MONITOR FLTR STATUS COMING UP ON MECO
- UPON MECO CALL:
 - √ SS → TLM
 - WHEN VI STABILIZES → RECORD MECO VI AND UNDER/OVERSPEED FROM THE FDO LAUNCH DIGITALS
- REPORT THE UNDERSPEED OR OVERSPEED TO FDO

BACKGROUND

Once MECO has occurred, FDO requires a MECO condition assessment. ARD Support, along with the rest of the backroom support team, provides inputs on the MECO condition in the form of underspeed (or overspeed). The MECO status is easily obtained by looking at the O/S or U/S value on the FDO LAUNCH DIGITALS in the Trajectory section after FDO has selected TLM and the O/S or U/S becomes stable.

When MECO occurs, the MECO PBI is shipped to terminate ARD processing and informs Ground Navigation (NAV) personnel that MECO has occurred. Ground NAV then configures the tracking filter to free-flight mode. When the MECO PBI is pushed, the selected source automatically modes to telemetry. The inertial velocity of the onboard state is then displayed for about 6 seconds. Once a stable velocity is output (changes by only a couple of feet per second with each update), it should be noted. The telemetry velocity is usually the best MECO velocity guess until the filter settles down. After 6 seconds, the selected source changes to filter. The filter may be noisy, so care must be taken to not use a velocity spike. Also prior to MECO, NAV may inform TRAJ that the filter is noisy or even NO-GO; in this case do not use filter data at all. If the filter confirms the onboard velocity, then either velocity (filter or onboard) may be used as the achieved velocity. If there is a significant discrepancy between the onboard and the filter velocities, ask the FDO or TRAJ whether there is an onboard NAV state error or a poor filter solution. Use the best source to determine the achieved velocity. This achieved velocity can then be subtracted from the targeted velocity to determine the underspeed or overspeed. The subtraction is automatically done now by the FDO LAUNCH DIGITALS display.

4.1.4.11 Launch Scrub Procedures

PURPOSE

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

PROCEDURE

- TRAJ: UPON SCRUB/PAD ABORT → OPS PHASE
- √ NO FURTHER ATTEMPTS TO BE MADE TODAY
- DOL LOADING ARD UPDATES HAVE BEEN MADE, RESET ALL UPDATED PARAMETERS TO THEIR ORIGINAL, DOL 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; ENSURE THAT TRAJ & FDO DO THE SAME
- NOTIFY FDO: "GO FOR CHECKPOINT" WHEN DATABASE O.K.
- THIS CHECKPOINT MAY BE USED FOR FUTURE ATTEMPTS. OTHERWISE, THE TRS WILL BE BROUGHT UP COLD

BACKGROUND

If another launch attempt is to be made within a reasonable amount of time, some work can be avoided by bringing the TRS 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 TRS 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 several 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 TRS software changes have been made, there is no choice but to come up cold.

4.1.5 Nominal Post-MECO

The post-MECO equivalent of the ARD is the AME. The ARD transfers mass properties (orbiter, OMS, and RCS weights) to the AME. Therefore, it is important to have the correct ARD masses prior to MECO. The AME uses selected source state vectors, mass properties, and OMS engine configuration to determine highest available mission mode. The AME evaluates multiple sets of OMS-1 and OMS-2 targets that are delivered by the post-MECO flight design group. The AME is initially configured to automatically start with the highest available option (typically nominal) and downmode through the various options. The results are displayed on the AME PRIMARY display. After Ground NAV has stopped the filter and the TRS has been stepped to OPS phase, the AME can be used for further planning using the single-pass option. This requires giving the AME a specific target to evaluate.

The TARGETING position on the FDO support console is currently staffed by a representative of the post-MECO design group. This person has primary responsibility for answering FDO questions pertaining to post-MECO targeting.

4.1.6 Post Launch Shift Tasks

All post launch steps are listed in Appendix D.13 and D.14. The launch team is not released until the successful completion of the OMS-2 burn and the crew has a GO for orbit ops. The entire team is retained mainly for Targeting and Entry Support, in the event an AOA case develops. Before release the FDO, TRAJ, and MPSR personnel will get together on the MPSR DYN A loop to compare boundary times and velocities. Set the ARDTools inputs, on-console FPR inputs, and SSME thrust limiting data back to the SIM configuration. This way the next sim user gets accurate values.

Back in the office, it is important to update the entirety of Appendix D, as well as the file below with the latest information:

s:\dm46\ARDSTUFF\RECORDS\THUPDATE\HISTORY.XLS

Keep all important documents and put them in the file cabinet for historical preservation. Be sure to include your checklist and any notes you made before or after the ascent. Toss out stuff that will not be useful in the future, like extra copies of data, DYNAMICS QA hardcopies, etc.

4.2 PROCEDURES FOR ANOMALIES

There are many systems failures that can occur during powered flight which must be correctly modeled in the ARD to ensure accurate performance estimates and mode boundary determination. They include engine failures, stuck throttles, OMS leaks, SSME chamber pressure (P_c) shifts, FPR adjustments, launch holds, and others. The intent is to model in the ARD what has happened onboard and to model it in such a way as to give the most accurate performance prediction possible. This will ensure adequate performance margins for proceeding on a nominal mission, or the selection of the highest priority (most desirable) abort mode.

4.2.1 Engine Failures

4.2.1.1 First Engine Out

PURPOSE

To accurately model the first SSME failure in the ARD.

PROCEDURE

- UPON CONFIRMATION OF SSME FAILURE (BSE, CREW, ARD OUTPUT, ΔV 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
 - REPORT TME-OUT AND VME-OUT TO TRAJ
 - 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: SET EQUAL TO O/B P/B TIME, AND LOCK THROTTLE AT ZERO% AT ACTUAL EO TIME AS ESTIMATED FROM ARD COMPUTED VALUE, ΔV MARG DROP OR BSE SUPPLIED 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 PUSHED LATER (NO VALUES DISPLAYED INITIALLY), UPDATE AGAIN AFTER PB PUSHED
 - IF ENGINE OUT IN FIRST STAGE, USE STAGING VREL
 - USE 3500 fps AS FIRST GUESS

- AT STAGING, UPDATE WITH VREL FROM FDO LAUNCH DIGITALS
- ✓ INPUTS ON ARD OUTPUT (TME-OUT = INPUT TIME + 2 SEC) & HM CONFIG
- ✓ OTHER NON-LOCKED SSMEs ARE AT 104.5%
- IF EO PRIOR TO END-OF-BUCKET, PASS DELWT OVERRIDE TO TRAJ
 - IF NOM SRBs: NO DELWT O/R REQ'D
 - ELSE:
 - IF SAFING PRIOR TO BEGINNING OF THROTTLE DOWN:
 - DELWT OVERRIDE = 0
 - ELSE:
 - DELWT OVERRIDE = $\text{SUM}_{(n=1..3)}(\text{TP}_n * \text{DELWT}/3)$
where TP_n = % OF ORIGINAL "AGT BUCKET"
FLOWN BY n SSME
- IF LOW (or High) MR SSME PERFORMANCE CASE → ENSURE TRAJ RECOMPUTES FPR
- IF DRIFTER WENT OUT: NO DELTA-V ADJUSTS REQUIRED
- IF A RUNNING SSME IS DRIFTING: RECONFIGURE ARDTOOLS; PASS NEW DELTA-V ADJUSTS TO FDO.

BACKGROUND

When an engine-out occurs, the FDO pushes the appropriate engine-out PBI twice. This gives the ARD an initial estimate of the engine-out time and Earth-relative velocity. TRAJ later gives DYNAMICS a more accurate time and velocity of main engine out (TME-OUT, VME-OUT) from the onboard telemetry.

The PRI and BFS engine-out time and velocity are downlisted and displayed on the ARD OUTPUT display in the lower left portion of the display. The engine status word is downlisted via telemetry once every second. If an engine shuts down, the status word changes and a BOOSTER computation then snaps the current time to determine engine-out time and velocity. The status word is examined once every second; therefore, this time and velocity can be inaccurate by as much as 2 seconds (late) or very accurate, depending on the timing. To get as accurate a mode boundary as possible, 1 second is subtracted from the earliest of the PRI and BFS engine-out times. TRAJ then passes this time to DYNAMICS to update the ARD. Note that data dropouts can result in a delay in the BOOSTER computation being performed to snap the current

time. Therefore, the computed time of engine failure can be late if telemetry is lost. ARD Support should always verify TME-OUT from the ΔV margin plot and notify TRAJ if there is a discrepancy.

The ARD engine-out velocity is also updated with the velocity corresponding to the computer system (PASS or BFS) the vehicle is flying. This velocity is used to select dump quantity for ATOs, and fuel dissipation attitude for RTLs. If an engine failure occurs in first stage, then staging velocity should be used for VMEOUT to match how onboard guidance works.

FDO pushes the engine-out PBI when there is sufficient data to show there is an engine out. There are several cues to indicate when an engine-out has occurred. The primary cue is BOOSTER. BOOSTER has responsibility for monitoring the SSMEs and makes the engine-out call on the FD loop. BOOSTER must have telemetry available to have insight into the engines. A second engine-out cue is the crew. The crew can call an engine-out based on onboard cues, assuming that communication capability exists on at least one of the A/G loops. A third engine-out cue is the ARD. The ARD will show a sharp decrease in performance margin when an engine fails in second stage. An estimate for the engine-out time can be obtained from the $\Delta VMARG$ display at the point the ΔV margin has a steep drop. The ARD uses state vectors from either tracking data or telemetry, so if telemetry is lost but tracking is still available, the ARD ΔV margin will be a prime indicator of engine failure. One word of caution: ΔV margin is not a reliable indicator of SSME failure during first stage due to the open-loop nature of first stage guidance. The ΔV margin has too much noise and scatter to accurately assess the presence of an engine-out quickly. However, prolonged running with the engine out WILL show up in a declining first stage margin eventually. In the event of an early failure and a long lag by the Booster Officer (such as that due to telemetry loss or data path) in determining that the engine has failed, the ARD may be able to confirm the failure before anyone else. This scenario does not happen often, and the signature does take time to develop. So, although you should use caution in concluding that an engine has failed in first stage via the ARD, it is not impossible to determine.

Whenever an engine fails onboard and the failure is not behind a data path, guidance will immediately execute the Engine-Out Safing subtask, which will command the remaining engine(s) to 104.5 percent. If the engine fails behind a data path, then the onboard guidance will not recognize the failure until the crew hits the Engine Out PBI onboard --- therefore it won't be until that time that the remaining engines throttle up to MCKMAX. This is very important to model this lag in the ARD. In this case, the ARD Support will work with the TRAJ to set the failed engine throttle to zero at the actual engine out time, and set TME-OUT in the ARD to the crew's onboard PBI time (which is the time grabbed when FDO pushes the console EO PBI); this engages the ARD's Engine-Out Safing subtask at the correct time that the O/B remaining engines throttled up.

If the Engine-Out Safing subtask is executed prior to the beginning of the bucket, then the remaining engines will not throttle down at all. The ARD also has this logic. Once an engine out PBI is pressed in the ARD, any remaining non-locked engine will throttle

up to 104.5 percent (or more correctly, the value of MCKMAX). Even though the ARD will not go through its programmed bucket, the TDEL/DELWT computation is still executed. Even with the engine-out time modeled correctly and the ARD and vehicle both throttled up (buckets wiped out), the DELWT value will still be computed and processed by the ARD. Therefore, since this value is trying to correct the bucket mass computation for a throttle profile that did not actually happen, the value needs to be zeroed out.

If safing occurs in or after the bucket (given a SSME failure sometime before the end of the bucket) and does occur at the same time as the engine failure (i.e., the failure was not behind a data path), then the DELWT computation is straightforward. Here TP, which is the time-percentage that the engines went through the "AGT BUCKET", is identical for each engine, and the above equation reduces to $DELWT\ OVERRIDE = TP * DELWT$. The "AGT BUCKET" is that portion of the bucket that was modified by AGT (if cold SRBs this is the portion at 76% for example; if hot SRBs, the portion at 98% for example; if nominal SRBs, the DELWT is already zero so no action is required).

If safing occurs in or after the bucket (given a SSME failure sometime before the end of the bucket) and does not occur at the same time as the engine failure (i.e., the failure was behind a data path, with the P/B and safing after the EO), then the DELWT computation is more complex. Here, the failed engine's TP must be treated separately from the other two. (All three will be treated separately if two engines have failed.)

If the EO was prior to the TDEL computation (~0:19 sec), the extra-delayed TDEL due to an engine failing early will cause a huge DELWT to be computed, and a cold SRB profile will almost surely be selected. This is not a problem if safing occurs before any throttle down (as discussed above). Nor is it a problem if safing occurs during or after the bucket. True, the AGT bucket that's partially or completely flown (depending on when the PBI is depressed) is based on a TDEL that is now due to off-nominal SRB performance AND the EO, but the O/B computers will still throttle based on this computation. Therefore, the procedures above work fine and the throttle tables do not have to be manually rebuilt.

If a SSME fails in 1st stage behind a data path, and you also perform throttle-table updates, make sure that the MED that updates VMEO to the staging velocity does not wipe out the throttle changes (the VMEO MED engages the ARD's EO Safing Subtask); it has done so in at least one sim. Since an engine failure extends the burn time of the remaining engines, and since the ratio of sick engines to nominal engines has changed (changing the overall MR), LOX/LH2 imbalance calculations due to a drifting engine which goes out or an SSME performance case (Section 4.2.3) will differ from pre-engine out results. For a drifting engine that goes out, the FPR should be adjusted and no further delta-V adjusts are required. (If a good engine goes out while a remaining engine is drifting, then ARD Tools should be reconfigured and new delta-V adjusts will be required). For low MR performance cases, the FPR will have to be updated whether a good engine or sick engine failed. The only time an updated FPR will not be required is if the engine fails late; then there is not much flight time left for the imbalance buildup

to change sufficiently. In this case the important calls have probably already been made. See Section 4.2.8 for FPR adjust procedures.

4.2.1.2 Second Engine Out

PURPOSE

To accurately model a second SSME out in the ARD.

PROCEDURE

- UPON CONFIRMATION OF SECOND SSME FAILURE (BSE, CREW, ΔV MARG, ARD OUTPUT):
 - FOLLOW ALL “FIRST ENGINE OUT” PROCEDURES (Section 4.2.1.1)
 - IF TAL LEG
 - IF CONT DUMP O/B
 - CHECK (K60) AM CONT DUMP ENABLE ON
 - RESET CONT DUMP IGNITION, K64 (DUMP TYPE “C”)
 - IF TAL SELECTED AFTER 2nd ENGINE OUT
 - DUMP IGNITION = O/B TAL DUMP START TIME (ARD MAINTENANCE)
 - ELSE
 - DUMP IGNITION = O/B TAL CONT DUMP START (OMS DUMP LOG)
 - IF NO CONT DUMP O/B, CUR ITEM 9 = TAL %
 - NOTE: ARD AUTOMATICALLY MODELS SINGLE-ENGINE ROLL CONTROL-- EXPECT CONTINUOUS ARD OMS USAGE

BACKGROUND

See background for First SSME Failure (4.2.1.1). Note that when two engines have failed, the vehicle uses OMS fuel through RCS jets for single-engine-roll-control (SERC). (Thus, the data path procedures will not be applicable because if a second engine fails behind a data path, the vehicle will likely lose control immediately since SERC won't be initiated quickly enough; even if the crew does happen to push the engine-out button quickly enough, PROP will see that SERC is active.) SERC is automatically modeled in the ARD and can be confirmed by a continuous decrementing of OMS propellant. If possible, the experienced ARD Support snaps the post-second-EO TGO and computes the quantity to be used by SERC via the formula: Quantity = TGO (in seconds) X 3 lb/sec. Sometimes FDO will ask what the amount will be if prop and uphill capability are tight.

If a TAL was in progress at the time of the second SSME failure, and the TAL dump was interconnected, the ARD automatically disengages the OMS/RCS interconnect to accommodate SERC, which is what happens in reality onboard. (This may be only when TAL is selected). It takes a contingency dump selection onboard to re-interconnect. If a second engine is lost on a TAL leg, the crew should enable the contingency dump (be sure to verify that the crew did in fact enable the contingency dump). This should also be performed in the ARD. If the second engine failure occurs prior to Droop capability, TRAJ may terminate ARD execution with a K60, ARD, STOP input since the vehicle will not have intact capability (Bermuda/ECAL contingencies are not monitored with the ARD).

4.2.2 SSME Command Path (Stuck Throttle)

PURPOSE

To accurately model SSME Command Path failure in the ARD.

PROCEDURE

- TRAJ: UPON NOTIFICATION OF COMMAND PATH FAILURE, MODEL LOCKUP:
 - PRE- OR POST-BUCKET, SHIP THE THRUST LIMITING CASE:
 - <L/C/R> ENGINE
 - HYDRAULIC LOCKUP
 - LEVEL ZERO HIGH
 - POWER LEVEL X% (FROM BSE)
 - TIME AS APPROPRIATE
 - CLICK FPR PBI
 - IN BUCKET, SHIP THE THRUST LIMITING CASE:
 - <L/C/R> ENGINE
 - HYDRAULIC LOCKUP
 - LEVEL ZERO <LOW/MID/HIGH> (PER POWER LEVEL)
 - POWER LEVEL X% (FROM BSE)
 - TIME OF: Y SEC
 - IF STUCK IN 1ST STEP OF 2-STEP BUCKET (HOT SRBs 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
 - NO DELWT OVERRIDE REQ'D

- IF PRE-BUCKET → PASS TRAJ DELWT OVRD = $N/3 * DELWT$ (WHERE N = # OF THROTTLING ENGINES)
- CONFIGURE HM CONFIG: TWO GOOD ENGINES (STUCK ENGINE OUT)
- CONFIGURE 2HM CONFIG: ONE GOOD ENGINE AND STUCK ENGINE (GOOD ENGINE OUT)
- IF RESTRING FOR STUCK-IN-BUCKET:
 - NOTE TIME OF THROTTLE-UP & PASS TO TRAJ
 - TRAJ, SHIP THRUST LIMITING CASE :
 - ADJUST
 - <L/C/R> ENGINE
 - 104.5%
 - TIME OF THROTTLE-UP
 - ✓ THROTTLE TABLE AFTER TRAJ MAKES INPUTS
 - ✓ FOR OMS ENGINE RESTART, IF NECESSARY

BACKGROUND

A stuck throttle must be modeled in the ARD anytime an SSME locks up onboard (i.e., loses throttling capability). Hydraulic lockup, electrical lockup, and command path are the three failures that can cause this. Procedures for hydraulic and electrical lockups are somewhat different than for command path cases, and are covered in Sections 4.2.3.2 and 4.2.3.3. This procedure applies only to SSME command path failures.

A command path failure is the loss of general purpose computer (GPC) commands to the main engine controller or rejection of the commands by the controller. BOOSTER reports a lockup on the FD loop, then gives more specific data (lockup time and throttle) to TRAJ on MOCR DYN. Command path cases are normally level 0 (i.e., nominal ISP and MR) on the main engine tables. If not, then the stuck engine must be modeled using electrical lockup procedures in Section 4.2.3.2. TRAJ ships the thrust limiting case via a GUI. If the engine is stuck pre- or post-bucket (i.e., approximately 104.5 percent), then a level 0 high lock is performed in the throttle table. This locks the throttle setting and loads ISP values that correspond to 104.5 percent into the throttle table. When the lock flag is set to ON, this tells the ARD not to throttle the engine. Thus the engine remains at a constant level through the throttle bucket, during auto-throttling, and after a different SSME out. If the engine is stuck pre-bucket or during the throttle-down transient, then it will be necessary to wipe the bucket in the throttle table for the affected engine only. This also requires overriding DELWT with a value 2/3

times its original value, since the stuck engine does not go through the bucket, and therefore requires no weight adjustment for an off-nominal bucket profile.

If the SSME is stuck in the bucket, then level 0 low or mid data must be input into the ARD to set the proper ISP as a function of power level in the throttle table. The actual throttle setting at which the engine is stuck at determines whether it is a mid or low. If stuck in the bucket, but not in the first step of a 2-step bucket, the ARD SSME is locked at the end of the pre-lift-off ARD throttle table bucket (just before time of throttle-up), so as not to require a DELWT override for AGT-modified buckets. If stuck in the first step of a 2-step bucket, the ARD SSME is locked at the last full second at 104.5% before throttle-down in the pre-L/O ARD throttle tables, also to avoid a DELWT override. These times are used regardless of any actual times given by BSE, because these times simplify the ARD Support responsibilities with no significant loss of modeling fidelity in case of a drifter.

Stuck-in-the-bucket cases result in marginal uphill capability and often require an ATO dump to satisfy design underspeed constraints (usually ETIP). If an ATO dump is not sufficient to regain uphill capability, then a restring may be performed if this will regain throttling capability for the affected SSME. When the restring is complete, the crew will take manual throttles and command 104.5 percent, then return to auto. It is important for ARD Support to note the time of throttle-up and provide this to TRAJ. This throttle-up time will not be captured on any ARD displays, and if the ARD Support does not catch it, we must rely on BSE. This will be modeled as an "adjust" in the throttle table so that the ARD can perform 3g throttling for that engine. Note that in some cases when 1 or 2 OMS engines are not working (e.g., with both a GPC and a bus failure prior to a restring) the OMS engine(s) will start when the restring occurs, and the OMS model will have to be adjusted appropriately.

The AM ONLY portion of the stuck-in-the-bucket procedure is included in order to keep the HM at two engines running (e.g., 0, 104.5, 104.5). If the HM is set at 0, 67, 104.5, this is not as accurate as the stuck throttle chart provided by Flight Design. Therefore, the HM is kept configured for the normal two-engine calls. This also gives insight into the performance in case the command on the stuck engine is recovered.

4.2.3 SSME Performance Cases

SSME performance cases refer to specific, Booster-identified thrust limiting failures that result in an engine continuing to run, but with degraded performance. This performance hit must be modeled accurately in the ARD to determine if the vehicle still has uphill capability. Also, abort boundary accuracy becomes extremely important since the sick engine may be more likely to fail, especially during high MR cases, where upper temperature redlines may be exceeded.

SSME performance case failures consist of Pc Shifts, Hydraulic Lockups, Electrical Lockups, Backup Lockups, HPOT Efficiency Loss, Flowmeter GPM Sensor Shifts, LPFT Discharge Temperature Shifts, and Nozzle Leaks. These cases have been identified through SSME testing as well as engine model predictions. BOOSTER uses his workstation to identify the presence of a case based on various engine parameters (e.g., Pc deltas, HPOT discharge temps, LH2 flowrates, valve positions, etc.). When engine parameters have satisfied sufficient criteria, BOOSTER passes performance case data to TRAJ on MOCR DYN (case name and level, affected engine, power level, and MET). The following procedures document correct steps to model these cases. Cases in which throttling capability is not lost (i.e., biased throttles) are covered in

- 4.2.3.1. Stuck throttle cases (Electrical and Backup Lockups) are covered in Section
- 4.2.3.2. Hydraulic Lockups, or Drifters, are covered in Section 4.2.3.3.

4.2.3.1 Pc Shifts, HPOT Efficiency Loss, Flowmeter GPM Sensor Shifts, LPFT Discharge Temperature Shifts, and Nozzle Leaks

PURPOSE

To accurately model non-locked SSME performance cases in the ARD.

PROCEDURE

- ENSURE RESTORE TO NOMINAL THRUST IF PREVIOUS THRUST UPDATE PERFORMED
- TRAJ: WHEN BSE PROVIDES DATA, ENTER PERFORMANCE CASE:
 - <L/C/R> ENGINE
 - <failure case> USE <table> DATA (from BSE: Electric Lockup, Pc Shift, Flowmeter, or Backup Lockup)
 - LEVEL <BSE value>
 - TIME of <N+NN> (from BSE, throttles no earlier than 1+07)
 - BOTH MODES (for 2 eng calls), OR AM ONLY (for 1 eng calls)
 - SHIP THE FPR
- √ HM CONFIG (good EO for two engine calls; bad EO for single engine calls)
- IF CASE TIME EARLIER THAN 1:07, COMPUTE PRE-1:07 WT ADJUSTMENT:
 - USE ARDTOOLS TO CALCULATE:
 - $\Delta\text{DELWT} = (104.5\% - \text{CASE THROT}) * (67 - \text{CASE TIME}) * 10.4$
 - ADD ΔDELWT TO ANY PREVIOUS ADJUSTMENT & SHIP THE FINAL DELWT OVERRIDE ADJUSTMENT TO THE ARD
- VERIFY CORRECT INPUTS & NOTIFY TRAJ GOOD DATA IN THE ARD. IF PRE-1:07, VERIFY THROTTLE IN AT 1:07, MR AND ISP IN AT BSE TIME.
- VERIFY TRAJ UPDATES FPR
- IF LOW MIXTURE RATIO CASE:
 - INFORM ABORT SUPPORT
 - INFORM TRAJ IF LOX IMBALANCE > 20,000 lb
- Pc SHIFT CASES ONLY: 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 HM (Pc SHIFT ENGINE OUT)
- FDO: IF UPHILL BIAS IS SATISFIED IN HM, REQUEST TURN BAD Pc CHANNEL OFF
- NOTE TIME SSME RETURNS TO NOMINAL & PASS TO TRAJ
- TRAJ: IF BSE REPORTS RETURN TO NOMINAL → ENTER PERFORMANCE CASE:
 - <failure type>
 - LEVEL ZERO, ADJUST
 - <L/C/R> ENGINE
 - TIME OF <N+NN> (time engine returns to nominal)
- VERIFY CORRECT INPUTS & NOTIFY TRAJ GOOD DATA IN THE ARD.
- VERIFY TRAJ UPDATES FPR

BACKGROUND

A Pc sensor shift occurs when a main combustion chamber pressure transducer develops a bias. The engine controller throttles the engine based on the average of the two Pc sensors. If one of the sensors is biased, either high or low, the average will also be biased in the same direction. Because the engine controller will adjust the throttle setting in an attempt to adjust the average Pc to its target value, the engine will be forced to operate in an off-nominal thrust condition. This results in high or low thrust compared to nominal and also causes MR excursions. Pc shift scenarios can also occur where both pressure transducers are biased.

When a Pc sensor is biased low, the average will give a Pc lower than reality. This situation is called Pc low, actual high, which means the Pc sensor is biased low, but the actual throttle setting is high. In reaction to this low reading, the engine controller throttles the engine up to achieve the desired Pc reading. This results in the engine running at a higher than desired throttle setting. Associated with the throttle setting delta is a difference in ISP and MR. For this case the ISP decreases while the MR increases. Conversely, when a Pc sensor is biased high, the opposite takes place. This is called a Pc high, actual low and results in a lower throttle setting, an increased ISP, and a lower mixture ratio. A Pc shift high, actual low level 0.5 occurred on STS-44 due to contaminants in the transducer pressure port.

There are several other BOOSTER-related failures that are not Pc shifts or lockups, but are handled in a similar way as Pc sensor shifts. These consist of: high pressure oxidizer turbopump (HPOT) efficiency loss, nozzle leaks (LH2 leaks out of the main engine nozzle coolant lines), low pressure fuel turbine (LPFT) discharge temperature shift low, and fuel flowmeter sensor shift (high and low). These failures are modeled in the ARD using BOOSTER-supplied Main Engine Tables. The data is given in levels that specify power level, ISP, and MR.

The Booster Officer reports an SSME performance case over the Flight loop and then passes detailed engine performance data to TRAJ on MOCR DYN. Once BSE supplies official data to TRAJ, TRAJ inputs the performance case using the Thrust Limiting application. All cases are treated as locks so that possible engine failures in the future do not reset the sick engine to 104.5 percent by the SSME-out safing task (recall that when an engine-out PBI is depressed, all non-locked, non-failed SSMEs are set to MCKMAX (104.5 percent) in the AM). During performance cases, two-engine boundary calls are made with a good engine out, and single-engine calls are made with a good and bad engine out. Therefore, usual procedures are to model the performance case in both the actual and hypothetical modes, unless the HM is already configured for single-engine calls.

After TRAJ completes the inputs, the throttle setting change should be apparent in the ARD throttle output for both the actual and hypothetical modes (ARD Support should check both of these). The ISP and MR appear in the lower right corner of the ARD OUTPUT display along with the MET the performance case began. ARD Support should check the values on this display with the main engine table to ensure that there have been no input errors.

K69 power level entries are not inserted in the throttle table prior to the throttle up transient, since an earlier throttle entry would overwrite the bucket, resulting in a significant mass error (~5000 lb). Non-locked SSME performance cases allow the real engine to throttle through the bucket with a bias, but the ARD is not capable of modeling this. For this reason, throttle data is input no earlier than 1:07, and the propellant usage delta prior to 1:07 is accounted for with a Δ DELWT adjustment computed by ARD Support. The formula for this weight adjustment is

$$\Delta\text{DELWT} = (67 \text{ sec} - T_{\text{inp}}) * (104.5\% - \text{PL}_{\text{act}}) * 10.4 \text{ lbs/sec/SSME/\%}$$

where 67 sec is the input time of 1:07 in the throttle table (note that this may change on a flight-specific basis for late throttle-up profiles--check this pre-ILC and notify TRAJ and FDO if so), T_{inp} is the time the performance case occurs (from BOOSTER), PL_{act} is the actual power level (from BOOSTER), and 10.4 lb/sec/%/SSME is the flowrate per percent thrust for one SSME (a generic number computed from TDDP). For example, a Pc shift high actual low level 2 starting at 30 seconds, and input with throttles at 30 seconds would wipe out the throttle bucket for that engine. However, the real engine goes through the throttle bucket with a power level biased 2 percent lower than a nominal throttle level of 104.5%. In the ARD, that engine would be locked at 1:07 at 102 percent in the throttle table, and a DELWT OVRD weight bias of $(67 - 30 \text{ sec}) *$

$2.5\% * 10.4 \text{ lb/sec/SSME}/\% = 960 \text{ lb}$ would be input. Note that biased-high power level cases (e.g., 105 percent) result in a negative weight adjustment quantity. This calculation is automatically performed by ARDTools (up to three cases are calculated automatically with ARDTools as long as they are each on different SSMEs). See Section 5.1.1 for further information.

The ARD is always configured to protect for 2σ ascent systems dispersions. This dispersion protection, called FPR, is a function of MR. For performance cases that result in a dispersed MR, the FPR must be adjusted in realtime to maintain proper 2σ protection. This FPR adjustment is computed automatically once TRAJ clicks on the FPR button on ARD OUTPUT. The ARD Support can check this value by using ARDTools. In the lower right corner of ARD OUTPUT is the imbalance computation output that is used for realtime FPR calculations. This output block displays current and MECO predicted fuel bias or oxidizer bias based on the sick engine running with any other good engines, for both modes and for all the abort channels. This data is used to compute the realtime FPR update. The proper imbalance read by ARDTools to get the new FPR.

High MR performance cases result in increased LH2 biases, which allow FPR reductions of about 200 lb. Since FPR becomes constant for fuel biases greater than about 1200 lb, most high MR cases do not require a recalculation of FPR in realtime. Low MR cases, on the other hand, result in large variations of FPR, depending on propellant imbalance.

If a low MR case is present, ARD Support must pass the sick engine's MR value to Abort Support for determination of ARD ΔV margin error. Abort Support uses the MR with an imbalance error vs. MR chart to determine ARD imbalance pessimism in the fuel-oxidizer ratio task. Several different sources of error are present due to ARD thrust limiting code design; these are detailed in Section 6.7. Abort Support computes and passes a ΔV margin correction to FDO. A low MR case can also develop over time a LOX imbalance that is very large (~25k lb). If this happens, the vehicle can run out of fuel before reaching the SSME arming mass, which means the SSME low level sensors are not armed, and the SSMEs will not shut down automatically. This can happen on any case, regardless of low level sensor failures or abort mode. The large LOX imbalance by itself can cause the engines to blow up. The "solution" is to shut down the bad engine at some convenient time (after some intact abort boundary or something similar) to get rid of the MR hit.

By the flight rules, for Pc Shift cases that result in loss of uphill capability, the bad Pc transducer can be turned off. This reduces engine redundancy from two Pc channels to one, but will be performed if doing so will avoid a TAL or RTLS. Reference flight rule A5.1.3-9, Engine Performance Dispersion, paragraph B.1.c. If the bad channel is turned off, ARD Support must note the time the O/B throttle returns to nominal and pass this to TRAJ. The throttle table is then updated with a level 0 (nominal) adjust at the return-to-nominal time. The adjust allows the SSME to throttle once again if required. Note that other cases besides Pc shifts can return to nominal, depending on engine performance characteristics. This is a BOOSTER call. After a low MR performance

case has ceased, TRAJ should redo the FPR adjustment, since the MECO imbalance computations will be different due to the MR dispersion no longer being propagated to MECO.

Note that LPFT cases can enter "fixed-density mode", and the off-nominal values go away. We need the time the SSME returns to nominal for the ARD.

Finally, note that the ARD will interpret a 104% throttle level in the throttle table as 104.5. This creates a problem with performance cases where 104.0 is the actual desired throttle level. To work around this problem, a value of 103.99 may appear in the throttle table automatically when TRAJ ships the case, and no further action is required. However, if 104.0 appears in the ARD throttle table, a manual update to the tables to 103.99 may be required. We've been seeing this in FFM L/H LVL 1 & 1.5, B/U HYD L/U LVL 1 AND 3 (PWR LVL 104), for all three engines --- WARNING: Don't assume these are the only possible instances.

4.2.3.2 Electrical and Backup Lockups

PURPOSE

To accurately model electrical lockup SSME performance case in the ARD.

PROCEDURE

- TRAJ: RESTORE TO NOMINAL THRUST IF PREVIOUS THRUST UPDATE
- TRAJ: WHEN BSE PROVIDES DATA, ENTER PERFORMANCE CASE:
 - ELECTRICAL LOCKUP
 - LEVEL <BSE value> <low/mid/high>
 - <BSE throttle value> % (from BSE: for backup lockup level 3 only)
 - PRE- or POST-BUCKET: TIME of <N+NN> (from BSE)
 - IN BUCKET: TIME OF Y SEC
 - IF STUCK IN 1ST STEP OF 2-STEP BUCKET (HOT SRBs 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
 - NO DELWT OVERRIDE REQ'D
 - UPDATE FPR
- IF PRE-BUCKET → PASS TRAJ DELWT OVRD = $N/3 * DELWT$ (WHERE N = # OF THROTTLING ENGINES)
- VERIFY CORRECT INPUTS & NOTIFY TRAJ GOOD DATA IN THE ARD.

BACKGROUND

An electric lockup is a failure that also results in the loss of throttling capability. This failure occurs when an engine controller loses all Pc and fuel flowrate data from the engine. This results in SSME performance similar to Pc shifts or fuel flowmeter shifts, with the exception that the engine can no longer throttle. There are no dedicated electrical lockup main engine tables; therefore, BOOSTER will determine, and must provide to TRAJ, whether Pc shift, fuel flowmeter shift, or backup lockup tables should be used.

See additional rationale from Sections 4.2.2, SSME Command Path Failure; and 4.2.3.1, SSME Performance Cases.

4.2.3.3 Hydraulic Lockup

PURPOSE

To accurately model SSME hydraulic lockup cases, including valve drift.

PROCEDURE

- ENSURE RESTORE TO NOMINAL THRUST IF PREVIOUS THRUST UPDATE
- TRAJ: WHEN BSE PROVIDES INITIAL LOCKUP DATA, ENTER PERFORMANCE CASE:
 - <L/C/R> ENGINE (C if APU1↓, L if APU2↓, R if APU3↓)
 - HYDRAULIC LOCKUP
 - LEVEL <BSE value>, <low/mid/high> (per power level <80, 80-94, >94)
 - POWER LEVEL: XXX % (from BSE)
 - TIME OF <N+NN> (from BSE)
 - APU FAIL TIME IF PRE- OR POST-BUCKET
 - Y SEC. IF IN THE BUCKET:
 - IF STUCK IN 1ST STEP OF 2-STEP BUCKET (HOT SRBs 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
 - UPDATE THE FPR
- IF PRE-BUCKET → PASS TRAJ DELWT OVRD = $N/3 * DELWT$, WHERE N = # OF THROTTLING ENGINES
- ENSURE ARD HYD FAIL PBI CLICKED.
- VERIFY CORRECT INPUTS & NOTIFY TRAJ GOOD DATA IN THE ARD
- CONFIGURE ARDTOOLS WITH INITIAL LOCKUP DATA

- IF BSE REPORTS ENGINE IS DRIFTING:
 - TRAJ: WHEN BSE PROVIDES DATA: ENTER PERFORMANCE CASE
 - <L/C/R> ENGINE
 - CLICK “DRIFTER MECO LEVEL”
 - MECO THROTTLE %
 - MECO LEVEL X
 - MECO TIME FROM BSE (USUALLY 15:00)
 - UPDATE THE FPR
 - CONFIGURE ARDTOOLS DRIFTING THROTTLES WITH MECO PREDICTIONS
 - PASS ANY DELTA V ADJUSTS FOR FUTURE METs TO FDO THAT ARE > 10 FPS MAGNITUDE; INFORM FDO IF NONE
 - IF BAD EO → NO DELTA V MARGIN ADJUST REQ'D
 - IF GOOD EO → UPDATE ARDTOOLS AS REQUIRED
 - PASS NEW ADDITIONAL MARGIN DRIFT (TOTAL DELTA V ADJUST) TO FDO
- NOTE: FOR A DRIFTER AFTER AN ENGINE OUT, TELL TRAJ TO HAVE DYN DO K69, ENGINE, ISP, ISP TIME, MR, MR TIME (IF DIFFERENT), LINE # \$

BACKGROUND

Hydraulic lockups are the most challenging thrust limiting cases to model, due to the fact that engine valves may drift without an APU and 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, throttling capability is lost for its respective engine (lockup).

As hydraulic pressure bleeds off, valves that control thrust and MR may not remain completely locked in their proper positions for the afflicted engine. This scenario is referred to as drifting throttles, and may result in extremely degraded thrust, ISP, and MR. Test stand hydraulic lockup experiments indicate that high MR drifts should be expected, with the possibility of a redline shutdown due to elevated turbine temperatures.

Initial indication of hydraulic lockup can be obtained from MMACS declaring an APU failed and DDD illumination of hydraulic lockup. TRAJ enters the performance case for hydraulic lockup level 0 until more information is obtained from Booster. A majority of

times the initial lock will actually be level 0, so this procedure is a good setup for likely cases. Sometimes it takes BSE quite awhile to come back to TRAJ with the initial level. Note that there is no FPR change required for a level 0.

Next, ARD Support must ensure that FDO/TRAJ have pressed the ARD HYD FAIL PBI. This is necessary to account for thrust losses due to the fact that the SSMEs also no longer thrust in the proper direction. SR T000672 "Enhancement to ARD hydraulic fail PBI" added logic to the ARD HYD FAIL PBI on the pbi_fdo_launch alarm panel. Currently you have to *remember* to push this button in the event of a Priority Rate Limiting (PRL) condition (i.e. failure of APU or HYD system). Now the button monitors the PRL flag for each hydraulic system, and flash red upon any system going into PRL. The flashing PBI will be the cue for FDO to push the button in order to send the ARD HYD FAIL MED. The button will stop flashing and turn yellow upon confirmation this flag is set in the ARD.

Next, TRAJ should set the bad engine out in the HM for two reasons: (1) a known problem exists and the drifting engine is now the most likely to fail, and (2) HM ΔV calculations in ARDSSP use current ISP, thrust, and MR propagated out to MECO (treated as constant values except for 3g throttling); therefore, future degradation of SSME performance is not accounted for in the HM. In other words, the ARD takes current power level, ISP, and MR of the sick engine (interpolated from the throttle table), assumes they remain fixed until MECO, and computes an inaccurate ΔV margin and predicted MECO imbalance. The HM is accurate for bad EO calls, since two constant-performance engines are being modeled out to MECO. It is therefore philosophically correct to make abort boundary calls with the bad engine out, even though two-engine HM management normally calls for a good EO.

Once BOOSTER passes the initial lock data to TRAJ, the performance case is updated, if necessary. This step may be skipped if the BOOSTER data is level zero and a time close to what was entered previously (after hydraulic lockup was enunciated). At this point, BOOSTER has determined an actual level for the initial phase of lockup--the drifting is a problem yet to be confirmed, quantified, or modeled. Enter the initial lock data into ARDTools - Drifting Throttle function while TRAJ is making the inputs in the TRS (see Section 5.1.1 for ARDTools procedures). The throttle table and ARD OUTPUT should be checked for correct inputs.

In order for the ARD mass track to remain accurate in the event that the engine drifts, it is necessary to force the ARD to linearly vary SSME thrust, ISP, and MR from the initial lock time out to MECO. This is handled by configuring the throttle table with initial and MECO data on subsequent lines so that the ARD linearly interpolates between them to obtain the correct value over time. This procedure results in the upper (lower numbered) line having the initial lock data and the next line having BSE predictions with time tag 15:00. The ARD linearly interpolates between the two for correct values during the time span between the two entries, thus maintaining an accurate mass track at all times.

Note that TRAJ should still lock the engine at the time determined by the pre-lift-off ARD throttle tables (see 4.2.2), even if given a lockup time from BSE. Recall that for a command path or electrical/backup lockup this time mismodeling leads to no mass track error, so it is acceptable as a reduction of ARD Support workload (a DELWT override would otherwise be required). Here, locking a drifter at the wrong time can lead to a very slight mass error. As a "worst-case" example from STS-110: if BSE reports stuck at 72 at 0:43 (beginning of bucket) but we lock at 0:52 (end of pre-lift-off ARD bucket), and then we have the SSME drifting to 109% at 15:00, then the weight error from our intentional mismodeling is only 167 lb, and that assumes we actually fly to 15:00! If you wanted to correct for this error, you would have two options: 1) compute the error as done above and do a DETP or DELWT O/R (but this requires knowledge of actual MECO time), or 2) lock the engine at the BSE time and then compute a DELWT override. To do the second option requires we have telemetry & depends on a manual computation of the override based on telemetry throttle steps and BSE info. Either option introduces the possibility of manual error (by ARD Support and/or BSE) which could actually make things worse, on an engine that we don't even know if it's drifting at the time of modeling. So, we live with what is known to be a very small error.

While waiting for BOOSTER to quantify and pass a predicted MECO level, it is wise to chase the throttles on paper if drifting occurs. This will provide a backup modeling method if BSE takes too long to get back or cannot compute the predicted MECO level for some reason. Use the K69 initial lock level along with the chased throttle setting. Pass this data to TRAJ as a last resort if BOOSTER does not come through. Also, if a revised time for the initial lock level is given by BSE (which they have done), update it in the ARD if time permits. This changes the anchor point of the throttle ramp, and thus the slope.

If the locked-up engine does drift, BOOSTER will require a minute or so to quantify the slope and come up with a good MECO prediction. Note that MECO predictions always have a standard time tag of 15:00 MET, even if this is not the actual new MECO time. (This was agreed upon after numerous meetings with Booster reps.) If ARD Support notices drifting power level on ARD OUTPUT and BOOSTER has not offered data within a minute, then remind TRAJ to ping BOOSTER for data. After BOOSTER passes the data, TRAJ will enter the data. Confirm that the MECO data is entered on the correct throttle table line with an 15:00 time tag.

After verifying good MECO data inputs (which performs an automatic mass recycle), ARD Support must update the FPR based on predicted MECO imbalance. For constant SSME performance, this is done using ARD imbalance output on ARD OUTPUT display. For non-constant SSME performance, however, the imbalance output must be adjusted to account for future MR degradation. This is because the ARD interpolates between initial and MECO time tags in the throttle table to obtain current engine data and uses this current data as a constant to compute the fuel/oxidizer imbalance and ΔV margin. Thus the future performance impacts of the drifter are not accounted for in either imbalance output or ΔV margin. A more correct approach is to use time-averaged engine parameters from the current time until MECO. ARDTools uses this methodology to provide future ΔV margin and imbalance hits based on the input

hydraulic lockup level (ISP and MR), power level, and drift start and stop times. See Section 5.1.1 for more details on ARDTools.

ARDTools outputs ΔV margin correction versus MET such that this is simply subtracted from the ARD's trending ΔV margin to obtain the true, constant value. (Note that ARDTools displays ΔV margin correction as a minus to remind you to subtract it from the ARD ΔV margin.) Pass each of the results to the FDO as the predicted ARD margin (i.e., "ARD margin adjust is -25 at 5 minutes", etc.). FDO needs to know how much the margin will change in order to get a heads up on whether we are uphill or not.

Should the bad engine fail at some point, the ARD will terminate power level, ISP, and MR in the throttle table at their correct, current values. This also will eliminate the trend in ΔV margin and imbalance. After the engine failure is modeled, TRAJ should recompute the FPR. Note that no correction to the ARD ΔV margin is required.

If a good engine fails, the bad engine will continue to burn past 15:00 that was used as the anchor point for MECO predictions. In this case, execute the good engine-out option on ARDTools/Drifting Throttle routine and enter the new TMECO. This will provide updated ΔV correction data that should be used as above, if time permits. Note that the later the engine failure, the smaller the ARD modeling error becomes, due to the fact that the ARD is seeing more and more of the SSME performance degradation.

4.2.3.4 SSME Thrust Vector Control (TVC) Hardover

PURPOSE

To model SSME TVC hardover (stuck actuator) cases for ISS missions based on DM44 analysis.

PROCEDURE

- UPON CONFIRMATION OF SSME TVC HARDOVER
 - IF C ENG STUCK HARDOVER IN -pitch (UP) OR L/R ENG STUCK HARDOVER IN +/- yaw (OUTBOARD):
 - TRAJ : MODEL THE APPROPRIATE THROTTLE LEVEL & Isp ON THE STUCK SSME w/ STUCK ACTUATOR ROSS ALARM.
 - ✓ MODELING IN ARD SSME ENGINE TABLE
 - ✓ THROTTLE & Isp ARE ADJUSTED ON STUCK SSME ONLY
 - ✓ UPDATED THROTTLE SETTING MATCHES THE APPROPRIATE VALUE FROM TABLE 4.2 BELOW. (TF = TIME OF TVC FAILURE)
 - 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
 - ✓ UPDATED Isp IS CORRECT:
 - $Isp_NEW = (TH_NEW/104.5) * Isp_INITIAL$
 - This is the corresponding Isp required to maintain constant MDOT. TH – Throttle setting, NEW – value needed to model stuck actuator, INITIAL – original value in the ARD
 - ✓ HM & 2HM CONFIG (SICK EO for two engine calls)

Table 4-2. 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%

- NOTES:
 - FDO: ADD 50 FPS TO ALL HM BIASES TO ACCOUNT FOR 6 DOF EFFECTS OF ENGINE SHUTDOWN
 - EXPECT ITEM 9 TO BE REQUIRED
 - EXPECT SICK ENGINE MANUAL SHUTDOWN (PITCH HARDOVER CASE SHUTDOWN BEFORE 7:00 MET, YAW HARDOVER CASE SHUTDOWN AT SEPTM)
 - ALL 2-ENGINE ABORT BOUNDARIES ARE ACCURATE ASSUMING THE SICK ENGINE FAILS; NOT ACCURATE IF GOOD ENGINE FAILS

BACKGROUND

It is possible that the actuators that drive the SSME gimbals can 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 toward one of its extreme hardover conditions. There are three possible hardover scenario outcomes: 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 MET¹; 2) an immediate loss-of-control may occur, possibly 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 amount of the 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 Isp values determined through this analysis should be used for hardover TVC failures only. The analysis concluded that throttle level and Isp 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. First, the single update is much easier to perform than an Isp and throttle setting update on three different SSMEs. Second, 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 Table 4-2. 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. However, with the 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 fails 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.

¹ According to FR A8-2, hardover gimbal failures in 1st stage are survivable until SRB tailoff, since the SRB nozzles provide the majority of control authority. After MET 1:40, the SSMEs begin to gimbal more in response to SRB tailoff, therefore any hardover SSME will be shutdown (except center -pitch) prior to this time in order to avoid bell collision and/or vehicle control problems. A center engine stuck in -pitch can be safely run until 7:00.

4.2.4 RTLS

PURPOSE

To perform proper modeling and monitoring tasks during an RTLS abort to maintain an accurate ARD model.

PROCEDURE

- IF EO IN FIRST STAGE
 - TMEOUT as usual, VMEOU (temporary) = 3500
 - STAGING: BE READY FOR MAX THROTTLES IF REQUIRED
 - √ VREL @ STG
 - VMEOU = VREL @ STG
- ABORT SELECTION:
 - √ RTLS SELECTED O/B (NOTE: IF BFS, O/B MAY SAY "TAL")
 - NOTE MET
 - IF THROTTLE-BACK → PASS TRAJ THROTTLE-BACK MET
 - IF ARD ABORT PBI LATE → PASS TRAJ ABORT PROCEED MET FROM PROP DUMP LOG OR OMS DUMP START IN ARD MAINTENANCE (MAY NOT BE POSSIBLE IF BOTH OMS ENGINES ALREADY BURNING AT ABORT SELECT)
 - √ ARD DUMP STATUS (INH vs. ENA, manifold fail, correct start time, cutoff by MECO)
 - √ THROTTLES (69% IF 3 ENG)
 - √ K51 SITE (CORRECT RUNWAY AT KSC)
 - √ ARD PREDICTED MECO TIME
- PPA:
 - NO TMEOUT ADJUSTMENTS AFTER THROTTLE CHASING!
 - CHASE THROTTLES & PASS TO TRAJ
 - √ THROTTLE TABLE INPUTS
 - MONITOR MARGIN

- AT DUMP STOP → √ ARD vs. VEHICLE TMECO FOR ARD STATUS CALL
- MECO-20 SEC:
 - CALL UP RTLS DIGITALS
 - CALL UP E/W VS RGO
 - √ TRS → LANDING PHASE
 - REPORT R-Ve STATUS @ MECO

BACKGROUND

An RTLS abort is an intact abort mode that results in a landing at KSC. Major system failures (cabin leak, loss of two hydraulic systems and third failing, thermal window-pane crack) or loss of an SSME early in the ascent profile can result in the selection of this abort mode. This abort can be initiated anytime prior to the FDO negative return call at approximately 4 minutes MET.

If aborting for systems problems (i.e., three SSMEs are still running), the vehicle will throttle down to 69% to allow time for the abort dump to complete. ARD Support must note the time of throttle-back and pass this to TRAJ so that the ARD throttle table can be precisely adjusted. This is necessary because the time that appears automatically in the ARD is often late due to telemetry lag (we've seen 4 seconds error in throttle-down time). Note that updating the Abort Proceed Time in the ARD will not correct this throttle time (although it will correct the dump start time), DYN will have to make a throttle adjust update.

Upon abort initiation, the vehicle continues downrange to use up excess propellant no longer required. This portion of the abort is called fuel dissipation. Abort selection also initiates an OMS propellant dump to ensure that landing weight and center of gravity (c.g.) constraints are not violated. Once a sufficient amount of ET propellant is used up, the vehicle pitches around to point back at the KSC landing site. This maneuver is called powered pitch-around (PPA). After PPA, the shuttle is in the flyback phase, which continues until near the powered pitch-down (PPD) maneuver. At PPD, the vehicle pitches down to get in the proper attitude for MECO and ET separation. PPD occurs when a PPD-specified R-V target line is achieved. MECO occurs about 20 seconds after PPD when a second R-Ve target line is achieved. ET separation occurs approximately 12 seconds after MECO.

Throttle monitoring - One of the specified MECO targets for an RTLS abort is mass. PPA is initiated based on a MECO mass estimate. For fine tuning this MECO mass, automatic throttling is used in the flyback phase. The throttle changes are largely unpredictable. A final change usually occurs when the OMS dump terminates.

To maintain an accurate mass track in the ARD, it is important to model all the onboard throttle changes in the ARD. This is called throttle chasing. Throttle chasing is the primary job of ARD Support and TRAJ during the flyback timeframe. Since several

changes tend to occur at one time, it is best to record the throttle value and time as they occur. The throttle value is available on the ARD MAINTENANCE display in the O/B Commanded Throttles section. TRAJ will give the throttles and times to DYN, who inputs them into the ARD. ARD Support should monitor the values that TRAJ gives to DYN to catch any errors, and verify that the throttle tables are updated accordingly.

A more accurate TMEOUT may be obtained later in the flight from the recovery of telemetry, from the Booster Officer, or from closer examination of the ΔV margin plot. If PPA has occurred, do NOT update the TMEOUT. Doing so will cause the remaining engines to throttle up, causing all throttle chasing inputs to be lost. This is because we input them as K62 adjusts.

For an RTLS abort, the ARD hypothetical mode is typically configured to show two engines running at 104.5 percent. It can be used to examine 2 @ 109% or 2 @ 67% or any other two engine combination. If the hypothetical mode were to be configured to a single engine, the software would not converge because of an insufficiently low thrust to weight. The actual mode is maintained to model the real vehicle.

MECO condition assessment - The vehicle is targeted to an R-Ve target line. The range is measured from the vehicle position to the Shuttle Landing Facility (SLF) via the HAC. Both parameters are available on the E/W VS RGO display. FDO should be given a MECO status in terms of fps above or below the MECO target line. The E/W VS RGO display is an energy versus range graph that plots selected source data. On this plot, the first data point to appear should be on or just above the lower target line. Warning: This line and display are designed for a nominal MECO gamma; if the gamma is off, the display may be misleading. This tells the FDO that the orbiter is on, above, or below energy at MECO in units of ft. Remember, for the E/W VS RGO display to plot, the TRS must be in landing phase since the high speed entry processor (HSEP) is used to compute range. About 1 minute prior to MECO, ARD Support should remind TRAJ that the TRS should be in landing phase at MECO-20 seconds if TRAJ has not already passed a time to DYNAMICS.

4.2.5 TAL

PURPOSE

To perform proper modeling and monitoring tasks during a TAL abort to maintain an accurate ARD model.

PROCEDURE

- ABORT SELECTION:
 - √ TAL SELECTED O/B
 - NOTE MET
 - IF THROTTLE-BACK → PASS TRAJ THROTTLE-BACK MET
 - IF ARD ABORT PBI LATE → PASS TRAJ ABORT PROCEED MET FROM PROP DUMP LOG OR OMS DUMP START IN ARD MAINTENANCE (MAY NOT BE POSSIBLE IF BOTH OMS ENGINES ALREADY BURNING AT ABORT SELECT)
 - √ ARD DUMP STATUS (INH vs. ENA, manifold fail, correct start time, cutoff by MECO)
 - √ THROTTLES (67% IF 3 ENG OR LATE 2-ENG)
 - √ K51 TO SELECTED SITE & VERIFY CORRECT ARD SITE
 - IF INCT ENABLED AFTER 2nd ENGINE OUT, NOTE TIME & PASS TO TRAJ “AM CONT Dump Enable to ON, start time of N:NN”
- AT DUMP STOP → √ ARD vs. VEHICLE TMECO FOR ARD STATUS CALL
- MECO-20 SEC:
 - CALL UP “TAL TARGETS” ON ARD OUTPUT
 - REPORT R-V STATUS @ MECO

BACKGROUND

A TAL is an intact abort mode that results in a landing on either the European or African continent. A TAL can be initiated in response to both systems failures (cabin leak, loss of two hydraulic systems and third failing, certain OMS failures) and major performance problems (SSME failure, stuck throttle, SSME performance case, etc.). There are three TAL sites available as approved intact TAL sites. Preflight, one site is chosen as the prime site for the launch attempt. The available TAL sites are Zaragoza, Moron, and Istres. Las Palmas and Amilcar Cabral are available as contingency sites, as are a host of downrange sites.

The ARD can evaluate one TAL site at a time per mode, which is controlled by a FDO PBI. The PBI can be toggled to evaluate different sites. Along with the actual and hypothetical mode margin outputs, the ARD also displays the targeted crossrange to the selected actual mode TAL site.

Throttle monitoring - Once a TAL is initiated, for whatever reason, the ARD must be configured to model what has happened onboard. For a typical engine-out TAL run, the engine-out must be modeled and TAL must be selected in the ARD to the appropriate site. The TAL abort initiates an OMS dump, which ensures that landing constraints (c.g. and tank landing weight) will not be violated. Any onboard throttling must be modeled in the ARD. Usually the only throttling that occurs on a TAL is an automatic throttle-down that occurs for TALs initiated at large velocities (late in the ascent profile) or with three engines. This throttle-down is necessary to allow sufficient time for the OMS dump to be completed. Even though ARD III has automatic TAL throttle downs and a throttle command logger function, ARD Support must note the time of throttle-back and pass this to TRAJ so that the ARD throttle table can be precisely adjusted (K62 adjust). This is necessary because the time that appears automatically in the ARD is often late due to telemetry lag (we've seen 4 seconds error in throttle-down time). Note that updating the Abort Proceed Time in the ARD will not correct this throttle time (although it will correct the dump start time), DYN will have to make a throttle adjust update.

MECO condition assessment - The MECO targets for a TAL consist of an altitude, a plane defined by site location and crossrange, and an inertial R-Vi target line. Each site has its own target line. As soon as there is an indication that MECO has occurred, the RNG to the site should be written down since this changes faster than velocity. The inertial velocity is written down next. The TAL target velocity and range are also displayed on ARD OUTPUT. The R-V status is then called out on the MPSR DYN A loop (e.g., "nominal R-V" or "250 fps underspeed"). A guided MECO will always produce a nominal R-V, unless there is a navigation error. In cases of early MECO and/or navigation error, the call will be how much underspeed there was. (Equivalently, the ARD Support could call how much range we were short, but underspeed is preferred.) Any underspeed (or overspeed) should be reported to TRAJ, similar to an underspeed report for an uphill MECO.

Two Engine Out TAL – In the case of a TAL abort after a second engine failure, the ARD's AM contingency abort dump must be manually enabled. Then the start time must be adjusted to reflect the onboard time of the Item 6 & 7 selection.

4.2.6 ATO

PURPOSE

To perform proper modeling and monitoring tasks during an ATO abort to maintain an accurate ARD model.

PROCEDURE

- ABORT SELECTION:
 - √ ATO SELECTED O/B (NOTE: IF BFS, O/B MAY SAY "TAL")
 - NOTE MET
 - IF ARD ABORT PBI LATE OR 3 ENG ATO → PASS TRAJ ABORT PROCEED MET FROM PROP DUMP LOG OR OMS DUMP START IN ARD MAINTENANCE (MAY NOT BE POSSIBLE IF BOTH OMS ENGINES ALREADY BURNING AT ABORT SELECT)
 - √ ARD DUMP STATUS (INH vs. ENA, manifold fail, correct start time, cutoff by MECO)
 - IF VARIABLE IY → CONFIRM IYs
 - IF PASS: USE ARD MAINTENANCE DISPLAY
 - IF IYs NO-GO → Section 4.1.4.6 (snap onboard)
 - IF BFS: CLOSELY MONITOR MARGINS
 - IF BFS VMEO < V_MSSN_CNTN: √ BFS IYs SELECTED
 - IF BFS VMEO ≥ V_MSSN_CNTN: GRAB NOM IYs AFTER 10 SEC DELAY FROM BFS ENGAGE OR ABORT SELECT
 - COMPUTE OMS DUMP/REMAINING QTY (ARDTOOLS)
- DO NOT UPDATE VMEO FOR ANY SUBSEQUENT SSME FAILURES
- AT DUMP STOP → √ ARD vs. VEHICLE TMECO FOR ARD STATUS CALL
- GO TO 4.1.4.10 MECO ASSESSMENT

BACKGROUND

An ATO is an intact abort mode that usually results in a pre-MECO OMS dump and can result in a lower orbit, a shortened mission, or possibly an AOA. An ATO is initiated because of loss of an SSME or other significant performance problems. The pre-MECO

dump is designed to lighten the vehicle in order to limit the underspeed and keep the ET from impacting a critical land mass.

OMS dump quantity determination pre-MECO depends on how the dump was designed. The dump can be designed to be a constant dump or a ramped dump. A constant dump design results in a fixed pre-MECO OMS dump upon selection of ATO. A ramped dump is a function of the engine-out Earth-relative velocity or abort selection Earth-relative velocity if no engines have failed. (Due to this, do not update VMEO for SSME failures after an ATO is initiated.)

ARD Support can determine the amount of OMS to dump using ARDTools. This program must be configured preflight with flight-specific data (see Section 5.1.1). Once the program is properly loaded, the Earth-relative velocity of engine-out (or abort selection) is input into the spreadsheet, which outputs the amount the vehicle should dump as well as OMS remaining.

For variable IY flights (usually high inclination and/or rendezvous), ATO selection may also result in freezing of the current plane in order to improve performance. If this happens onboard, the ARD must also track this in order to provide accurate ΔV margins. Anytime a variable IY flight aborts ATO, ARD Support should execute IY target verification procedures outlined in Section 4.2.14.

Note that it is a good habit to check IYs after ATO selection even during non-variable IY flights in which the planar target is fixed.

4.2.7 OMS Failure Cases

This section details modeling necessary when problems develop in the OMS system.

4.2.7.1 OMS Propellant Leak/Fail or Helium Tank Fail

PURPOSE

To accurately model OMS propellant leak cases, propellant fails, and OMS helium tank fails in the ARD.

PROCEDURE

- √ FAILED OMS ENGINES = 1
- √ K64 (Current Dump Type) DUMP CUTOFF = Time good engine off
 - If TAL/RTLS or TAL Delay: Initial Guess = He/Prop Fail Time + 2:00
- PASS TRAJ: Δ OMS / Δ RCS per failed side total dump duration using Prop Fail / Helium Tank Fail tables -OR- expected total dump duration = 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 FAIL ONLY: √ K87 update TAL/RTLS timers to 120 sec (unless TAL/RTLS already)
- If needed to evaluate ATO capability, √ TRAJ: Δ OMS = Δ OMS - good OME dump needed

- FOR SUBSEQUENT ATO
 - √ K64 ('11' Dump Type) DUMP CUTOFF = I1 start + 1 sec
- FOR SUBSEQUENT TAL/RTLS
 - √ K64 ('11' Dump Type) DUMP CUTOFF = Time of 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.

PROP will announce on the FD loop that there is a propellant leak, propellant fail, or helium tank fail/expected fail. Propellant leaks (a leak in either the fuel or oxidizer tank) 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.) Remember that the ARD does not track the RCS as a usable quantity. Therefore, ΔRCS can be thought of as a bookkeeping location for increments to orbiter "dry" 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 by FDO 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 for TRAJ to consistently determine the amount of good OMS dump needed is with ΔOMS . The ΔOMS needed is then passed by TRAJ to PROP, who manages the good OMS on/off time to achieve the desired dump. The minimum good-side dump that PROP can manage the manual dump on/off times is approximately 750 pounds. Alternately, FDO may call for an ATO abort 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. For a prop leak, the goal is to reduce the amount leaked into the pod and to make use of the leaking propellant while it is still usable. 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. Any depletion dump will be cutoff at MECO - 10 seconds, and 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.

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. PROP manages the dump time and cg management of the vehicle for these aborts.

4.2.7.2 OMS Engine or 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

- \checkmark FAILED OMS ENGINES = 1
- PASS TRAJ: $\Delta OMS = -20 * \Delta t_{fail}$
- \checkmark ATO / TAL / RTLS INTERCONNECT = ENA

where:

- Δt_{fail} = time bad eng burned (OMS assist + abort dump)

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 ΔOMS adjustment is required to inform the ARD how much propellant was dumped through the engine prior to its failure. This adjustment assumes a flowrate of 20 lb/sec through one OMS engine.

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 that allows an OMS dump with an OMS engine failure on an uphill abort. For this case, Press to ATO is made assuming a 1 + 24 ATO dump, regardless of the ATO interconnect I-load, because if ATO is selected PROP will call for the interconnect. FDO's PTA call is made once the HM ATO SUM critical bias is reached –AND- an MPROP ≥ -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.

Note there is no ΔRCS step since there is no assumption of a leak into the pod - the mass was thrown overboard.

4.2.7.3 OMS He Leak

PURPOSE

To accurately model OMS helium leak cases (OMS He TK P Low) in the ARD.

PROCEDURE

- IF PRE-MECO DUMP REQUIRED AND TANK FAIL EXPECTED PRE-MECO:
 - Use OMS Prop Leak / Fail & Helium Tank Fail procedure (see Section 4.2.7.1)
- IF PRE-MECO DUMP REQUIRED AND TANK FAIL NOT EXPECTED PRE-MECO:
 - \checkmark FAILED OMS ENGINES = 1 (AFTER 2E TAL)
 - \checkmark TRAJ ENTERS ITEM 9 PER PROP OFFICER (SLIP OMS ASSIST START TIME, IF NECESSARY)
 - Using He LEAK table LB TRAPPED for leaking side expected total dump duration, PASS TRAJ:
 - $\Delta\text{OMS} = -(\text{LB TRAPPED}) - 20 * \Delta t_{\text{DUMPED}}$
 - $\Delta\text{RCS} = +(\text{LB TRAPPED})$
 -
 - \checkmark TAL INTERCONNECT = INH
 - If needed to evaluate ATO capability, \checkmark TRAJ: $\Delta\text{OMS} = \Delta\text{OMS} - \text{GOOD OME DUMP NEEDED}$ as determined by FDO
 - FOR SUBSEQUENT ATO: IF ATO DUMP LESS THAN BLOWDOWN DUMP, PROP OFFICER WILL CALL FOR ITEM 9 TO RESTORE BLOWDOWN DUMP
 - \checkmark ITEM 9 BLOWDOWN DUMP RE-INPUTED PER PROP OFFICER
 - FOR SUBSEQUENT RTLS/TAL:
 - \checkmark FAILED OMS ENGINES = 0
 - PASS TRAJ:
 - $\Delta\text{OMS} = + 20 * \Delta t_{\text{GOOD OME OFF}}$ OR RTLS/TAL LBS HEAVY
 - FOR SUBSEQUENT He TANK FAIL:

- \sqrt ITEM 9 updated to match actual dump cutoff
- PASS TRAJ: Δ OMS / Δ RCS to match actual dump duration
- IF PRE-MECO DUMP NOT REQUIRED:
 - \sqrt Δ OMS ASSIST DIAL DOWN (CUTOFF TIME), IF NECESSARY

where:

- Δt_{DUMPED} = time good engine burned (OMS Assist + abort dump)

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 leak or slow leak. If the leak is fast enough, helium tank fail can be expected pre-MECO, in which case the “OMS Prop Leak / Fail & Helium Tank Fail” procedures (see section 4.2.7.1) 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 and ARD Support initiate the steps on this Helium Leak procedures, TRAJ and ARD Support 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 such a later downmode to “helium tank fail.” This is preferred over attempting to back out of this procedure and then switch to the procedures in Section 4.2.7.1.

If the helium leak is slow enough to react to and no abort dumps are in progress, a procedure called “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 Helium Leak tables. 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 delta V potential is marked with an asterisk. 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 Δ OMS. This additional Δ OMS 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.

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 by FDO. 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 unfailed 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 by FDO 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 ΔV loss towards achieving the mission. Therefore it is prudent to trade excess ascent performance margin to increase the OMS propellant available post-MECO.

4.2.7.4 Item 9 Dumps

PURPOSE

To accurately model an Item 9 dump in the ARD.

PROCEDURE

- NOTE: WAIT UNTIL THE OMS ASSIST HAS STARTED ONBOARD BEFORE MODELING AN ITEM 9 IN THE ARD.
- UPON CONFIRMATION OF ONBOARD ITEM 9:
 - IF ITEM 9 START IS AFTER OMS ASSIST STOP
 - PASS TRAJ: K64 Dump Type 'N', Start Time = (OA Start + OMS Off Duration)
 - IF ITEM 9 IS INTERCONNECTED
 - √ ABORT ATO IN THE ARD WHEN O/B I/C DUMP STARTS
 - √ ONBOARD IYs RESELECTED
 - √ ARD ATO INCT = ENA
 - √ K65 RCS ON TIME = O/B INCT START (FROM PROP DUMP LOG)
 - √ ABORT PROCEED TIME = O/B ITEM 9 START
 - √ ITEM 9 = AMOUNT VOICED UP TO THE CREW (USUALLY THE CONTINGENCY DUMP%)
 - √ Item 9 "K64 Quan" on ARD Maintenance

BACKGROUND

In certain situations, it is advantageous to start an Item 9 dump to regain uphill capability without aborting, or prior to engaging an abort. If the Item 9 starts during the OMS Assist, the ARD will automatically model (by extending the Dump Type "N" stop time) the additional burn time due to the Item 9. If the onboard Item 9 starts after the OMS Assist, the ARD will also automatically model a change in the stop time, however it will be in error by the amount of time the OMS engines had been off. Because there is only one channel in the ARD to model these two separate dumps, it is possible to model the duration correctly, and either the start or stop time can be correct (but not both times). The ARD will automatically get the start time correct, and the stop time incorrect. It is more important to have the stop time correct in the ARD than the start time, and thus the stop time must be fixed. Otherwise, the onboard dump will stop

sooner than the ARD (by an amount equal to the OMS Off Duration), and cause errors in the ARD until the ARD also stops.

In certain situations, it is advantageous to start an interconnected Item 9 dump prior to engaging an abort. For example, TAL delay was implemented to optimize ECAL coverage in the event of a subsequent SSME failure. To further optimize, an OMS dump was initiated to improve the ECAL landing mass properties (C.G. and tank landing constraint). Interconnecting this OMS dump will further improve the ECAL landing mass properties by getting more OMS dumped prior to MECO. It is important to get as much off prior to MECO because very little will be dumped on an ECAL trajectory prior to Nz limit cutoff. An interconnect may also be required if an OMS engine should fail during the Item 9.

The crew can both increase and interconnect the OMS assist dump on SPEC 51 via item 9 and item 5 respectively. Due to software limitations, the ARD cannot interconnect the OMS assist dump. (The ARD cannot model such a dump as an OMS assist, the channel normally used for Item 9 dumps, because the ARD OMS assist model is capable of straight-fed assists only) Since we are eventually going to abort TAL, and do not need the NOM channel, it was decided to use the ATO channel as a work around to the software limitations. The ATO channel does not have the same OMS interconnect restriction.

Once an Item 9 is onboard, and running interconnected, to the FDO aborts ATO in the ARD (which allows INCT). This initiates an ATO OMS dump in the ARD and (most likely) freezes the inertial insertion plane. TRAJ grabs the onboard IYs (since variable IY logic may have engaged), sets the interconnect flag to match the onboard (not required if ATO dump is already interconnected via I-load), sets the RCS on time and/or abort proceed time to match the Item 9 start time to sync the ARD with the O/B, and sets the Item 9 quantity to match the amount voiced up to the crew. The standard voice up amount is the contingency dump percentage.

Note that the ARD will ignore attempts to model an Item 9 if the Item 9 modeled quantity is the same as the K64 CUR quantity, or if the K64 MED is shipped prior to the start of OMS Assist (if manifested) (this would only be attempted to get ahead of things). If the CUR Item 9 is shipped before the OA starts, the K64 MED gets accepted (hence the K64 QUAN updated) but the ARD doesn't do anything with it since there is no current dump in progress.

4.2.7.5 RCS Interconnect Switch During a Burn

PURPOSE

To accurately model in the ARD an interconnected switch during OMS/RCS burns.

PROCEDURE

- UPON CONFIRMATION THAT INCT STATUS HAS CHANGED ONBOARD:
 - √ INCT = ENA FOR APPROPRIATE MODE
 - IF INH TO ENA
 - √ RCS START TIME = ENA TIME FOR APPROPRIATE MODE
 - IF ENA TO INH
 - √ RCS STOP TIME = INH TIME FOR APPROPRIATE MODE

BACKGROUND

In certain situations, the RCS jets may switch interconnect status during a burn. In either case (switch from ENA to INH, or from INH to ENA), the interconnect must be enabled in the ARD for the appropriate mode (e.g. TAL).

For a switch from INH to ENA, the RCS START time is set to the time of the switch; this tells the ARD the RCS jets were not on until the specified start time, otherwise the ARD would assume the jets were on the whole duration.

For a switch from ENA to INH, the RCS STOP time is set to the time of the switch; this tells the ARD the RCS jets were on, but only until the specified stop time.

RCS START/STOP times are seen in ARD CONTROL DATA. START/STOP times must be set for the appropriate mode (e.g. "I1", "I2", "CONT RCS JET").

4.2.7.6 RCS Leg/Manifold Failure/Recovery

PURPOSE

To accurately model an RCS Manifold failure in the ARD.

PROCEDURE

- NOTE: ARD ASSUMES 2+10 OR 2+24 FOR THE ENTIRE DUMP; DUMP STOP TIME WILL DIFFER FROM O/B. ARD IS NOT MODELED UNTIL DUMP HAS STOPPED BOTH O/B AND IN ARD.
- UPON CONFIRMATION OF RCS MANIFOLD FAILURE (“2+10” or “1+10” JET INDICATION IN PROP DUMP LOG):
 - √ “MAN 1/2 FAIL LOGIC” OR “MAN 3/4/5 FAIL LOGIC” = ON
 - IF MANIFOLD FAIL NOT RECOGNIZED ONBOARD
 - IF MANIFOLD FAILS PARTIALLY INTO DUMP
 - PASS TRAJ: $\Delta OMS = -32 * \Delta t_{24}$
 - IF MANIFOLD RECOVERED AFTER PREVIOUS FAILURE
 - √ “MAN 1/2 FAIL LOGIC” OR “MAN 3/4/5 FAIL LOGIC” = OFF
 - PASS TRAJ: $\Delta OMS = +32 * \Delta t_{24}$

where:

- Δt_{24} = time of normal operation (1+24 or 2+24)

BACKGROUND

During interconnected dumps, the normal burn consists of two OMS engines plus 24 RCS jets. Should an RCS manifold failure occur, a loss of some RCS jets will occur, and a “2+10” (if 2 OMS burning) or “1+10” (if 1 OMS burning) message will appear in the PROP DUMP LOG. This is modeled by “failing a manifold” in the ARD. ARD Support verifies a manifold failure in the ARD on ARD CONTROL DATA by verifying either the “MAN 1/2 FAIL LOGIC” OR “MAN 3/4/5 FAIL LOGIC” is set to ON.

If the failure occurred after partially into the dump, so that the dump started at 2+24 (or 1+24), then fails down to 2+10 (or 1+10), then step one of this procedure now has a lower-than-actual flow rate for the time that the OMS system was working properly, and OMS must be removed from the ARD. The difference in flowrate is 32.44 lb/sec for both the 1- and 2-OMS cases. Thus, the ARD must be corrected by an amount of -32 lb/sec times the time at 2+24 (or 1+24).

In the case where a dump starts off with a manifold failure, i.e. 2+10 (or 1+10), then the OMS system returns to nominal, i.e. 2+24 (or 1+24), then the manifold fail flag must be turned off (best case modeling for the rest of ascent). This causes a higher-than-actual flow rate for the time that the OMS system was working improperly, and OMS must be added to the ARD. The difference in flowrate is 32.44 lb/sec for both the 1- and 2-OMS cases. Thus, the ARD must be corrected by an amount of +32 lb/sec times the time at 2+24 (or 1+24).

4.2.7.7 Forward RCS Leak

PURPOSE

To accurately model a forward RCS leak in the ARD.

PROCEDURE

- UPON CONFIRMATION OF FORWARD RCS LEAK:
 - IF BALLASTING REQUIRED:
 - $\sqrt{\Delta RCS} = +(\text{BALLAST QNTY})$
 - $\sqrt{\Delta OMS} = -(\text{BALLAST QNTY})$

BACKGROUND

Usually no ARD action is required for a forward RCS leak. However, in certain cases the FDO may have to bias calls based on this failure. This is accomplished by modeling a reduction in ΔOMS and increase in ΔRCS , affecting the XOMS channel in the AM, giving the appropriate delta-V capability reduction.

4.2.8 FPR Adjustments

PURPOSE

To update the ARD FPR to maintain adequate 2σ ascent systems protection during SSME performance cases.

PROCEDURE

- NOTE: IF DRIFTING HYDRAULIC LOCKUP → USE ADJUSTED IMBALANCE
- CHECK/RE-COMPUTE FPR BASED ON NOM AM IMBALANCE OUTPUT USING ARDTOOLS
- VERIFY CORRECT CONSOLE FPR INPUT BY TRAJ THRU FPR BUTTON
- NOTIFY TRAJ...GOOD FPR

BACKGROUND

Console procedures for an FPR adjust are fairly straightforward; it is a simple matter for TRAJ to click the FPR button. The following data is included as information. See also Section 6.1. (Note: As of April 1999, this rationale is under review.)

The nominal ARD FPR protects for ascent dispersions that could result in an optimistic ARD configuration (early boundary calls). This prevents the ARD from falsely indicating capability the vehicle may not actually have on a low performing day, but also causes boundary calls to be late (about 15 seconds) on a nominal or better-than-expected performance day. Thus FPR is a balance between providing abort boundary confidence to the required statistical level (2 sigma for most), while not excessively penalizing vehicle performance. For nominal ascent the ARD FPR is about 2500 lb; however, it increases dramatically for some SSME performance case scenarios.

Nominal ARD FPR is based on flight-derived dispersions that are determined from post-flight reconstruction. For example, ISP is predicted prior to flight, and this value is used in preflight trajectory simulations as well as the ARD throttle table. After the flight, the slope of the FT_FACT curve can reveal the actual ISP to a pretty good accuracy. The dispersion is simply the difference between reconstructed and predicted. Over many flights a statistical database can be built up that yields standard deviation (sigma) for SSME thrust, ISP, MR, ET, orbiter inert weight, etc. These values are then used in ARD FPR equations to determine how much propellant is required to protect for these historical dispersions. ARD FPR does not protect for Booster Uncertainties. See Section 6.9 for more details.

Prior to declaration of a performance case, the preflight fuel bias is output as the predicted imbalance, while the rest of the ARD MEP weight is considered burnable at the nominal MR. The performance case MR upsets the nominal LOX/LH2 ratio and results in an imbalance different from the prelaunch bias. Once the Booster Officer (BSE) detects an SSME performance case and passes engine data to the Trajectory

Officer, the FPR situation changes. SSME power level, ISP, and MR are input in the ARD throttle table at the MET passed from BSE. The performance hit or gain due to thrust/ISP degradation or improvement manifests itself as a shift in the delta V margin. The ARD imbalance task takes the off-nominal MR and recomputes a predicted LH2 or LOX imbalance for both current time and MECO, for each abort channel. Since the non-6:1 FPR components (ET load and MR) are a function of predicted bias at MECO, any change in MR (i.e., imbalance) will require an update to the ARD FPR holdback.

Figure 4-7 shows FPR required vs. Imbalance/mixture ratio. It is obvious that fuel biases (high MR cases) are much more desirable than LOX biases (low MR cases) in terms of FPR requirements. This is because LOX biases grow six times faster per MR dispersion than LH2 biases (due to the OBMR of about 6.04). Needless to say, FPR must protect for the possibility of imbalance growth (among other things) due to the MR dispersion, since unusables are dead weight (extra payload). The plot is generated by a certified subroutine, FPR_NON_6TO1, that also provides nominal FPR data for ARD and preflight performance assessment. The ARDTools program on the workstation has this subroutine and computes an exact FPR quantity in realtime (see ARDTools User's Guide).

Only the "press" FPR curve is shown in Figure 4-7. In reality, there are two curves, one for uphill (three engine) assessment, and one for press (engine out at press to ATO). Theoretically, the ARD should be configured with the quantity corresponding to what calls are going to be made. This is not the case due to the operational complexity involved. (Note: The uphill curve, which is not shown, would terminate at about 5.95, since uphill capability is almost always assured at MRs greater than this).

Cluster MR uncertainty is a function of the number of engines running, which makes the curves different for the two cases. (Root-mean-squaring individual engine MR uncertainties yields different answers for two- and three-engine configurations). The press case requires more FPR since the potential cluster MR dispersion is greater for two engines than three.

To check the FPR using ARDTools, use the hypothetical mode predicted MECO imbalance data on ARD OUTPUT. The column used should correspond to current abort mode (or nominal if no abort selected). Hypothetical MECO imbalance output changes with time, since the hypothetical mode does not actually reflect onboard engine status. The hypothetical predicted MECO imbalance at press time is the correct quantity to be used to calculate delta FPR, but the FPR must be set up prior to the press call, so this requires an estimate of what the imbalance will be. Note that it is important to model the proper engine out in the hypothetical mode. For most performance cases, a good engine is modeled as failing. This will yield the most conservative performance since the longer the bad engine runs, the more off-nominal the imbalance will be at MECO.

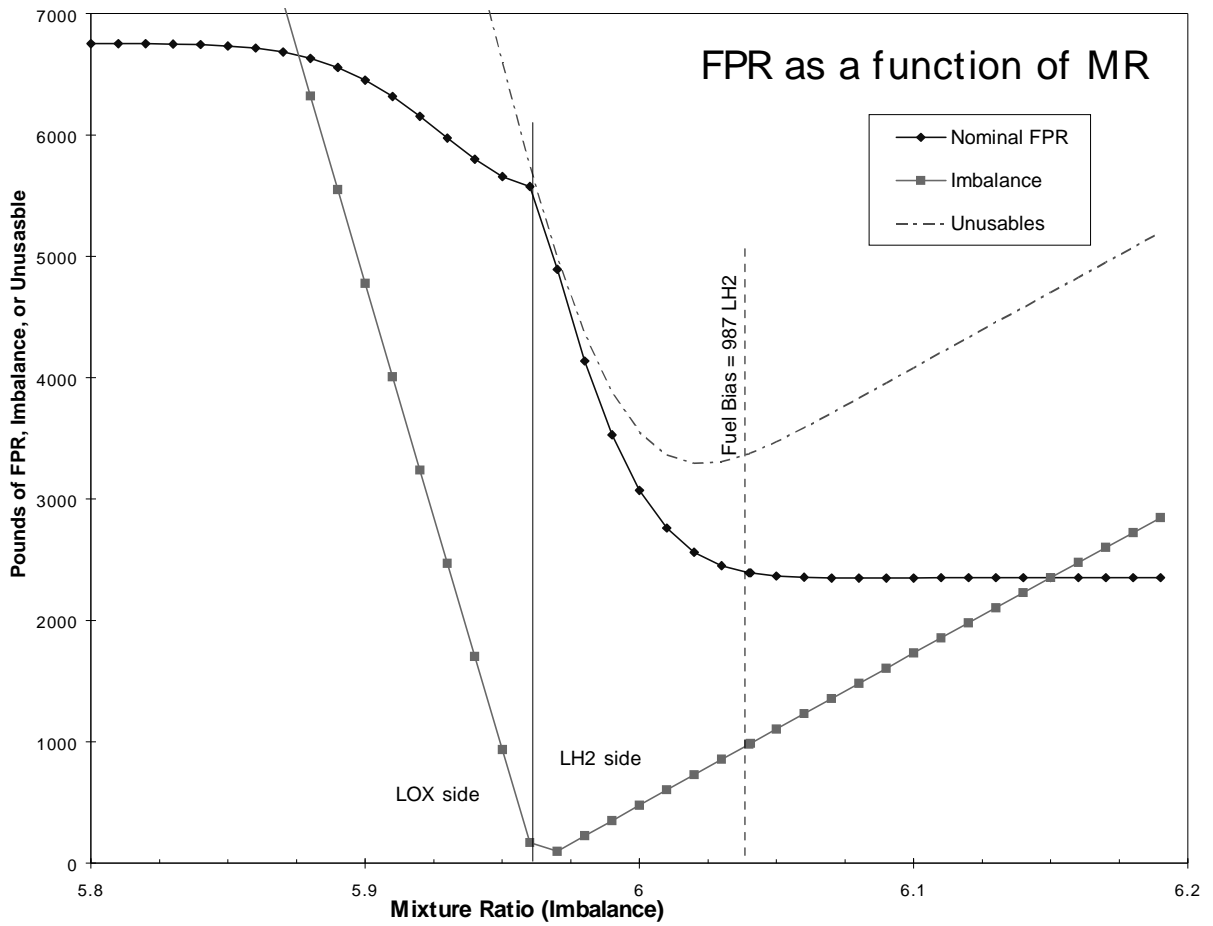


Figure 4-7. FPR vs. Imbalance Curve

4.2.9 Flow Control Valve Anomaly (Manual Throttle for Low LH2 NPSP)

PURPOSE

To accurately model capability for manual throttle back for SSME low NPSP in the ARD. This applies for two or three fuel flow control valves failed closed. For three failed closed, a TAL will be declared. For two failed closed, TAL will not be declared by BSE, but may be required for performance.

PROCEDURE

- TRAJ: UPON BSE CALL OF MANUAL THROTTLE REQUIRED FOR FLOW CONTROL VALVE (FCV) FAILURES, MODEL THROTTLE DOWN IN HM → 95/95/95
- FDO: MONITOR CAPABILITY FROM HM CONFIGURATION
 - THREE FCVs FAILED: A TAL TO THE INPLANE SITE (TAL or ACLS) WILL BE DECLARED FOR THIS FAILURE
 - TWO FCVs FAILED: MONITOR PERFORMANCE -- TAL MAY BE REQUIRED
- WHEN THROTTLEBACK OCCURS
 - ARD:
 - CHASE FIRST MANUAL THROTTLE STEP → 95/95/95
 - CHASE NEXT THROTTLE STEP → 80/80/80
 - CHASE FINAL THROTTLE STEP → 67/67/67

BACKGROUND

For three FCVs failed, earliest MECO conditions and earliest multiple-engine-out capability are required since all engines will shut down early due to low NPSP, hence a TAL to the inplane site will be declared. Throttling is done to reduce NPSP requirements. For two FCVs failed, TAL may be avoided if uphill capability remains after each throttle step. Reference Booster rules A5.1.4-5, MANUAL THROTTLING FOR LOW LH2 NPSP, and A5.1.4-6, ABORT PREFERENCE FOR SYSTEMS FAILURES.

4.2.10 Ullage Gas Leak (Manual Throttle for Low LH2 NPSP)

PURPOSE

To accurately evaluate capability for this failure.

PROCEDURE

- NOTE: NO ARD ACTION REQ'D
- NOTE: TAL TO INPLANE SITE (ACLS) WILL BE DECLARED FOR THIS FAILURE
- UPON BSE CALL OF ULLAGE LEAK:
 - FDO: INFORM FD OF TAL CAPABILITY, ESPECIALLY IF NEAR LAST TAL
- PRIOR TO TAL ABORT, BSE WILL CALL FOR MANUAL THROTTLES. AUTO THROTTLES WILL BE RESELECTED AFTER THE ABORT IS INITIATED

BACKGROUND

The ullage gas provides the pressure to use the prop in the ET. If the ullage pressure drops too low, the SSMEs will shut down. Earliest MECO conditions and earliest multiple-engine-out capability are required since there is no way to predict when all engines will shut down; hence, a TAL to the inplane site will be declared. Reference Booster rule A5.1.4-5, MANUAL THROTTLING FOR LOW LH2 NPSP, and A5.1.4-6, ABORT PREFERENCE FOR SYSTEMS FAILURES.

4.2.11 Three Low-Level Sensors Failed Dry

PURPOSE

To identify method of determining abort capability for this failure.

PROCEDURE

- TAL (OR RTLS) WILL BE REQUIRED ALMOST EXCLUSIVELY BECAUSE DESIGN UNDERSPEED MUST BE PROTECTED
 - √ THAT TRAJ CORRECTLY MODELS CUT-OFF ARMING MASS IN THE ARD
 - $\Delta ETP = -32,000 \text{ LBS}$
 - $\Delta ETD = +32,000 \text{ LBS}$
 - IF NOM MPROP $> 2\sigma$ DESIGN UNDERSPEED BIAS, THEN CONTINUE UPHILL WITH NO ACTION, OTHERWISE ABORT TAL OR RTLS
 - NOTE: AN ATO DUMP MAKES THE UNDERSPEED WORSE DUE TO REDUCED VEHICLE MASS AND EARLIER LOW-LEVEL CUTOFF
- WHEN TAL/RTLS ABORT IS REQUIRED
 - IF NEG ABORT MARGIN: √ RCS INTERCONNECT TO INHIBIT
 - CALCULATE THE CUTOFF AT ARMING MASS FOR THE ABORT CASE AND PASS TO TRAJ
 - $\Delta ETP = -(32000 + \text{TAL/RTLS DUMP QUANTITY} - \text{ASSIST}) \text{ (LBS)}$
 - $\Delta ETD = +(32000 + \text{TAL/RTLS DUMP QUANTITY} - \text{ASSIST}) \text{ (LBS)}$
 - Note: The full TAL and RTLS dump quantities are available from Abort Support
 - NOTE: IF ABORT DUMP IS GOING TO BE CUTOFF BY MECO THEN GET PREDICTED DUMP AMOUNT IN LBS FROM PROP

BACKGROUND

If three low level sensors are failed dry then MECO will occur at the arming mass. Reference : ACME Presentation on XMASSL Bias/SCES Timer Process by USA/S. Cristol 1/28/99. The presentation explains that the arming mass is computed by adding a bias to the Nominal Zero Weight. The exact equation for computing the arming mass is:

$$\text{XMASSL} = \text{zmwt} - \text{FPR} + \text{bias} + \text{mass tracking error}$$

where: XMASSL is the arming mass, zmwt is the nominal zero margin weight, and FPR is the flight performance reserve. The bias is 32,000 lbs. The FPR and mass tracking error roughly cancel each other out. Therefore to assess the uphill case, the ARD must be configured to reflect the 32,000 lbs of ET propellant remaining at MECO. This is done by subtracting that quantity out of the usable ET propellant and adding it to the dry weight of the vehicle. Once it has been verified that uphill capability does not exist, which it won't because the design underspeed must protect for this case, a TAL (or RTLS) is required.

The TAL (or RTLS) case must be assessed to determine if capability exists to the prime site if it is not the INPLANE site. (Note: any kind of dump will cause MECO to occur even earlier because the total vehicle mass is being reduced, therefore ATO is not an option.) The TAL (or RTLS) OMS dump will cause MECO to occur at the arming mass with more ET propellant remaining than on the nominal case which did not include a dump. The RCS interconnect should be inhibited to ensure that all propellant dumped has a propulsive effect and is not just reducing the weight. The amount of additional ET Propellant remaining is directly proportional to the amount of OMS propellant dumped. This is modeled by adding the TAL (or RTLS) OMS dump quantity to the 32,000 lb bias. The corresponding amount must also be kept as dry weight. If the performance bias to the prime site is still positive, then the INPLANE/ACLS site is not required. If capability to the prime site cannot be evaluated, then the INPLANE/ACLS site should be selected.

Also reference flight rule A5-157. Here is an excerpt from this rule: "Propellant low level shutdown software is provided to protect the vehicle from an uncontrolled engine failure which would be caused by the depletion of either LO2 or LH2 propellant to a running engine. The software logic requires two qualified sensors to indicate dry after the arming mass is reached in order to start the low level timer and issue the MECO command. On the first pass after the arming mass is reached, the software will disable one dry low level sensor. On the next pass, the software will command MECO if two other low level sensors on the same tank are failed dry. Therefore, three sensors dry when the arming mass is reached will result in an early MECO which may require a TAL or ACLS abort. The failure of two sensors will not cause a premature MECO when the arming mass is reached, since one will be disabled. The crew will be required to abort TAL (or ACLS if no TAL site is available) on some performance-critical missions (as determined by flight design) to prevent a MECO from occurring in a region where no abort capability exists."

4.2.12 Three Low-Level Sensors Failed Wet (Loss of Low-Level Cutoff Cap.)

PURPOSE

To document procedures used to ensure safe MECO conditions in the event of loss of low level cutoff capability (three or more low-level sensors failed wet).

PROCEDURE

- NOTE: NO ARD ACTION REQ'D
- FDO: ADVISE FD OF TAL/ACLS CAPABILITY

BACKGROUND

While there is no flight rule governing this situation, the BOOSTER hip pocket procedure is to call for a TAL. Since the sensors usually read wet, it is very hard for BOOSTER to call this case.

4.2.13 Throttle Bucket Modeling Procedures

Information in this section was moved to earlier sections.

4.2.14 BFS Engage

PURPOSE

To point out PASS/BFS differences and document console procedures for ascent on the BFS.

PROCEDURE

- UPON BFS ENGAGE:
 - CONFIRM IYs FROM MPROP TREND
 - IF ATO:
 - IF BFS VMEO < V_MSSN_CNTN: √ BFS IYs SELECTED
 - IF BFS VMEO ≥ V_MSSN_CNTN: GRAB NOM IYs AFTER 10 SEC DELAY FROM BFS ENGAGE OR ABORT SELECT
- NOTE BFS LIMITATIONS:
 - NO CSS DURING POWERED FLT
 - NO SE CALLS (NO SERC)

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 and ARD Support must verify good IYs. A one-to-one comparison on ARD Maintenance is not possible since BFS IYs 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 IYs are in sync with the BFS.

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 IYs by performing a K84\$, K84B\$. During the next three ARD cycles, the BFS IYs are automatically grabbed and compared to the current BFS IYs in the Traj Server. Note that since the onboard BFS IYs are currently not downlinked, the "BFS IYs" that are grabbed are actually set equal to $-R \times V$ from the onboard BFS state vector. If the comparison shows the "grabbed" IYs are different from what's in the Traj Server, then the "grabbed" IYs are stored as the new BFS IY 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 IYs 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 IYs, while the ARD will grab and use BFS IYs 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 IYs using the IY selection menu at the top of ARD MON (equivalent to K84\$, K84N\$). This step should be delayed until after the ARD performs its automatic IY grab for 3 cycles --- about 6-10 sec delay is sufficient. Then IYs can be verified as before, by monitoring nominal MPROP and steering commands.

5 TOOLS

5.1 ON-CONSOLE TOOLS

5.1.1 ARDTools

This section discusses the basics of accessing and using ARDTools, a Tcl/Tk based, Workstation application that ARD Support uses for realtime and pre-launch computations. For an in-depth description of ARDTools features and coding, the User's Guide can be found at

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\Cert ARDTools DA\V1.0.1\UG-
ARDTOOLS-V1.0.1DA.doc

Manual execution of the auto features is only described in the User's Guide. How the ARD/TRAJ/DYN team works to communicate, authorize, ship, and QA MEDs sent via ARDTools is documented in

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\Handbook\ARDTools MOU.doc

This document also includes a list of all possible MEDs that ARDTools is capable of shipping, and describes how to proceed if ARDTools has a MED shipping failure.

5.1.1.1 Main

Figure 5-1 shows the ARDTools main view. This view provides a summary of the dynamic functions used during powered flight. It also shows the buttons that access the detailed views for each of the powered flight and pre-launch functions. The background on the Delta TMECO field will turn red if the value is greater than 2 and will turn yellow if the value is between 1 and 2. The background on the FPR field will turn red if the displayed FPR is more than 200 lb different than the FPR currently in the ARD. The background for each engine in the Delta throttles block will turn red if the current ARD throttle is different from the BFS throttle setting by more than 1%. However, if the thrust limiting flag is turned on in the ARD for an engine, the background will turn yellow for throttle deltas greater than 1%.

Before the application can be run, the static input data must be loaded by selecting File → Open → All. Then, after lift-off (i.e. the lift-off button has been pressed and the ARD is running) the dynamic mode may be entered by selecting Options → Run. Only the biased throttle application runs during first stage. The other functions will automatically start at staging if the application is already in run mode.

5.1.1.2 Biased Throttle

The biased throttle feature calculates the amount of ARD delta ET propellant required for performance case throttle shifts before completion of the throttle bucket. During Pc shifts, HPOT efficiency losses, LH2 F/M shifts, LPFT discharge temperature shifts, and nozzle leaks, the affected SSME will experience a throttle level bias. Trajectory personnel input ISP, MR, biased throttle level, and event time in the ARD for the

anomalous SSME. For cases occurring before or during the throttle bucket, the sick SSME will throttle down with the good engines, but will experience a constant throttle delta, the same bias as at 104.5 percent. Since the sick SSME throttle setting is locked in the ARD, this would eliminate that engine's throttle bucket if the actual event time were used for the throttle setting. Thus, the biased throttle level is input later than the throttle bucket; with current SOP, this time is 1:07 MET (see Section 4.2.3.1).

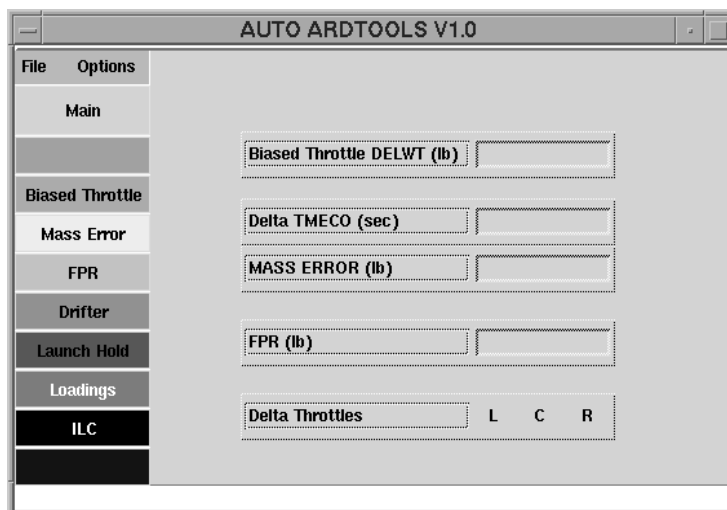


Figure 5-1. ARDTools Main Display

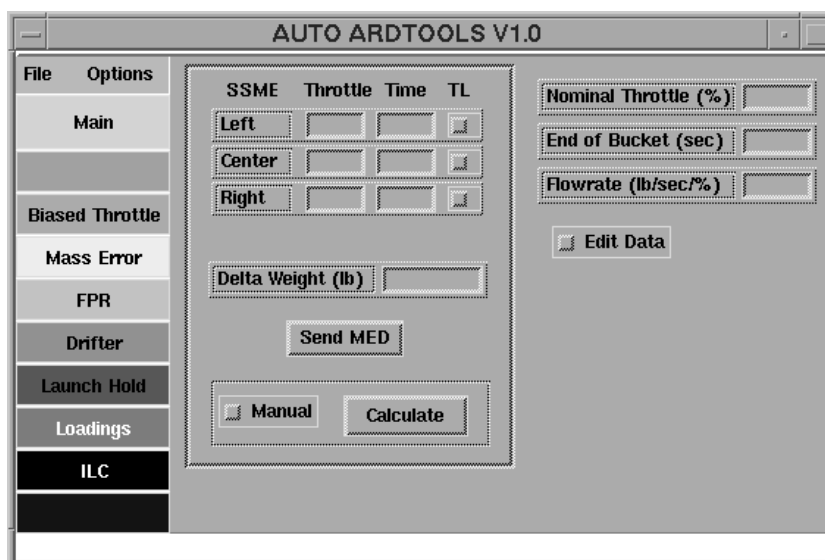


Figure 5-2. Biased Throttle View

To account for the change in ET propellant consumed by the sick engine before 1:07, it is necessary to calculate a delta ETP value. This is the amount of propellant consumed at the nominal power level (T_{nom}) (currently 104.5 percent) from the time of thrust limiting ($T_{T/L}$) to 1:07, minus the propellant actually consumed at the biased throttle level (T_{act}) over the same time. The formula for this is:

$$\Delta WT = (T_{nom} \% - T_{act} \%) * (67 \text{ sec} - T_{T/L} \text{ sec}) * 10.4 \text{ lb}/\%/sec$$

with 10.4 lb/percent/sec being the nominal mass flowrate per percent throttle for one SSME. The ΔWT value is input in the ARD with a K67 DELWT OVRD MED. Note that this equation yields the proper sign for the delta propellant.

ARDTools automates this calculation by extracting the sick engine throttle level and case time. This calculation is continually performed through ascent. The ΔWT value is displayed with the proper sign. This delta must then be applied to the DELTA WT OVERRIDE value displayed on ARD Output. There is a "Send MED" button, which when double-clicked, will ship this ΔWT value to the ARD via the K67 MED. Figure 5-2 shows the detailed view for the Biased Throttle section. See also Section 4.1.4.5, Adaptive Guidance Monitoring.

The auto application does not work properly if there are two or more performance cases on a single SSME. The application only "sees" the last case, so it will only compute a partial delta ETP. Also, if a case occurs in the first 1:07, and a subsequent case occurs after 1:07, the original case will again be over written, in this situation with a "0" delta ETP, since the last case did not require any delta ETP.

5.1.1.3 Mass Error

The Mass Error feature attempts to emulate the Weight Error versus $\Delta TMECO$ chart shown in Figure 3-1. ARDTools continually monitors the $\Delta TMECO$, and calculates the necessary ΔETP to correct the TMECO difference. The "Send MED" button may be double-clicked here to ship the calculated ΔETP to the ARD via the K67 MED. Prior to shipping any delta weight to the ARD, ARD Support and Traj should obtain concurrence from FDO. The Mass Error view is shown in Figure 5-3.

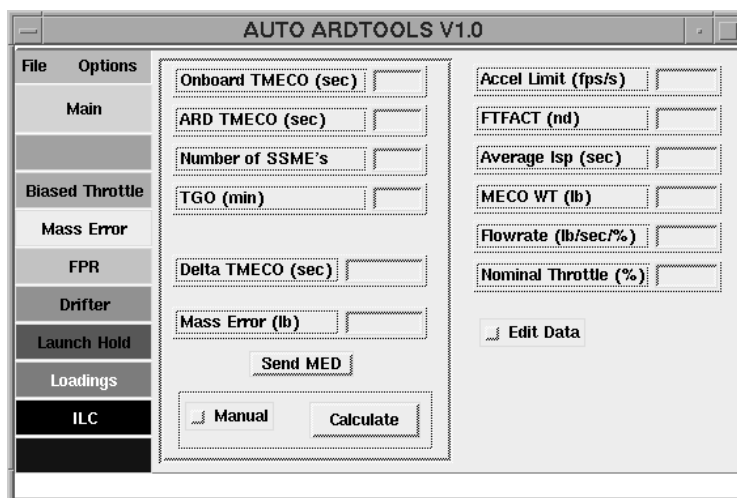


Figure 5-3. Mass Error View

5.1.1.4 FPR

The FPR function continually extracts the ARD-calculated propellant bias and computes the 2σ ATO FPR. See Section 4.2.8 for details of this computation. This quantity is then compared to the current ARD FPR to determine if Auto FPR (via ARD Monitor) needs to

be run by TRAJ. Figure 5-4 shows the FPR detailed view. The static input data is extracted from the same file used by the ARD to calculate FPR.

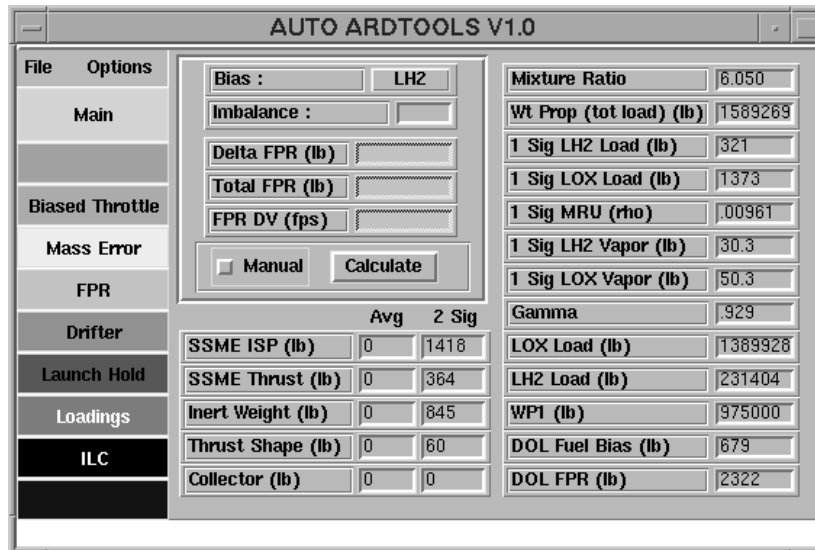


Figure 5-4. FPR View

5.1.1.5 Drifter

The drifting throttle section is used to compute corrections to the ARD imbalance and nominal MPROP margin as described in Section 6.7. The Drifter view is shown in Figure 5-5. Basically, the initial and final case information are entered into the interface, and the application calculates future performance deltas to be applied to the ARD margins at 1 minute intervals. If the drifting engine later fails, then the ARD will be configured properly, and no future updates will be required. If a good engine later fails, however, then the Good Engine out button is selected and the future delta margins are recomputed. These deltas should be provided to FDO approximately 15-20 seconds prior to the time they are applicable (see Section 4.2.3.3).

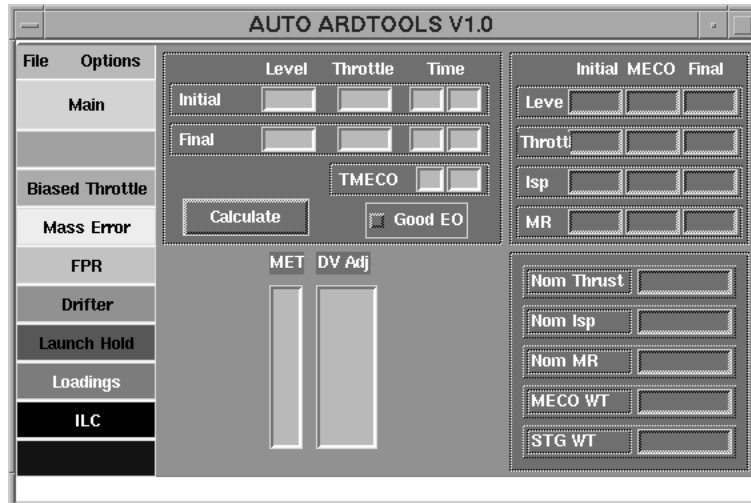


Figure 5-5. Drifter View

5.1.1.6 Launch Hold

This view, shown in Figure 5-6, allows the user to enter a launch hold duration in 5-second increments and calculates the deltas to the ARD database due to LOX drainback effects. When the “Calculate” button is depressed, the application determines the appropriate ARD database updates and retrieves the current values from the server and calculates and displays the deltas. When the “Send MEDs” button is double clicked, the application ships the data to the server and then retrieves the same data to ensure that the updates have been made appropriately. All values in the delta column should be zero at this point. Pressing the “Build Hold Table” button will build a hold table and save it in a file. This file may then be printed via the file menu. Figure 5-7 shows an example of a Launch Hold Chart, which shows the break down of the changes to ET dry, ET prop, fuel bias, and FPR due to holds inside of drainback.

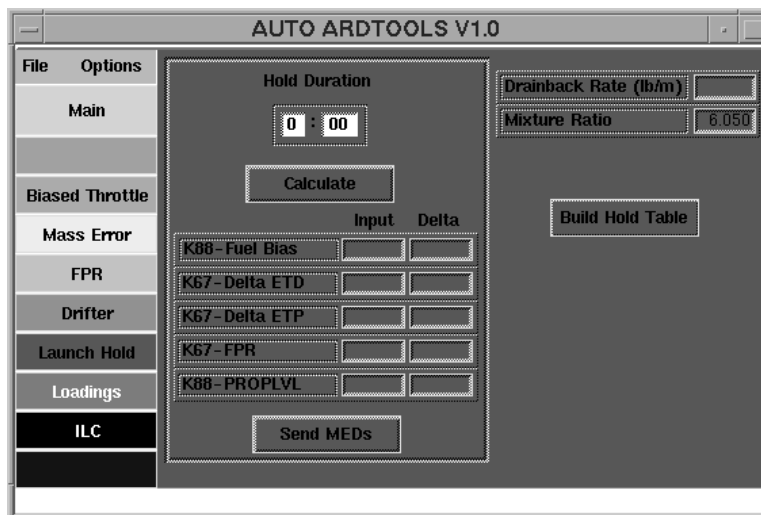


Figure 5-6. Launch Hold View

5.1.1.7 Loadings

ARD Support uses the loadings function to compute certain parameters for the MCC ARD. It is used on launch day to re-compute six ARD parameters based on predicted LOX and LH2 loading data from KSC at about L-3 hours. ARDTools computes the new quantities and calculates the deltas from the current traj server values. It can also then be used to ship the data to the server via a double click of the "Send MED" button. Figure 5-8 shows the details of the loadings page. The loadings input file used by ARDTools is auto-generated by an IPS application called AT Data. The data required to build this file is usually available by L-3 days.

The actual ET loadings should arrive on a hardcopy at about L-2:35 hours on DOL from the Ascent Support team. The Ascent Support Team collects temperature, pressure, and other data from the KSC ET loading process and runs it through a program called PLOAD to predict the amounts of LH2 and LOX loaded at end of replenish (EOR). Make sure there has been plenty of stable replenish time. See Section 4.1.3.3 for further details. Enter the EOR loadings and press "Calculate". ARDTools will calculate the ARD database updates required by the predicted loadings. The user can then print the updated Loadings page and the Launch Hold Table as desired. The updated parameters can be shipped to the server by double clicking the Send MEDs button.

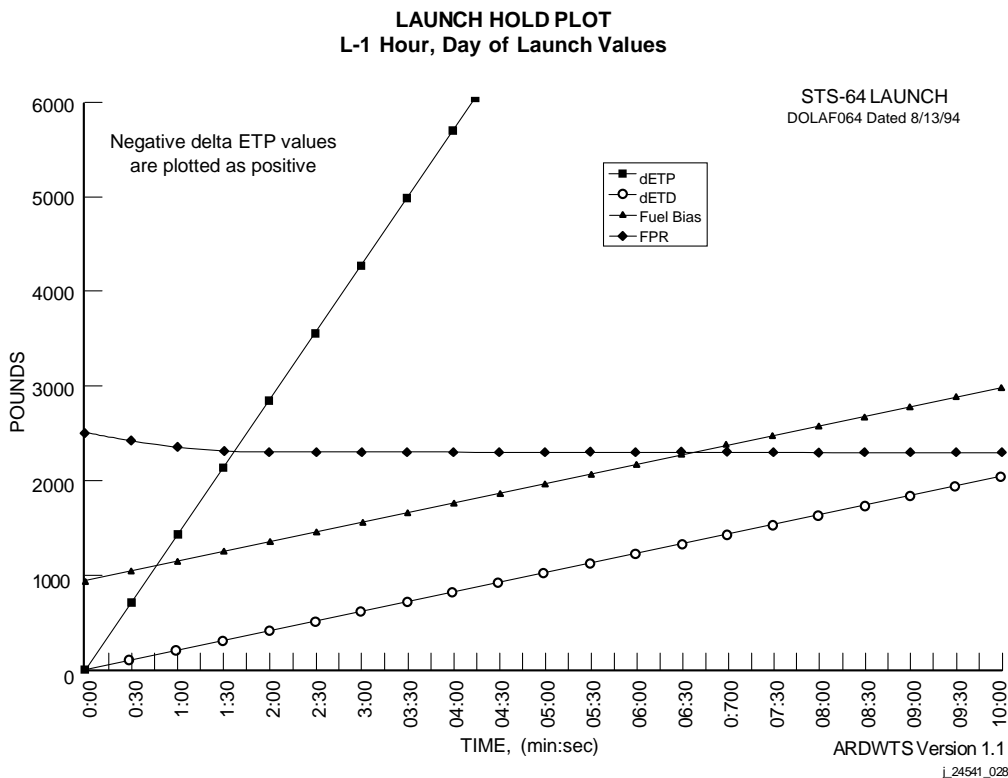


Figure 5-7. L-1 hr launch hold plot

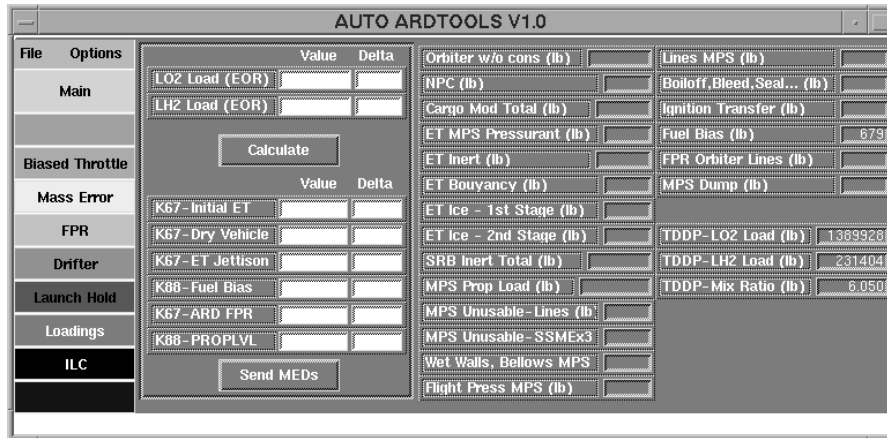


Figure 5-8. Loadings View

5.1.1.8 ILC

The Integrated Load Checkout (ILC) function is used to synchronize the performance between the ARD and the SMS. Figure 5-9 shows the ILC view. The “Delta Mass 1”, 2, and 3 buttons are pressed to capture delta TMECOs and their appropriate mass biases. These biases are averaged and applied to the SMS for the second run. After the engine is failed on the second run, the predicted underspeed is entered and the real underspeed is entered at MECO. The second run will provide the breakdown of the mass delta between fuel, Lox and dry weight. The calculations employed by the ILC function are shown in Section 3.3.4.

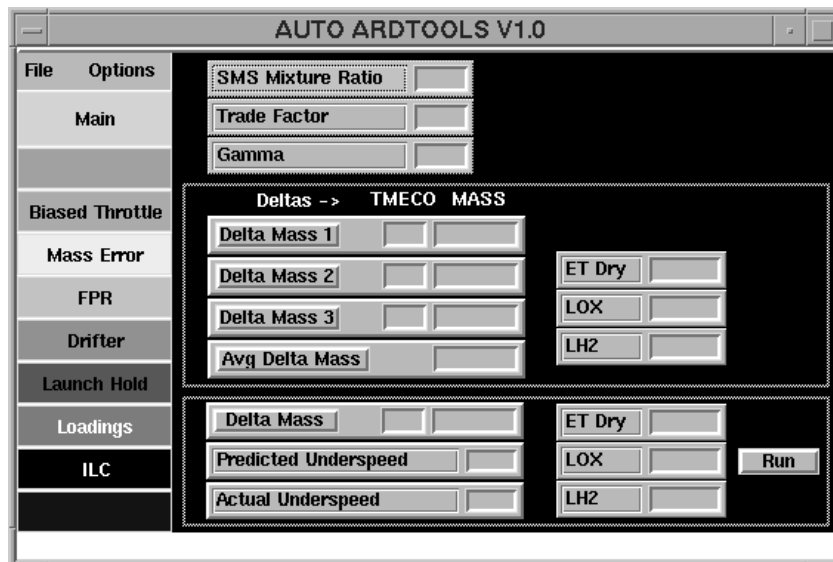


Figure 5-9. ILC View

5.1.2 ARDWTS

This section was incorporated into Section 5.1.1 with the release of the workstation-based ARDTools.

5.1.3 EDTE Application

This section is no longer applicable.

Figure 5-10. EDTE display (Deleted)

5.1.4 ARD/AME/DAE Database Verification Tool (DBCHEK)

The ARD/AME/DAE Database Verification Tool (AADDVT) or “database checker” (DBCHEK) (Figure 5-11) provides an automated means of verifying the over 5800 parameters required to initialize the ARD, AME, and DAE processors. DBCHEK makes use of an advanced spreadsheet application called Xess designed specifically for the X Windows environment that provides flexible and powerful C programming interfaces.

The DBCHEK is used initially at the ILC, and then prior to each simulation, confidence run and DOL operation. Specific procedures for each activity will be discussed here, but the pre-launch preparations are in the checklists in Appendix D. The DBCHEK identifies all miscompares between the chosen reference and current data.

Miscompares are items where the two values are not the same, and are highlighted in red. Placeholders are fields that for a particular flight contain no data or should be ignored. Rather than identify them as erroneous miscompares, they are flagged as placeholders and highlighted in yellow. There is an Ops Note for DBCHEK. It and all other DBCHEK documentation (including the Users Guide) can be found at

S:\...\ARDSTUFF\DOCS\Cert DB Verif Tool

	A	B	C	D	E	F	G	H	
1	ARD/AME/DAE DATABASE VERIFICATION TOOL V1.6								
2									
3	Parameters in Database	5040			Number of Place Holders	1487			
4	Number of Miscompares	2389			File: loef_1_51.6B_K_place_holders				
5									
6	Aug 10, 1999	Jun 21, 2000							
7	test	13:07:17							
8	Reference Value	Current Value	Difference	MSG	Units	MSK	MED	PROC	Description
327	0	0	0		deg	555		ZDEPD	Atmosphere Table 8: First prebank (0-180 d
328	8	8	0		nd	555		ZDEPD	Atmosphere Table 8: N-cycle
329	90	90	1.421085e-14		deg	555		ZDEPD	Atmosphere Table 8: Second prebank (0-18
330	8	8	0		nd	555		ZDEPD	Atmosphere Table 8: N-cycle
331	AT9	AT9	0		txt	555		ENTRY	Atmosphere Table 9: Atmosphere profile inc
332	DN-W57AS-S	DN-W57AS-S	0		txt	555		ENTRY	Atmosphere Table 9: Atmosphere profile de
333	0	0	0		deg	555		ZDEPD	Atmosphere Table 9: First prebank (0-180 d
334	8	8	0		nd	555		ZDEPD	Atmosphere Table 9: N-cycle
335	90	90	1.421085e-14		deg	555		ZDEPD	Atmosphere Table 9: Second prebank (0-18
336	8	8	0		nd	555		ZDEPD	Atmosphere Table 9: N-cycle
337	28	27.9	0.1	ERR!	fps2	555		SYSP	Canned value of D23C (Entry Guidance)
338	KSC	KSC	0		txt	562	K92	ARD	Slot 1: RTL5 AREA ID (3 char)
339			0		txt	562	K92	ARD	Slot 2: RTL5 AREA ID (3 char)
340			0		txt	562	K92	ARD	Slot 3: RTL5 AREA ID (3 char)

Figure 5-11. DBCHEK Screen

The DBCHEK is driven by a menu bar that allows the user to perform the following:

- Retrieve data from: the TRS, saved sheets, or reference data from a text file.
- Save the latest retrieved data as the reference set on the sheet.
- Save the sheet or delete previously saved sheets.
- Print a range of data or the complete sheet.
- Search for a specified value or string.
- Go to the top or bottom of the sheet or go to a specified cell on the sheet.
- Assign the correct place holder file.
- Edit place holder files.

5.1.4.1 ILC/Flight Cycle Checkout Preparations

A few days prior to the ILC, ARD Support should transfer the DPS product reference files and placeholder files from the FADS system to the OPS platform. Specific procedures for the DPS and how to complete the file transfer are given in Section 5.2.4. The product and placeholder files are placed in the flight's DBCHEK directories. This must be completed in order for the next section to work. The print files are not moved to

the OPS but are for printing only. These can be placed in the Console Data Book for reference.

5.1.4.2 At the ILC/Flight Cycle Checkout

At the ILC, the DBCHEK is used first to check the cold TRS data against the Flight Design products to verify that the TRS load was built correctly. Then DYNAMICS loads the Group MEDs and system parameters and DBCHEK is used to verify that the only changes from the products are from init pads that ARD Support submitted.

There are differences that are encountered due simply to differences in the way the TRS and products display data, plus some unit conversions. All of these have been identified and documented in the ILC Checklist in Appendix D.6. This checklist identifies all the parameters that should change, so make sure those rows identified do in fact show up as miscompares instead of just reviewing all the miscompares.

The checkout of all these databases can take up to 1.5 hours to complete, so work with TAO and DYNAMICS to be there as soon as the TRS is up. Once the DBCHEK verification is complete, there is more to do to prepare for the ILC.

5.1.4.2.1 Cold TRS Procedures

ARD Support should run DBCHEK to verify the product data was transferred correctly to the TRS and save the reference data into the DBCHEK application. This is done with a "cold" TRS before DYNAMICS loads any Group MEDs or system parameters. Specific procedures are in the Ascent ILC Checklist in Appendix D.6.

5.1.4.2.2 After the Group MEDs & System Parameters are Loaded

Once cold TRS data checkout is complete, tell FDO that you are "go" to load the Group MEDs and system parameters. Once all are loaded, ARD Support should use DBCHEK and verify that the only changes made were due to the init pads submitted. Specific procedures are in the Ascent ILC Checklist in Appendix D.6.

5.1.4.3 Operation for Simulations

Before each sim, ARD Support is responsible for checking the TRS database and notifying TRAJ of any differences. The DBCHEK makes this much easier. The Base-Ref (cold TRS or ILC) or Local-Ref (checkpoints) files are used as a comparison to current data. Miscompares are flagged for quick identification. Then once TRAJ is happy with the data and the TRS is ready to take a checkpoint, ARD Support should also save a copy of the data as a checkpoint file for use either prior to each run or for future sims. Sim procedures are as follows:

- 1) Bring up DBCHEK.
- 2) Retrieve a reference file from either Base_REFs (for ILC files), or Local_REFs (for checkpoint files). DYNAMICS will know if the TRS is up from a checkpoint.

- a) NOTE: Even if you are up from checkpoint, it is a better idea to use the ILC checkpoint whenever possible. Unless there are strange circumstances with the load, the number of mismatches when compared to the ILC file should be small (<20), and the mismatches that do show up should be the “standard” ones you’ll see on a regular basis. Although this is a bit more work, it avoids propagation of a missed erroneous mismatch in an earlier checkpoint.
- 3) Select the appropriate placeholder file from the “Placeholder” pull down menu.
- 4) Get current data.
- 5) Review mismatches with TRAJ.
- 6) Once satisfied with the data (and after any targeting and/or mass properties changes), Save as Ref using the file name format: CP_MMDDYY (i.e. CP_042800).

5.1.4.4 Launch Preparations

The DBCHEK obviously is used for pre-launch and launch operations. Its use is similar to the pre-ILC activities and sim activities. The specifics are detailed in the Appendix D checklists for launch preparations.

5.2 OFF-CONSOLE TOOLS

The Ascent/Entry Trainer System is one of the primary off-console analysis tools. It hosts the STAMPS ascent trajectory simulation, Bench ARD, Bench AME, DAE, ETIP, and other processors. Other off-console tools are the Ascent Event Summary (ASEV) script and the DPS script. Additionally, the office PC contains exact copies of the on-console PC applications ARDTools and ARDWTS. Programs not previously discussed are covered here.

5.2.1 ASCENT/ENTRY TRAINER

The purpose of the Ascent/Entry Trainer is to provide the Flight Controllers in DM with an off-line, realistic console procedures training tool. The Trainer can be run standalone or with multiple users tied into one session. The STAMPS application is the engine that drives the Trainer. It models the Orbiter systems, the onboard navigation state, and the environment. STAMPS only provides single string nav and PASS modeling. All BFS data displayed is just a repeat of the equivalent PASS data. Data from several TRS processors is required to drive the FDO and GPO console displays; therefore, customized versions of these processors are part of the Trainer.

Currently, the trainer project is in development. For details on this project, contact the DM46 Group Lead for the correct point of contact. Documentation for the project, such as the Ascent/Entry Trainer User's Guide can be found in this directory:

S:\...\DM46\Training\Trainer

5.2.2 GOFPR

This section is no longer applicable.

Figure 5-12. GOFPR menu (Deleted)

Figure 5-13. Mode 1 (Deleted)

Figure 5-14. Mode 2 (Deleted)

5.2.3 Ascent Events Summary Script (ASEV)

The ASEV script is an automation of the data retrieval and ordering required to build the ASEV. It is described in Section 2.2.1. It is only valid for the standard flight design cycles: OCF, ENG, & FLT. Any updates for launch support must be done manually by ARD Support by editing the Microsoft Word file.

The ASEV script is used in two fashions. It is run as a "cron" job that polls the Flight Design product directory on a daily basis and when it finds all the necessary products it generates the product and sends it to all ARD Support personnel via e-mail to their PC e-mail address. To be added to the distribution, contact Roger Rojas. It can also be run manually as needed. Additional information can be found in the ASEV Users Guide, UG-ASEV-1.0DA, found in

S:\...\ARDSTUFF\DOCS\Cert ASEV Script

The ASEV Script can only run when all the necessary products are available. Additionally, the Script only runs automatically with the standard files. If a product is redelivered with the same name, the script is re-run. If a product is redelivered as a "special" redelivery and its name is changed, then the script does not run correctly. For example, the redelivery of "asct17a.trajsumm.asc" would be called "ascts.asct17a.trajsumm.asc". In this case, the Script owner would need to be notified so the script could be edited and re-run to pick up the correct file. Trying to include all the special redelivery cases in the script would have made it much too complicated, so those cases will have to be handled individually.

5.2.4 DBCHEK Product Script (DPS)

The DPS is a script written by Roger Rojas in the fall of 1999 to enhance the capabilities of DBCHEK. The purpose of DPS is to copy the data needed by DBCHEK from the various Flight Design products, and list them in the required order. It is run on the Integrated Planning System (IPS)/FADS system.

The DPS generates files that contain the product data given a flight configuration. It also generates the associated placeholder file and a print file. The print files are not moved to the OPS platform but are for printing only. These can be placed in the Console Data Book for easy reference.

All the DPS documentation (requirements, test plans, user's guide, etc.) can be found in the following directory:

S:\...\ARDSTUFF\DOCS\Cert DPS Script

Like the ASEV, the DPS is used in two fashions. It is run as a "cron" job that polls the Flight Design product directory on a periodic basis and when it finds all the necessary products it is run and sends a notification to all ARD Support personnel. It can also be run manually if needed. (See the User's Guide.)

The DPS can only run when all the necessary products are available. The DPS uses the prop02.fopchart.asc product to determine the launch pad and inclination and data22b to extract the rest of the data. If a product is redelivered with the same name, the script is re-run. However, if a product is redelivered as a "special" delivery and its name is changed, then the script does not pick up the new product and is not run correctly. In this case, the Script owner would need to be notified so the script's product input file could be edited and re-run to pick up the correct file.

5.2.4.1 Product Data

The DPS files should be generated well prior to the ILC. However, they reside on the IPS/FADS platform and need to be transferred to the OPS platform. Approximately a week prior to the ILC, the GA should set up the mission configuration and the DBCHEK file structure.

When that is done, then ARD Support should copy the product and place holder files to DBCHEK's MCC/OPS directories (See Section 5.2.5.2, and the Appendix D Checklists). The target home directory is:

`/users/fdo/Data/SSPXXX/Ard1.0/AADDVT/`

where XXX is the three-digit flight number.

- Product files (called `<flt><cyc>_<rev>_<inc><pad>.dbchek`) go into the `PRODUCT_REFERENCES` directory.
- The place holder files (called `<flt><cyc>_<inc><pad>.place_holder`) go into the `PLACE HOLDER` directory. It may be necessary to edit the placeholder file. This can be done in DBCHEK (see Section 5.1.4.2.1).
- DO NOT copy the files ending in `“.print_nc”` into OPS. These are the print files and trying to open them in the Xess environment will bomb DBCHEK. Print the file (in FADS) with the following command: `enscript -G -2 -fCourier8 - Pyour_printer filename`.

5.2.5 File Transfer Procedures

To conduct the ARD Support activities, data is generated on various platforms, but often needs to be transferred to a different platform for another tool. This section describes the most common file transfer methods.

5.2.5.1 FADS to PC

Transfer the file from FADS to the PC via your e-mail account using one of two methods:

- If you have access to the PC Drop Box: copy the file to the following location where the `“.”` at the end keeps the same file name (e.g. `cp 099_asev /fads/msn/gds/gen_common/topo/pcdrop/jpdoe/.):`

`/fads/msn/gds/gen_common/topo/pcdrop/<your e-mail id>/.`

- If you don't have access to the PC Drop Box, transfer the file using the following command (e.g. `uuencode testfile.asc test_file_1.asc | mailx john.p.doe@nasa.gov):`

`uuencode <fads filename> <PC filename> | mailx <full e-mail id>`

5.2.5.2 FADS to MCC/OPS Platform

This assumes the user is in the MPSR and wants to access the IPS/FADS files. This file transfer is done by:

- 1) Perform the standard logon on the MCC workstation/OPS platform.

- 2) In your home directory, go to the directory you want the files/products to go into. If necessary, create a temporary directory. Then go into that directory. (This is a good thing to do when transferring DPS products. Otherwise you might get file permission errors, etc.)
- 3) At the command line, type "ftp 130.196.75.1". When prompted, enter your IPS/FADS id and password. This remotely logs you into FADS.
- 4) Maneuver to the FADS location where the desired files are.
- 5) Type "dir" to see the directory contents.
- 6) Transfer the data files to your OPS directory by entering the following command "get filename". This will get (copy) the file from FADS to OPS. (Another useful command is "put filename". This moves files the other way --- from OPS to FADS.)
- 7) When all the files have been transferred, enter "quit". This returns you to OPS.
- 8) Now, move the files from your directory to the target directories if necessary.

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6 ASCENT TOPICS

This section discusses some additional ascent-related topics with which the ARD Support should be familiar. Section 6.10 is written in a question and answer style and is very informative regarding realtime ARD operations.

6.1 FLIGHT PERFORMANCE RESERVE

6.1.1 FPR 101

This “FPR 101” section is intended to serve as an informal, low detail, introduction to the basic concepts of FPR. The target audience is the novice ARD Support or those who just want to understand the principles and terminology. This section can be, and has been, broken out for use in other documents. The ideas presented here are developed further in subsequent sections.

Just what is FPR? Well, in four pages or less we will try to explain Flight Performance Reserve and what it means to the Ascent world. FPR is sometimes used interchangeably with the quantity FPR + Fuel Bias. They are not the same thing, but many times the distinction is not made. Here we will refer to FPR + Fuel Bias as “Total Reserves”. We will discuss Fuel Bias a little later. FPR is basically insurance. It is an extra amount of propellant (prop usage, both LOX and LH2 at the nominal MR of 6.05 to 1) carried to cover dispersions in ascent flight performance due to dispersions in a lot of things, either mechanical or environmental, such as ISP, thrust, inert weight, atmosphere, etc.

All these dispersions have an average value, and each average value, of course, has some error value associated with it. Think of it as a measure of the sloppiness of the data around the average. This is statistically known as the standard deviation or sigma (σ) level. For example, the average weight of 20 Cadillacs may be 5000 pounds; the plus or minus error that one would find when measuring any random Cadillac and comparing it to the average might be anywhere from +200 to -600 pounds. The plus or minus error range in which 95.44 percent of all the measured weights fall is called the 2σ level. Anyway, some folks determine what the 2σ dispersion levels are for all the different environmental and mechanical factors. Others determine what the effect on propellant consumption would be during an ascent. In fact, they do it for several types of profiles, nominal, TAL, and RTLS. They come up with 2σ dispersion levels of prop usage for any given 2σ off-nominal condition.

Another confusing point, best shown by example, is: A +2.3-second ISP dispersion may cause a +4000-lb increase in prop consumption, but a -2.3-second dispersion may only cause a -600-lb decrease in prop consumption. Point is, these prop consumptions are not necessarily symmetrical. But in the Ascent world, we are worried about the high prop consumption cases, because we want to size the FPR quantity to ensure that we always have enough prop onboard to cover the combination of 2σ bad/everything going wrong and using up more prop than would normally be required. But we do not want to make FPR bigger than necessary because the weight of it subtracts right out of payload

capacity, and that is what it is all about. So we build the 2σ FPR quantity according to the following equation:

$$FPR = \Sigma\mu + 2\sqrt{(\Sigma\sigma^2)}$$

where:

- μ = mean (average) value of prop consumption,
- σ = standard deviation of prop consumption, and
- 2 is the desired sigma protection level in this case.

Notice we have added all the averages of the prop consumption dispersions, and to be extra safe, we have added (via the root sum square (RSS) method) all the 2σ dispersion levels, thereby protecting against the chance of a combined 2σ bad day! (The RSS method is the proper way to realistically combine sigma levels. We do not stack 2σ on 2σ by directly adding them.) But there is one small complication. There are two types of dispersions, those that affect the prop consumption in a 6 to 1 manner and those that do not. For instance, inert weight dispersions affect prop consumption as expected, six parts LOX to one part LH2. The overall MR through the system is not affected. Something like an MR dispersion or ET loading dispersion will affect the prop usage more on one side (LOX or LH2) than the other! The overall MR of the total system will be affected. So we split our μ 's and σ 's into two types, as follows:

$$FPR = \Sigma\mu_{6to1} + \Sigma\mu_{NON6to1} + 2\sqrt{(\Sigma\sigma_{6to1}^2 + \Sigma\sigma_{NON6to1}^2)}$$

You are probably wondering how much prop we are talking about. Well, it comes to about 2600 pounds for 2σ (second-stage ARD) (a whopping 4000 lb 3σ on the real vehicle). Plus, holding back that prop affects ARD computations. The more FPR you hold back, the later in time your abort boundaries are achieved; e.g., TAL exposure. So, we can see from these two things alone why FPR is so important.

Let us look at the equation and Figure 6-1. (We will drop the Σ notation from here on.) We have not plotted μ_{6to1} or σ_{6to1} since they are basically constants and do not depend on MR. But we have plotted $\mu_{NON6to1}$ and $\sigma_{NON6to1}$, and you can see that they do depend on MR. Notice that the average values, μ (mu), are symmetrically distributed about the zero Fuel Bias point. This makes sense, since with a proper balance of LOX and LH2, these NON 6 to 1 dispersions will have their maximum combined impact. So, we understand three of the four parts to our equation. The last part, $\sigma_{NON6to1}$, is the driver of it all. The equation for this term plots as shown in the Figure. You can clearly see the dependence on MR. From our knowledge of the terms, we now see the logical shape of the FPR-required curve; it is mainly shaped by $\sigma_{NON6to1}$. If you measure the slopes on each side of the zero Fuel Bias point, you will see that their ratio is roughly 6 to 1.

MR 6.0391, Fuel Bias 944, FPR = 3200, Total Reserves = 4144

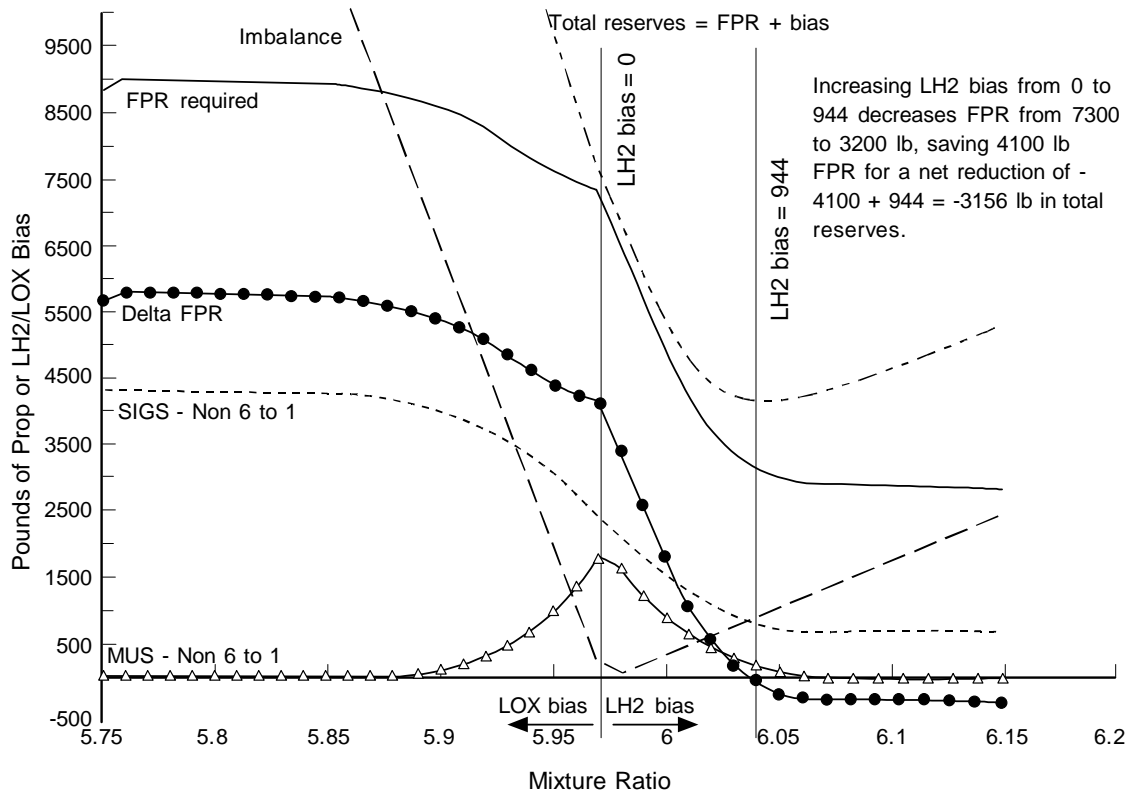


Figure 6-1. Plot of FPR parameters for standard case

The reason the FPR-required curve peaks out on either end is because you have met your coverage requirement. That amount of FPR covers the 2σ requirement, regardless of how much your MR shifts to high or low. As you look at the graph, you will notice the LOX/LH2 bias line, shaped like a reversed check mark. Let us call it the "Imbalance line". The computation of σ_{NON6to1} depends on the amount of Imbalance; therefore, so does FPR. How do we get an Imbalance? By a change in the overall MR. At low MR, there is not enough LOX being burned; the unburned (imbalance) amount builds up in the ET as unusable and really kills performance since you cannot burn it for ΔV , and yet you have to carry it along as dead weight. And it is six times worse than in high MR case, where the relatively light fuel is building up because it cannot be burned. This loss of usable prop is bad enough, but look at what it does to the FPR requirement! You have to "set aside" 5800 pounds of usable prop into unusable prop in the ARD just to keep your 2σ protection! In realtime, the FDO adjusts the ARD and protects his calls appropriately. In fact, part of ARD Support's job is to use the ΔFPR curve in Figure 6-1 to properly configure the ARD and hold back the right amount of FPR so the boundary calls are accurate. ΔFPR is the amount to add to or subtract from the ARD original nominal 2σ FPR to currently maintain the required 2σ FPR level.

You have seen how the changing MR changes the Imbalance, which changes σ_{NON6to1} , which changes FPR, which changes ΔFPR in the ARD, which affects performance/abort boundary calls. The only question left is, "Why is there a Fuel Bias at the nominal MR

of 6.05 to 1, and why do we do that?" It is not to prevent Low Level LH2 cutoff. That is why we have Low Level sensors and shutdown logic. The real reason is to maximize performance by minimizing FPR + Fuel Bias! ARDs try to be consistent and call the sum of FPR + Fuel Bias "Total Reserves," but some people call it FPR, which can be confusing.

Let us look at the chart (Figure 6-1). If there were no Fuel Bias, the chart tells us that FPR required would be about 7300 lb. Our Total Reserves at this point are $7300 + 0 = 7300$ lb. But if we add increasing amounts of Fuel, look what happens--the FPR required drops more rapidly than the increase in the Fuel Bias (Imbalance line). At this point, it is the $\sigma_{NON6to1}$ term, controlling the show. The Total Reserves line drops too, but only to a point where the increasing Fuel Bias begins to hurt you. Then, the increasing Fuel Bias "overpowers" the effect of the $\sigma_{NON6to1}$ term in the composition of Total Reserves. You can see that increasing from Fuel Bias = 0 to 944 lb has saved $7300 - 3200 = 4100$ lb of FPR, for a combined net savings of $-4100 + 944 = 3156$ pounds! It is that minimum point on the Total Reserves line that sets the Fuel Bias. It is that simple, and that is the real-reason for Fuel Biasing. As a side effect, of course, you have extra fuel protecting against a Low Level LH2 cutoff, but only if you have a nominal MR day.

On launch day, when the actual ET loadings come into MCC, the ARD personnel compute what the DOL Fuel Bias is based on how well the LOX and LH2 tanks were filled. They update the ARD with this for the best accuracy possible. If you set the Fuel Bias to the left of the minimum point on the Total Reserves curve, then you can actually gain performance during LOX drainback (from T-4:55 to lift-off), since your Fuel Bias would increase, driving the Total Reserves to their minimum point. Then Total Reserves would begin to increase. We do not plan things this way, but the ARD personnel also make a plot of this on launch day so we can determine how a hold will affect FPR and Fuel Bias, which affects performance.

If you have a nominal day, you have carried 3200 pounds prop + 944 pounds of Fuel = 4144 pounds of Total Reserves along for nothing; you just threw it away at ET SEP. So, we have touched on the topics of environmental and mechanical dispersions, prop usage dispersions, sigma levels, the FPR equation, 6 to 1 and NON 6 to 1 terms, the shape of the FPR curve, the importance of FPR, how MR affects FPR required, how FPR affects boundary times, the true origin of Fuel Bias, and Fuel Bias changes during a launch hold.

6.1.2 General

The FPR is an amount of usable ET propellant that is considered unusable when determining mode boundaries and vehicle capability. This is necessary to provide for a sufficiently high level of confidence in determining performance-related capabilities. The FPR is reserved to protect for the effects of systems and trajectory dispersions.

Every computer model of orbiter systems and components has limitations in accuracy. This includes engine parameters, mass properties, and the environment. Each individual dispersion has an effect on propellant consumption. The changes in propellant consumption due to a dispersion are not always repeatable; however, a

mean and standard deviation can be assigned for each individual dispersion. By combining the propellant consumption statistics from several dispersion sources, the FPR can be directly computed.

FPR is defined as the sum of the means (μ) plus the desired level of protection times the RSS of the standard deviations (σ) of all propellant consumptions due to the relevant dispersions. In equation form

$$\text{FPR} = \sum\mu + N\sqrt{(\sum\sigma^2)}$$

where:

- n is the desired sigma protection level.

A sigma_level of N provides an N sigma level of confidence in the mode boundary. This level of protection is mission mode dependent. Nominal performance is defined as 3σ , as is last RTLS capability. Most other boundaries (TAL and press to ATO (PTA)/press to MECO (PTM)) use a 2σ protection level. There are some boundaries made at a zero sigma level of protection. This essentially gives the boundary call a fifty-fifty chance of being accurate. The ARD, as we shall see later, is "loaded" to protect 2σ . We make boundary calls at other σ levels by using the ARD biases. See Section 6.11 for a description of the biases.

The individual dispersions can be grouped into two categories, non-6:1 dispersions (denoted by a subscript_s) and 6:1 dispersions (denoted by a subscript_xc). Means and standard deviations can be assigned to propellant usage dispersions for each of these categories. Taking this into account, the FPR equation can be rewritten as

$$\text{FPR} = \sum\mu_s + \sum\mu_{xc} + N\sqrt{(\sum\sigma_s^2 + \sum\sigma_{xc}^2)}$$

The two categories are discussed in Sections 6.1.4 and 6.1.6. The statistical derivation of the equations is documented in the memo "Documentation of Ascent Flight Performance Reserve Methods," RID/J. Wolfe, Aug. 12, 1980.

6.1.3 Preflight FPR vs. ARD FPR

Preflight and realtime (ARD) FPR are computed differently. One of the reasons for this is the differences in available information when each is computed. The preflight FPR has no information on actual trajectory conditions and must protect for all potential dispersions. The ARD FPR has first-stage performance effects visible in the state vector; therefore, it does not have to protect for them. In general the ARD FPR is not as large as the preflight FPR because some of the major dispersions (e.g., SRB performance, first-stage winds, aero and atmosphere dispersions, and GN&C performance) are visible in the state vector. Secondly, preflight FPR is computed to 3σ , whereas ARD FPR is computed to 2σ . This results in earlier boundaries from the ARD for identical cases.

The final difference is the statistical approach taken in the computations. Preflight FPR is computed to ensure that the usable residual propellant at MECO is greater than or

equal to zero. This FPR is used by the flight design community to determine no comm mode boundaries and performance margins. Performance margin data is available in the TDDP. The ARD FPR is computed to ensure that the ARD-computed ΔV available is greater than or equal to the ΔV required to achieve desired targets. This FPR is used only by the ARD and affects the realtime mode boundaries and performance calls.

In reality, the realtime FPR varies with MET. Currently, the ARD is capable of handling only one FPR value. This FPR is computed preflight for the PTA time point. A future proposed enhancement will have the FPR computed every ARD cycle. The FPR protection, expressed as a ΔV , is then applied to all mode boundaries, resulting in a small error for boundaries other than PTA. Some of these errors are corrected with biases. A bias is applied to the FPR ΔV , which, in effect, correctly adjusts the mode boundary time. The ARD FPR must protect for unknowns at the computed time point. The most significant of the unknowns is propellant weight.

6.1.4 Non-6:1 Dispersions

Non-6:1 dispersions affect propellant residuals at MECO in a non-6:1 MR manner. For example, assume that a trajectory with no dispersions results in residuals of 600 lb of LOX and 100 lb of LH2 at MECO. The same trajectory with a single dispersion (e.g., the LH2 loading is 50 lb less) may result in residuals of 500 lb of LOX and 80 lb of LH2. Since the change in the residuals is not affected in a 6-to-1 manner (ΔLOX residual = 100, $\Delta LH2$ residuals = 20; or 5:1), the individual dispersion is classified as a “non-6-to-1” dispersion. The following five dispersions are in this category:

- LOX loading uncertainty
- LH2 loading uncertainty
- LOX vapor residual uncertainty
- LH2 vapor residual uncertainty
- MR uncertainties

6.1.5 ET Loading and Mixture Ratio

ET loading and MR dispersions are handled the same for preflight and ARD FPR. The loading uncertainty is a physical limitation. Because of the large quantities involved (approximately 1.5 million pounds of liquid propellant) and the physical limitations of the sensing hardware, the loadings (both LOX and LH2) are known to some value, plus or minus a certain amount. A standard deviation can be assigned to the loading uncertainties.

The vapor residual uncertainty is due to two factors. One is the uncertainties in vapor from boiloff and evaporation. The other is the uncertainty in the exact repressurant flow from the SSMEs. A certain amount of the propellant is bled off from the low pressure pumps and routed to the ET to maintain acceptable ullage pressure levels.

The MR uncertainty arises solely because of physical limitations in the controlling hardware and flight conditions. The propellant is being forced through valves (of limited tolerances) that control P_c . The P_c is determined by P_c sensors that are of limited accuracy. The actual flight conditions in the engine MR are typically slightly different from what is expected.

From the means and standard deviations of the components, the overall non-6:1 mean and standard deviation can be directly computed. These means and standard deviations are flight-derived numbers and are assumed constant from flight to flight. As more flight data points are accumulated, the flight-derived numbers will be updated by the Downey performance group (via the AFSIG), if required.

Effect of Fuel Bias---

The fuel bias is the additional amount of LH2 that, if the propellant were burned at the exact planned MR, would be left over as unusable. The fuel bias is chosen to maximize payload capability. The mean and standard deviation of the non-6:1 dispersions are a function of the fuel bias. Figure 6-2 shows how the non-6:1 mean and standard deviation vary with fuel bias.

A mean and standard deviation can also be assigned to the 6:1 dispersions. These are not a function of Fuel Bias. For simplicity's sake, assume that μ_{xc} and σ_{xc} are zero. The FPR equation becomes

$$FPR = \sum \mu_s + N\sqrt{(\sum \sigma_s^2)}$$

Since both μ_s and σ_s are functions of the Fuel Bias, the FPR is a function of Fuel Bias. The FPR and the Fuel Bias are both negative impacts to performance, and it is desirable to minimize them. Figure 6-3 is a plot of (FPR + Fuel Bias) vs. Fuel Bias. The minimum point represents the maximum payload capability. This is the Fuel Bias that is selected for this flight. This proves that the Fuel Bias is statistically derived and does NOT take into account the systems desire to protect a low-level LH2 depletion situation. However, as an added benefit, this Fuel Bias does provide sufficiently low probability of a fuel depletion cutoff.

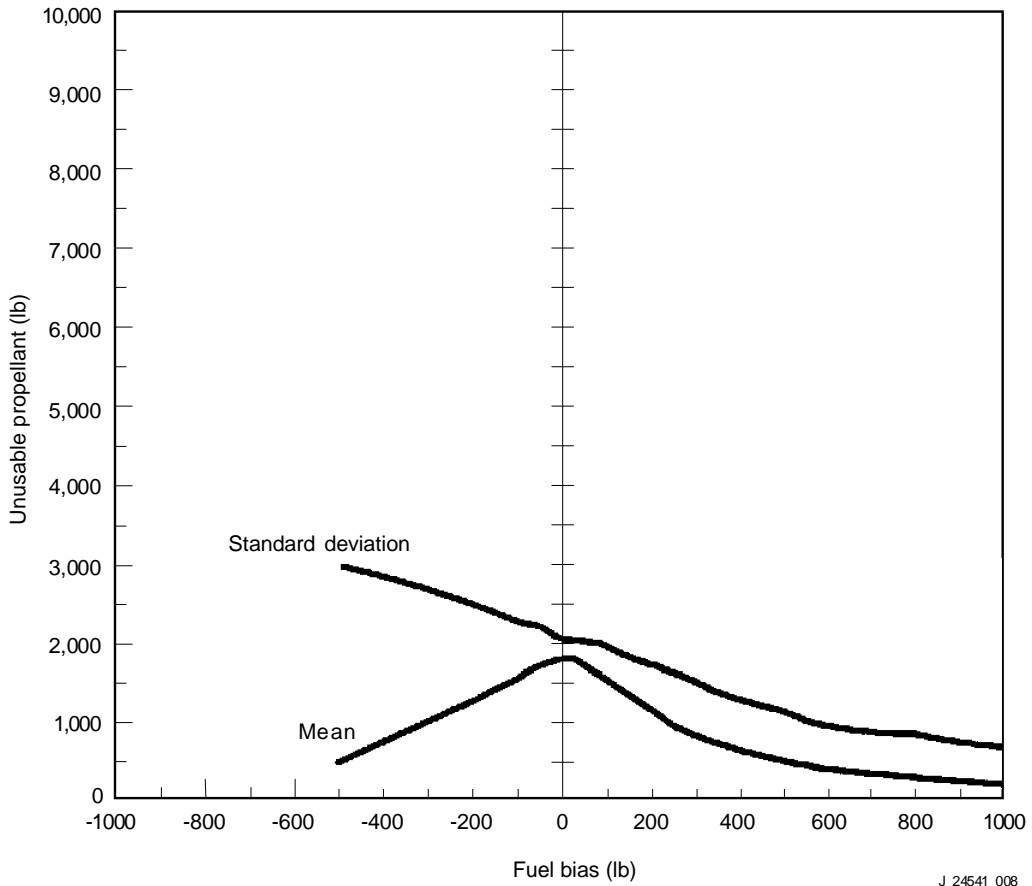


Figure 6-2. Non-6:1 FPR contribution

J_24541_008

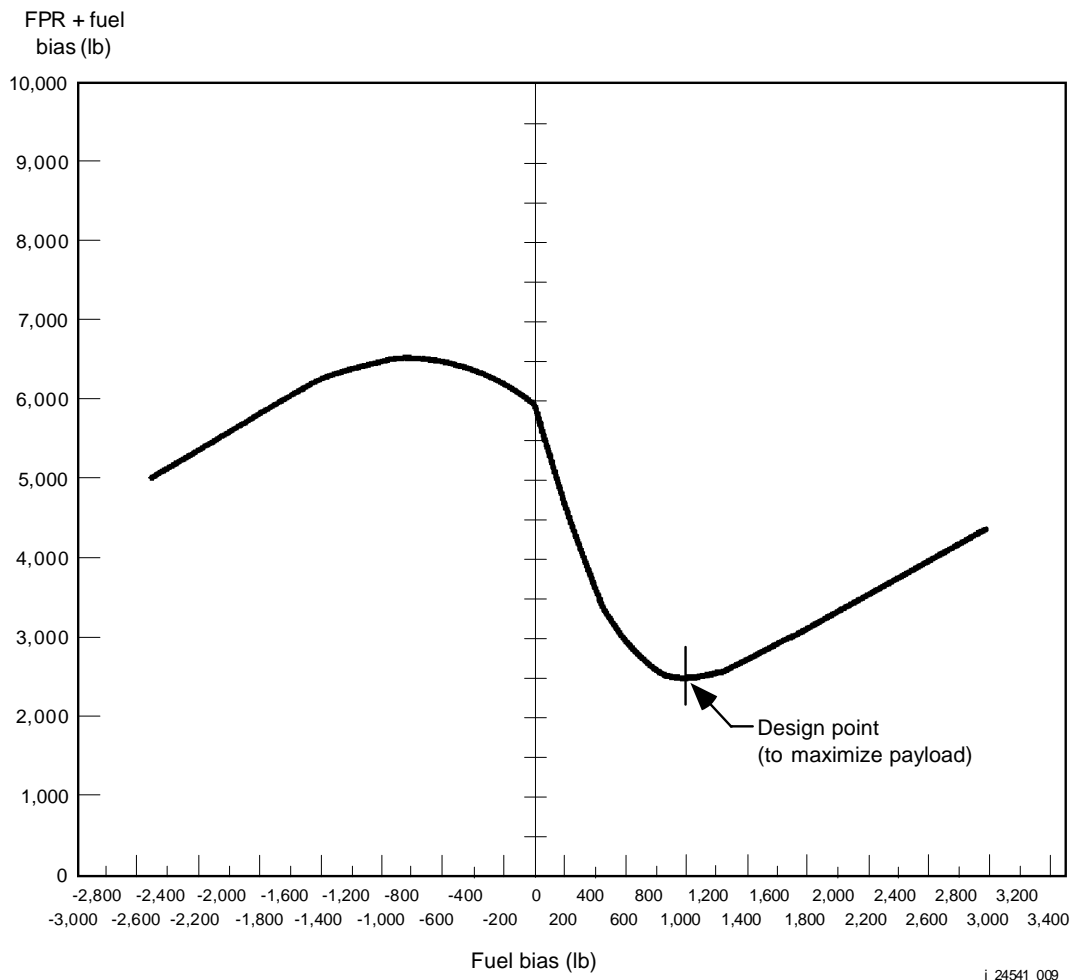


Figure 6-3. Plot of FPR + fuel bias vs. fuel bias

6.1.6 6:1 Dispersions

The 6:1 dispersions affect the propellant residuals at MECO in a 6:1 MR manner. For example, compare the initial trajectory of the previous example (residuals of 600 lb of LOX and 100 lb of LH2 at MECO) with the same trajectory considering a single dispersion (e.g., vehicle weight increased by 15 lb). This dispersion results in residuals of 540 lb of LOX and 90 lb of LH2. Since the change in the residuals was effected in a 6-to-1 manner (Δ LOX residuals = 60, Δ LH2 residuals = 10; nominal MR for this example), the individual dispersion is classified as a 6-to-1 dispersion.

In the past, the specification (spec) and known uncertainty values for each individual dispersion were used to determine individual means and standard deviations. Starting with STS-27, flight-derived data was used to calculate uncertainties. Using data derived from flight experience yields more realistic values for individual uncertainties and standardizes FPR computations. There are many dispersions that fit into this category. The Downey FPR personnel have narrowed the number of 6:1 dispersions from about 30 down to 8. The eight include:

- SRB burnrate
- SRB ISP
- SRB thrust shape
- SSME thrust*
- SSME ISP*
- SSME climbout*
- Collector*
- Inert weight*

(*The ARD protects for these. Of the last three bulleted items the largest contributor is inert weight.)

Most of these dispersions are self-descriptive. The two that may require some explanation are SSME climbout and collector. SSME climbout is the tendency of the SSMEs to increase in thrust over the duration of the ascent profile. The increase in thrust is attributed to the heating of Pc sensors during ascent, which results in a loss of calibration and a gradual increase in thrust. The collector is the collective effect of all other dispersions that are too small to be individually accounted for.

6.1.7 SSME Thrust and ISP

The thrust and ISP errors are 6:1 dispersions that uniquely affect realtime FPR computation and, thus, the ARD. The major detrimental effect of both the ISP and thrust uncertainties is a mass flowrate (\dot{m}) error.

$$\text{Thrust} = \dot{m} * \text{ISP}$$

The flowrate error builds a mass error over time - the later into the ascent profile, the greater the uncertainty in the usable MPS. A pound of propellant near MECO is worth a lot more (ΔV -wise) than a pound of propellant earlier in second stage. The relationship between the two is called the trade factor and is a result of the rocket equation:

$$\text{Trade factor} = m (1 - e^{(-\Delta V / (g * \text{ISP}))})$$

Both of these effects, the increasing mass error and the propellant sensitivity, combine to cause the realtime FPR to drastically increase near MECO. Some constraints can be added to limit the growth but not eliminate it. This FPR growth is due to uncertainties in the ascent profile history.

There are also ascent profile uncertainties that occur in the future that must be protected. The future ISP error does have a small effect on the computed ΔV available. The future thrust error is even smaller than the ISP contribution. Both of these future errors are small when compared to other FPR contributors.

6.2 THRUST UPDATE REFERENCE MATERIAL

The reader should reference the background material in Sections 4.1.4.8.1, 4.1.4.8.2, and 4.1.4.8.3. This additional material is presented in its original form as references and to preserve the documents. Note that reference values may have changed over time. Make sure you are using the latest and greatest. Future PCNs to this section will combine all the information into a more conventional writeup.

When a mass discrepancy is detected between the vehicle and ARD, there is no infallible means to isolate the source. The weight difference could be due to inert error or propellant load. Furthermore, any flowrate differences integrated over time also result in a weight error in the propellant mass track, so thrust and ISP errors could also cause a mass error. Obviously, correcting a weight error blindly without having some idea of what is causing it is dangerous. For example, if the vehicle is 3000 lb heavy due to ice on the ET, then updating the ARD with +3000 lb Δ ET Propellant (ETP) would be nonconservative, since extra ΔV capability would be added to the ARD prop model, when, in fact, the vehicle capability is actually degraded by the extra inert weight. The ARD would be even more in error after such an update than if it had simply been left alone. So if a large TMECO and digital weight discrepancy is observed in second stage (with an associated trend in AM nominal MPROP channel), what do we do? The answer is to use flight history to determine the most likely source of the weight error and correct as much of the error as we can without being nonconservative.

Postflight reconstruction provides ascent dispersions data, which indicates the maximum likely error for each type of dispersion. An ARD run can be made with individual plus-or-minus 2σ dispersion on the vehicle side only to show how each dispersion affects the ARD.

Table 6-1. Dispersion vs. Trend ref: etldupdt.xls

Dispersion	+2 σ value	Trend in nom MPROP (2:30 to 3:30 MET)
SSME thrust	6387 lb cluster	+16.8 fps/min
SSME ISP	0.67 sec cluster	-2.6 fps/min
SSME MR	0.027 mru cluster	approx 0 fps/min
OV/ET inert wt	1501 lb	-3.2 fps/min
LOX load	2683 lb	-5.8 fps/min
LH2 load	510 lb	-1 fps/min

The table shows that thrust errors generate a more noticeable trend in the AM nominal ΔV margin than any other dispersion (per sigma). This fact can be used to isolate thrust errors from other dispersions. For example, if a trend of -10 fps is observed between

2:30 and 3:30 MET (when the margin slope is approximately linear with respect to dispersions), it could either be a combination of 2σ high ISP, 2σ heavy inert weight, and 2σ extra LOX onboard or it could be due to 1.2σ low thrust. Obviously the most likely scenario (statistically speaking) is low thrust (since the alternative requires less likely dispersions stacked together in the downward-trend direction, or alternately, an extremely unlikely 3.4σ LOX load error).

This is the concept behind the thrust update method, which converts trend in nominal ΔV margin into thrust error that is modeled in realtime. Accounting for thrust errors during ascent improves ARD abort boundary predictions significantly and allows a smaller FPR since thrust errors beyond a certain threshold can be detected and modeled. Of course, dispersions with less of a signature cannot be effectively identified, so full protection in the FPR must be provided for these.

Before converting nominal ΔV margin trend into thrust error, the possibility that non-thrust dispersions could be responsible for part (or all) of the trend must be considered. Just as performing a ΔETP update for an unknown weight error could be nonconservative (from the above example), performing a thrust update can be similarly wrong if certain other dispersions are present. For example, suppose the vehicle is 1500 lb heavy due to scale errors, and there are 500 lb extra LH2 due to inaccuracies in the PLOAD-reported load (note that these are “reasonable” errors from the above table; i.e., within 2σ probability). The combination of these two dispersions results in a downward trend in the nominal ΔV margin of -4 fps from 2:30 to 3:30 MET. This would also result in a noticeable TMECO discrepancy between the ARD and vehicle.

If a thrust update were allowed to correct for this trend, low thrust would be modeled in the ARD (about 103.9 percent on each SSME). The primary effect of this is to essentially add ΔV capability to the ARD since the mass track is given more gas (due to lower flowrate) than the ARD thought it had. This results in an increase in the ΔV margin and a reduction in the slope of the margin. A secondary effect is a slight degradation of performance due to reduced thrust efficiency, but this is more than offset by the gain in performance due to mass track recycling. So post-update, the ARD would believe the vehicle has more capability than it thought pre-update. This would be nonconservative since the vehicle actually has significantly degraded capability with the 1500 lb extra inert weight and 500 lb extra LH2 that is unusable (just more Fuel Bias). Thrust updates should not be performed for this case since it is nonconservative.

To solve this problem, a deadband was incorporated into the algorithm. This prevents updates from occurring for dispersions in which the correction in ΔV margin via the update would be in the wrong direction relative to actual vehicle performance. The only dispersions for which the thrust update method does not correct the margin in the proper direction are inert weight and LH2 load errors. All other dispersions (thrust, LOX load, and ISP errors) create margin signatures to which thrust updates respond correctly. This means the update adds ΔV when it has actually been added by the dispersion (e.g., thrust update for extra LOX onboard) or takes away ΔV when it has actually been taken away by the dispersion (e.g., high ISP). (Analysis has shown that ISP and LOX load errors generate margin trends that thrust updates can partially

correct. The update never adds or subtracts more propellant from the mass track than is actually added or subtracted due to the dispersion. Therefore, abort boundary accuracy is slightly improved by allowing thrust updates to correct for not only thrust errors but LOX load and ISP errors as well.) The deadband is determined by RSSing the margin signatures of inert weight and LH2 load errors (about 3.4 fps from 2:30-3:30 MET). Thrust updates are never performed for trends within the deadband, since it cannot be guaranteed that it is not inert weight or LH2 errors.

Furthermore, margin trends outside the deadband are corrected to the deadband only (not to a zero trend), since it cannot be guaranteed that inert weight or LH2 errors are not partially responsible for the observed trend.

Console procedures for manual thrust updates are as follows. At about 2:20 MET, notify TRAJ with the "IYs confirmed" call to go to telemetry for the selected source. This will provide extremely clean state vectors for the ARD to use (filter noise significantly degrades accuracy of margin trend evaluation). Note the nominal MPROP ΔV margin from the AM at 2:30. Coming up on 3:00 MET, TMECO for the ARD and vehicle should be fairly converged, so any difference above about 0.8 sec is sign of probable thrust error that will be beyond the deadband (unless there is a NAV problem). Prior to 3:30 MET, have TRAJ select telemetry again and snap the ΔV margin. If the trend is beyond the deadband, then a thrust update per the console chart should be performed.

TRAJ will call DYNAMICS with the throttle setting to be input in AM at 1:07 (after throttle bucket) with the adjust option, HM for the two active engines at current time. If required, a ΔETP value may be passed to DYNAMICS to account for flowrate error that is not modeled with throttles prior to 1:07. Since we use an adjust and not a lock, any subsequent engine-out PBI input will execute the ARD safing task, which will throttle all AM engines to 104 percent. The ARD solution should then be re-examined, and the thrust update can be re-performed on the remaining engines if TMECO discrepancy is in the appropriate direction. (For example, a large thrust dispersion on the right engine causes a trend of +10 fps/min between 2:30 and 3:30 (high thrust onboard)). This results in an update of 104.12 percent on all three engines. At 6:00, the left engine fails and the remaining two are automatically reset to 104 percent. This causes the ARD TMECO to be later than onboard, since the onboard is still seeing higher acceleration due to the right engine thrusting higher. A significant TMECO discrepancy would indicate that the thrust update solution should be re-input on the remaining ARD engines.)

To: DM46/Ascent FDO's and ARD Supports
From: DM46/C. Edelen
Subject: ARD Thrust Update Console Procedures

Dec 13, 1993

OVERVIEW

The thrust update SR will be ready for use with the STS-62 FLT load. This document contains background information and console procedures you will need in order to use this feature. I have included the level A/B requirements (with some extra details) to give you an overview of the formulation, and displays that have changed. Prelaunch data input requirements are also outlined, and a preliminary console handbook section is included to outline realtime procedures. This is the first draft, so give me any redlines/additions you come up with and I will include them in a final package. This will probably wait until after we've simmed with the SR a few times so we can see what lessons are to be learned that may change these procedures.

LEVEL A/B REQUIREMENTS

A thrust update algorithm based on the use of ARD nominal ΔV margin slope to obtain thrust error has been developed. It will be incorporated into the ARD code for automatic thrust error computation and correction in order to provide accurate abort boundary prediction. This algorithm is an expansion of the current empirical update procedure used on console. Automation will eliminate several shortcomings of the current manual method: time-critical manual inputs to the ARD throttle table will not be necessary, and the useful timespan will be expanded from 1.5 minutes in second stage (2:30-4:00) to about 3 minutes (3:00 - 6:00).

The algorithm will store a user-defined number of actual mode nominal MPROP ΔV margin points vs. time in an array (baselined to store 10 points). Then a linear least-square curve fit will be applied to the points in order to obtain an equation in time for the ΔV margin profile. This equation is differentiated to obtain margin slope, and the slope is adjusted to account for any nominally expected slope (determined preflight). Finally, a margin slope deadband is stripped out of this adjusted slope. The deadband is necessary to prevent thrust updates from occurring due to inert weight errors and ISP errors. These dispersions result in acceleration errors in the same manner as thrust errors, causing the ΔV margin to trend slightly. This reduced slope value is used in an empirical relation that determines thrust error as a function of margin slope and current time. This algorithm assumes that the thrust dispersion is constant in time over the whole ascent profile.

The cluster thrust error determined above is divided by the number of operating SSMEs to obtain an average thrust error per engine. A table of thrust errors calculated over previous cycles will be maintained so that the mean and standard deviation can be determined (number of data points being user defined; currently five). Each cycle, the current thrust error will be inserted into the table and the oldest entry deleted. The mean thrust error (lb and percent rated power level (RPL)) and computed margin slope

(fps/min) will be displayed each cycle. Also, standard deviation of the thrust error array (% RPL) will be displayed to enable the operator to determine if the algorithm is converged. A GO/NO GO flag will also be output based on (1) standard deviation (GO if $\sigma < 0.007\%$) and (2) ΔV margin array filled criteria (GO if all 10 slots have been filled). Once a satisfactory solution is obtained, the currently displayed thrust error can be frozen via "Thrust Update Freeze" push-button indicator (PBI) on the TRAJECTORY console. (The MET that the "freeze" PBI is depressed will also be displayed along with frozen thrust error, throttle error, and standard deviation). A "Thrust Update Execute" PBI input will incorporate this frozen thrust error into the ARD by updating the nominal 100 percent thrust value, FNSME. Therefore, no changes to the ARD throttle table will be required. A "Thrust Update Restore" PBI will be available to reset FNSME to its prelaunch value in case the updated solution is found to be unsatisfactory after incorporation.

The algorithm will also provide an estimate of equivalent power level assuming all of the calculated thrust error is occurring on one engine. This will also be displayed each cycle, and can be used to perform a K62 power level update in case there is reason to suspect an individual engine. This is a single-engine thrust update to the throttle table at 1:07 MET (identical to current procedures). The ΔET propellant adjustment to correct for flowrate error prior to the throttle adjustment time will also be computed and displayed.

Changes are also required to other ARD subroutines to support the auto thrust update SR. The ARD mass module (ARDMSS) requires a slight modification to force inclusion of discrete points in the throttle table during building of the ET propellant table. This will maintain a more accurate mass track and minimize deviations in ΔV margin behavior, thus improving output of the thrust update function (also eliminates need to perform mass track recycle at SRB separation to prevent early filling of ET propellant table). In addition, the ΔV margin module (ARDDLTV) shall incorporate an improved ΔV margin correction scheme. ΔV margins will be corrected with a cubic equation for better stability, minimizing the nominal margin slope. TAL solutions will require a separate correction equation since the coefficients will be different from non-TAL solutions. Improved stability of the nominal margin will minimize errors in thrust update function output.

BACKGROUND

Smooth ΔV margin points are required for an accurate curve fit. To satisfy this, telemetry (TLM) vectors are much preferred over filter (FLTR) vectors. However, HP9000 FDO Ascent Trainer tests of the thrust update algorithm with FLTR vectors and noise indicate an approximate solution may be obtained if TLM is not available. This will be examined further during integrated sims. So far from flight experience, telemetry has been available for manual thrust updates, so riding TLM from 2:30-3:00 should not be a problem. This provides 10 smooth entries in the ΔV margin array (20 seconds). When this is filled the algorithm starts outputting thrust data. Another 10 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, extensive periods of static TLM will require selection of FLTR until data is restored, then reselection of TLM for up to 30 seconds prior to obtaining a good thrust update; less if the FLTR vectors are smooth.

At 3:00 MET, Trajectory and ARD Support controllers should determine the health of the ARD solution by evaluating several cues. TMECO difference between the vehicle and ARD should be < 1 second generally. Differences greater than this indicate presence of anomalies such as: (a) significant thrust mismatch (requiring a relatively large thrust update), (b) SSME performance case, (c) large NAV dispersion or guidance problem, or (d) non-thrust dispersions beyond flight experience such as large loading error, inert weight error, or ISP dispersion. The nominal ΔV margin should trend in a direction consistent with the TMECO discrepancy; e.g., 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 (see flight rule 4-21). This is because the ΔV margin is much more sensitive to thrust dispersions than other dispersions, which provides a means to model this in realtime. However, thrust updates are not performed beyond the SSME system specification limit (10,392 lb/cluster or 0.74 percent, 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 preflight 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 realtime if they can support this.

Thrust update output can be examined once the ΔV margin and averaging arrays are filled with telemetry-based data (3:00 MET). Thrust error computations should be checked for agreement with ΔV margin trend and TMECO difference (i.e., high computed thrust should be accompanied by early O/B TMECO and upward margin trend). If the standard deviation of thrust error solutions coming out of the averaging routine is below a certain threshold, then a comps "GO" flag (MSK 600) is turned on to tell the user 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 updates if the user decides to disregard this data. (Updates are inhibited only during first stage, or if the ΔV margin array is not filled, or if there is 3-g throttling, or if any engines have failed). If no thrust error is present, or if errors are not large enough to exceed the deadband, then 104.00 percent will be output and no update is required. If the trend is greater than the deadband, then the algorithm will divide the cluster thrust dispersion equally among the operating engines and display it as equivalent percent throttle setting for each engine, and a new "FNSME" (nominal main engine thrust) will be displayed as well. In addition, the thrust error in lb 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 "ARD's go at 3:00, slope -11, low thrust O/B, stand by for Freeze", followed shortly by "Freeze" when the "go" flag is set. Note that the statement "ARD is go" here refers to the overall ARD solution and not specifically the comps "GO" flag; this is signified by requesting a freeze. Note also that margin slope output becomes stable well prior to obtaining a "GO" flag, so this can be eyeballed for stability over a couple cycles prior to achieving a "GO" flag.

Activation of the Freeze PBI records the currently computed "FNSME" coming out of the algorithm and displays it on MSK 600. If the freeze throttle output on MSK 430 is stable compared to the updating solution for a couple cycles, then a good solution has been frozen and TRAJ can reselect FLTR for state vectors if desired. The Booster Officer should next be consulted to determine if an SSME performance case is present. If so, then data should be requested and modeled via SSME Performance Case procedures (Section 4.1.1.4). If a performance case is suspected but data is still in work, then it is best to model the thrust hit with a thrust update on one engine only. This is outlined in Single-Engine Thrust Update procedures (Section 4.1.4.8). If BOOSTER reports three nominal engines, then the Thrust Update Execute PBI is depressed to ship the new "FNSME" to the ARD for actual use. This triggers a mass recycle and will reset the thrust error output to 0 lb/104.00 percent as well. A discontinuous change in the ΔV margin will occur, along with (hopefully) better agreement of onboard and ARD MECO times. The ΔV margin should now trend at about the deadband. After the ΔV array has re-filled, the algorithm should indicate either no update required, or a very small thrust error beyond the deadband detected (e.g. 103.98 percent). 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 FLTR is noisy, the GO flag may not reset, however this is not necessary to verify a good update.

Validity of the solution is verified occasionally by confirming that approximately 104 percent is being displayed by the algorithm. This can be done periodically from 3:00 - 6:00 MET, which is the range over which reliable solutions can be obtained. Do not use the thrust update output outside of this timespan. If for some reason it is desired to remove the updated thrust, the Restore PBI can be depressed to set FNSME back to the pre-launch value. This will trigger a mass recycle, reset the ΔV array, and initialize thrust error output to 0 lb/104.00 percent.

Thrust updates can also be performed with a K62 throttle table adjustment MED if the Booster Officer believes one engine is responsible for the observed thrust error. This is preferred over a PBI update to the cluster main engine thrust value, FNSME, since it does not require a Restore PBI prior to inputting a K69 thrust limiting MED input if BOOSTER provides data at a later time. It is also better for engine-out modeling for bad engine out (although good engine out requires re-input of the K62 data if an adjust is performed). An example of when this procedure would be used occurred during STS-44 when a 1/2 level Pc shift was present that the Booster Officer could not officially call, but knew was present. In this case, instead of modifying the cluster FNSME, we should adjust the individual SSME power level in the throttle table. The thrust update algorithm

supports this by outputting power levels for each SSME assuming the entire thrust dispersion is concentrated on that engine. This is output for all three engines on MSK 600 along with ΔET propellant quantity to account for flowrate error due to the thrust error prior to the throttle table timetag (normally 1:07).

ALGORITHM DATA REQUIREMENTS

The shape of AM nominal MPROP will be determined with a nominal ARD run during the flight design process and again on launch day. This run will record the non-dispersed ΔV margin vs. Tsrce. A quadratic curve fit will be applied to this data to yield coefficients such that the nominal margin is defined as follows:

$$\text{nominal } \Delta V \text{ margin} = \text{MCDVN1} + \text{MCDVN2} * \text{Tsrce} + \text{MCDVN3} * \text{Tsrce} ** 2$$

Slope of nominal profile is obtained by differentiating this equation with respect to time; therefore, only MCDVN2 and MCDVN3 are actually loaded into the ARD. These trajectory parameters (F02) are displayed on MSK 2445.

The deadband slope will be determined from a quadratic curve fit as well, except this will probably be a generic equation. The coefficients are determined by applying a 2σ RSSed inert weight error and LH2 loading error to a run (total error of 1586 lb for flight-derived dispersions). The AM nominal MPROP margin vs. Tsrce will be recorded. The nondispersed margin shape (from DVNOM coefficients above) should be subtracted from this profile to yield a pure margin response to the inert weight and LH2 errors. A quadratic curve fit is then applied to the data points to obtain coefficients such that

$$\text{deadband } \Delta V \text{ margin} = \text{MCDBD1} + \text{MCDBD2} * \text{Tsrce} + \text{MCDBD3} * \text{Tsrce} ** 2$$

Slope of deadband profile is obtained by differentiating this equation with respect to time. These trajectory parameters (F02) are displayed on MSK 2445.

The partial of ΔV margin with respect to thrust error must also be determined, and this should be generic. This partial is not a constant value, but instead varies with time since margin trend due to thrust error is approximately linear from about 2:10-4:00 and is a function of mostly the acceleration difference due to thrust error, but after 4:00, the margin trend becomes quadratic due to the growing weight error. This partial equation is defined by an exponential curve fit with coefficients determined as follows. A run is performed with 2σ thrust error (3193 lb cluster) and the AM nominal MPROP is recorded vs. Tsrce. The nondispersed margin shape (from MCDVN coefficients above) should be subtracted from this profile to yield a pure margin response to the thrust error. The slope vs. Tsrce is determined from a curve fit of the data points, then this slope (vs. time) is divided by thrust error to obtain the partial of margin slope with respect to thrust error vs. time.

A quadratic curve fit is applied to these values to obtain coefficients such that

$$d(\text{margin slope})/d(\text{thrust error}) = \text{MCDFT1} + \text{MCDFT2} * \text{Tsrce} + \text{MCDFT3} * \text{Tsrce} ** 2$$

These trajectory parameters (F02) are displayed on MSK 2445.

Several additional trajectory parameters (F02) are used by the algorithm for general control. Computation of ΔETP for single-engine thrust updates is accompanied by use of MCDMDT, which is 1/ISP of the cluster at 104 percent. This will not need to be updated with the actual ISP of the cluster on a flight-specific basis, since computation of ΔETP weight does not vary more than about 10 lb for extreme differences in ISP. MCTINP is the timetag for single-engine updates in the throttle table. This will be delivered as 67 seconds, so you may have to update this occasionally for flights in which the throttle bucket ends after 1:07. MCONVR is the convergence criteria for the GO flag, and is set to 0.007 percent RPL (derived during testing). MKNUMD is the number of entries in the ΔV margin array (set to 10). MKNUMT is the number of entries in the averaging array (set to 5).

These coefficients are all delivered as standard inputs by flight design to the MOC via the SPF. They can be found in product DATA-22B TMTT. All of these are displayed on MSK 2445.

Finally, the ΔV margin "correction" coefficients MCC1DL and MCC2DL have been replaced as described in the level A/B requirements above. Now the TAL channel will be tweaked separately from other channels by cubic coefficients MC0DVT, MC1DVT, MC2DVT, and MC3DVT. All other channels will use coefficients MCC0DL, MCC1DL, MCC2DL, and MCC3DL. These system parameters are located on MSK 2360, and are delivered by flight design via the SPF. You can find the correct values in DATA-22A.

Informal Memo

March 10, 1994

To: DM46/Ascent FDO's, TRAJ's, and ARD Supports

From: DM46/C. Edelen

Subject: ARD thrust update accuracy for engine-out trajectories and sequential single engine press FPR

The objectives of this memo are to (1) identify sequential single-engine (SE) press FPR protection requirements, (2) determine if current FPR buildup methodology provides sufficient protection, and (3) assess the accuracy of thrust updates for engine-out trajectories, particularly with the new PBI thrust update algorithm.

BACKGROUND

POST ENGINE-OUT THRUST UPDATE ACCURACY

The thrust update algorithm was not designed to compute thrust deltas after an engine failure, due to the enormous task of correlating margin drift to thrust error for different abort modes and engine failure times. Data continues to be output after an engine failure; however, once an abort is selected, the algorithm is terminated. Note that a thrust restore can still be performed when the thrust update algorithm is no longer active.

After a PBI thrust update has been performed, the ARD 100 percent thrust value, NOMMETH, will retain its updated value even after an engine failure. Post engine-out, this will result in the ARD accounting for 2/3 of the dispersion that was present prior to the engine failure. This is accurate as long as the dispersion was equally distributed among the three engines. However, if the dispersion is concentrated on one or two engines, then errors will result regardless of which engine fails. For example, if the dispersion was concentrated on one engine, and the Booster Officer had not identified that engine as being suspect for the thrust dispersion (i.e., a single-engine K62 thrust update had not been performed to the throttle table), then post engine-out modeling will result in thrust and mass track errors if (a) the bad engine fails (zero thrust dispersion present post engine failure) or (b) a good engine fails (full thrust dispersion present post engine failure). Note that if most/all of the thrust error had been on one engine and a K62 throttle table entry had been performed for that engine, then post engine-out modeling will be accurate regardless of which engine fails (thrust update must be re-input if a good engine fails).

If the ARD is found to be misconfigured after an engine failure, several options are available to remedy the situation. An example scenario again is low thrust on one SSME (104 percent, 104 percent, 102 percent), followed by a PBI thrust update that reduces the value of NOMMETH, followed by failure of the 102 percent engine. The ARD will build up a mass error because its updated thrust value is too low relative to the remaining cluster. If you find yourself in this situation (evidenced by TMECO difference and margin trend), potential options are to: (a) sit on the pre-engine-out NOMMETH

(that was input with the PBI) or (b) hit the Restore PBI which sets NOMMETH to its prelaunch value. Option (b) has the drawback of erasing all of the mass track benefit the thrust update gives you up to the time the engine failed. Other more complicated options are possible, such as hitting the Restore PBI and then modifying the throttle table to put all of the pre-engine-out dispersion on the engine that failed, for example. Previous manual procedures basically corrected thrust error via the throttle table until an engine failure, after which time nominal SSME performance on the remaining engines was assumed, unless sufficient cues were available to justify re-input of the thrust dispersion on the remaining engines. The data below documents weight error growth due to thrust mismodeling for both the manual and PBI thrust update method (a) above.

SEQUENTIAL SINGLE-ENGINE PRESS FPR

The ARD is loaded with AOA FPR designed for the press to ATO call (about 2500 lb or 115 fps). ARD biases for other than press-to-ATO (PTA) are adjusted to the proper FPR amount if required since ARD FPR is a function of time. Figure 6-4 shows FPR vs. time for STS-62/FLT assuming an SSME fails at 5:00. FPR increases with time due to dispersion-induced weight error growth. The SE press bias includes an FPR term to bump it up to 2σ for the simo press call around 7:00 MET. This results in about 3100 lb holdback or 140 fps (this is determined from a calculation of FPR vs. MET for no engine failure). The same Δ FPR amount is also used to bump up the sequential SE press biases. However, depending on the time of the first engine failure, sequential SE press could occur much later and thus require more than 3100 lb of FPR. This will be explained further below.

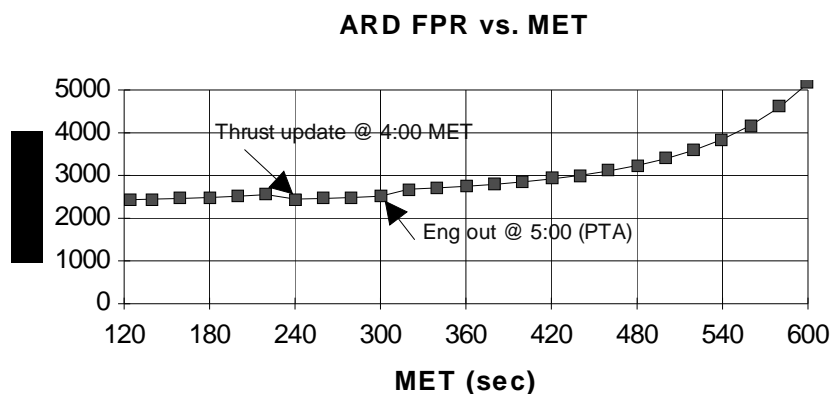


Figure 6-4. ARD FPR vs. MET

METHODS AND RESULTS

Several cases were examined to determine post engine-out mass track error (hence abort boundary error) for the sequential single-engine press time-frame. This reveals the implications of different thrust dispersion distribution scenarios and thrust update techniques for engine-out trajectories. Single-engine TAL boundary errors were not looked at since the implications of an erroneous single engine TAL call are not as

serious as for single-engine press to MECO. FPR thrust protection requirements were determined by a comparison of the thrust component of FPR (which is a function of weight error) vs. actual thrust-induced weight error for each case. All cases are based on STS-62/FLT FPR buildup and STS-50/FLT abort boundaries (both cases are Spacelabs to about 160 nm).

Figure 6-5 shows MET of sequential SE press 104 percent vs. first engine out time assuming nominal SSME performance for STS-50/FLT. STS-50 PTA occurs at 4:55 MET, but for this case the sequential SE press call requires gap closure techniques (109 percent and AOA-SH) after last manual TAL Vi is passed. Instead, it was desired to look at cases where single-engine press could be made “conventionally” with the ARD at 104 percent or 109 percent; therefore, 5:00 MET was used as the earliest PTA time for this study to provide at least single-engine press 109 percent capability or better. It was found that SE press time is extremely sensitive to dispersions, especially thrust. ARD-indicated SE press times were determined for each individual case below.

At the latest sequential SE press time (around 9:40 assuming 1st engine out at PTA 5:00) the actual FPR requirement is about 4600 lb or 210 fps (see Figure 6-4). This is 50 percent more than what is currently covered via the simo SE press FPR buildup. This means we are actually protecting somewhere between 2σ and 1.3σ for sequential SE press call, depending on how late the call is. However, some dispersions that result in FPR consumption (e.g., high thrust, high ISP) also cause the SE press boundary to move earlier in time, thus decreasing the time over which weight error growth occurs. Therefore, since the SE press boundary is so sensitive to dispersions, it is somewhat simplistic and conservative to design FPR for a worst-case MET without considering what impact the dispersions themselves have on the boundary time. The following cases seek to address this.

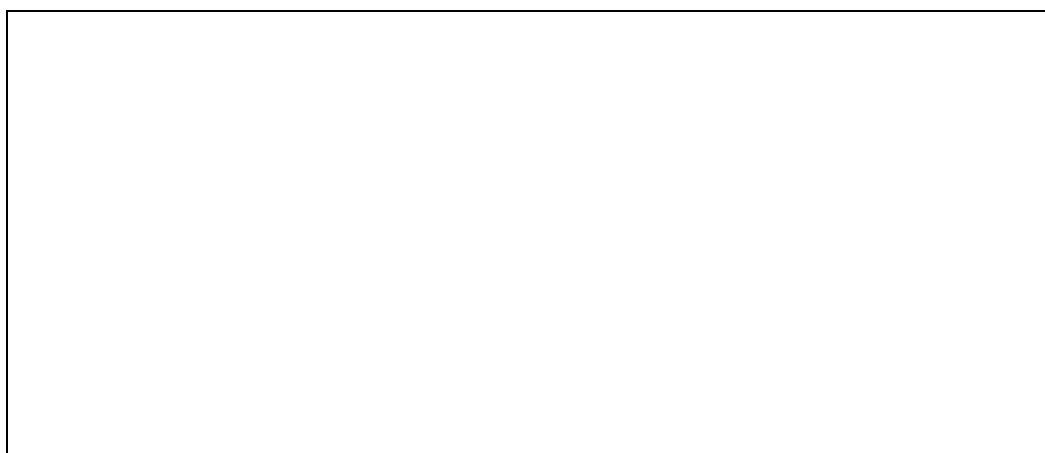


Figure 6-5. SE press time vs. time of 1st engine-out

All of the following cases kept dispersions within $\pm 2\sigma$. The cases below are the most extreme examples of ARD mass track error (resulting in FPR usage) found by varying thrust dispersion distribution.

CASE 1 - SSME FAIL AT 5:00, ATO, DEADBAND THRUST DISPERSION (NO THRUST UPDATE).

This case assumes 2σ heavy inert weight and fuel loading error RSSed for a margin trend of -3.4 fps/min. This is at the negative deadband slope since the deadband is determined from precisely this combination of dispersions. On top of this, a positive thrust dispersion of 104.59 percent (0.88σ cluster) is modeled on one SSME, along with two nominal engines. This combination raises the margin slope to about +3.4 fps/min; therefore, no thrust update is performed. (This is the scenario for which 0.88σ was selected as the thrust sigma protection level.) A good engine is failed at 5:00 MET.

Figure 6-6 is a plot of ARD weight error due to SSME thrust error vs. MET. Also shown is the thrust weight error covered by FPR vs. MET. This is the amount of weight error due to thrust mismodeling that determines thrust FPR protection, which is RSSed with remaining FPR components to determine total FPR. Note the step decrease at 4:00 where protection drops from 2σ to 0.88σ due to thrust update, and the leveling off at 7:00 MET since simo SE press bias is designed for this MET. The curve with box symbols shows weight error due to thrust assuming no thrust update is performed. The curve with circle symbols shows weight error due to thrust for the case in which a thrust update is performed. (These curves overlay each other for this case since no thrust update is performed). The thrust component of FPR is adequate until about 8:30 MET, after which time the weight error due to the thrust error exceeds thrust FPR protection. The ARD reaches SE press for this case at 8:51 MET (531 sec). FPR protection provided by the SE press bias is 140 fps, but from Figure 6-4, total FPR required at 531 sec is about 3700 lb or 170 fps. Therefore, 1.7σ protection is provided in this case. This shows that without even considering thrust update limitations, a case can be identified that violates 2σ requirements for SE press.

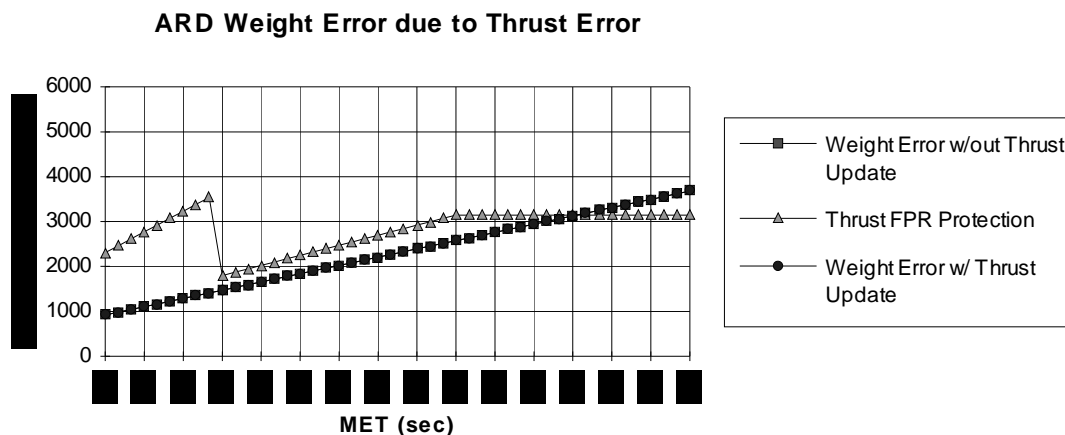


Figure 6-6. ARD weight error due to thrust error

CASE 2 - SSME FAIL AT 5:00, ATO, WORST-CASE DISTRIBUTION OF 2-SIGMA HIGH THRUST DISPERSION (W/PBI THRUST UPDATE).

This case again assumes 2σ bad inert weight and fuel loading error RSSed for a margin trend of -3.4 fps/min (at the deadband). On top of this, a $+2\sigma$ cluster thrust dispersion is modeled with a 2σ individual SSME dispersion on one engine (104.78 percent), and the remainder on another engine (104.58 percent). This distribution does not break 2σ for either engine, but still provides an overall 2σ cluster dispersion. This combination raises the margin slope to about +13 fps/min which triggers a PBI thrust update to lower the margin trend to the positive deadband. The one good engine is failed at 5:00 MET (PTA), leaving two dispersed engines running. The thrust update performed at 4:00 MET provides a much better mass track than if no action had been taken; however, due to the deadband it cannot completely model the dispersion that is present. Since the post engine-out ARD is modeling 2/3 of the pre engine-out dispersion (minus the deadband), and the vehicle has all of the pre engine-out dispersion present, the ARD becomes heavier over time. (ARD thrust value/mass flowrate is lower than that of the vehicle.)

This ARD prop-heavy configuration results in optimistic ΔV available computations, causing the ARD to over predict vehicle performance. Therefore, FPR is necessary to provide protection for early abort boundary calls. Figure 6-7 shows ARD weight error due to SSME thrust error vs. MET again. The thrust dispersion is covered until 8:10 MET, after which time the weight error due to thrust error exceeds its FPR protection. The indicated SE press call comes at 8:40 MET (520 sec), as determined from an HP9000 run with the actual dispersions modeled in the environment. Total FPR protection provided by the SE press bias is 140 fps, but from Figure 6-4, total FPR required at 520 sec is about 3600 lb or 163 fps. Again, 1.7σ protection is provided, and the true boundary is reached a few seconds later than the ARD indicates. The thrust update makes this case similar to case 1 since the dispersion is corrected back to the deadband. Note that a thrust update is much preferred over not updating.

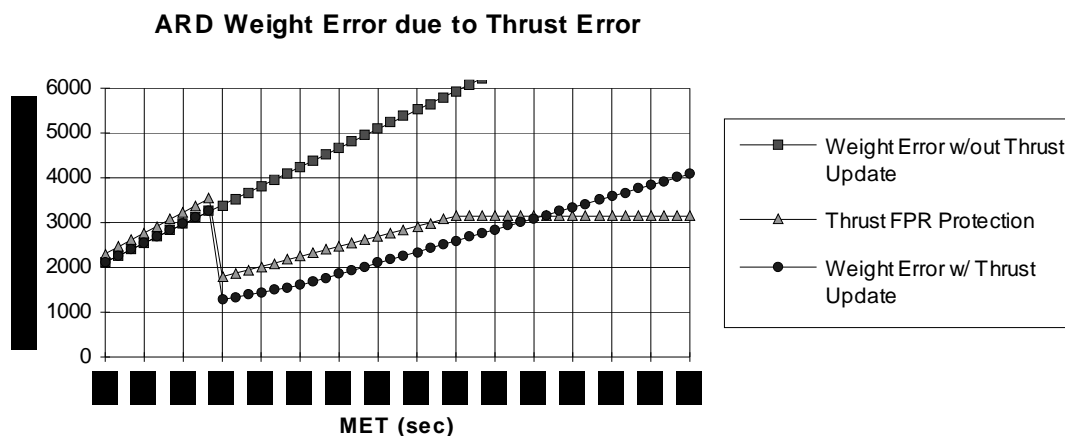


Figure 6-7. ARD weight error due to SSME thrust error vs. MET

Had a manual thrust update been performed, the weight error would have increased at the same rate as above until the SSME failure. Once an engine failure occurs, ARD throttles are set to 104.00 percent by the safing task, effectively zeroing out the thrust update from TMEOUT onward. For this case, weight error growth would have increased due to two dispersed SSMEs still running and a 104 percent throttle value for both engines in the throttle table (see Figure 6-8). If an upward trend and TMECO discrepancy had been noted post-engine failure, then the thrust update may have been re-input for the remaining SSMEs. This would have resulted in a weight error identical to the PBI update (Figure 6-7 again).

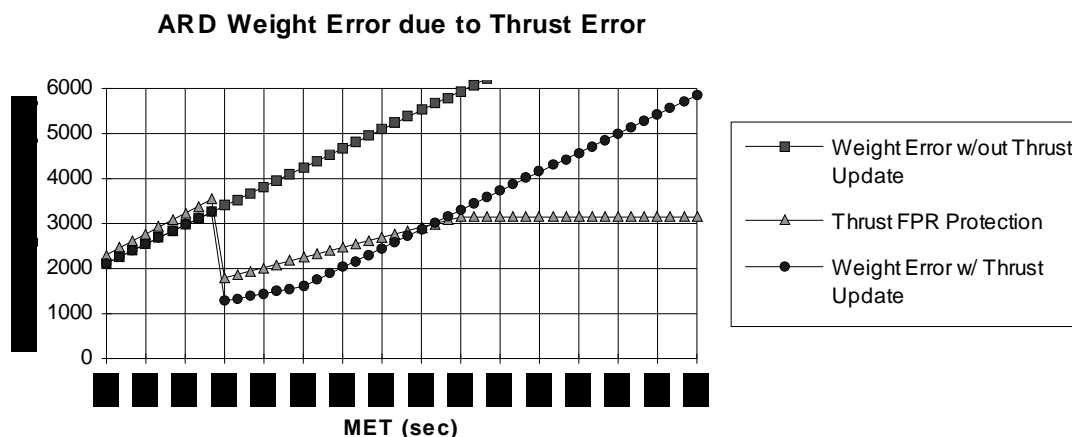


Figure 6-8. ARD weight error due to thrust error

CASE 3 - SSME FAIL AT 5:00, ATO, EQUAL DISTRIBUTION OF 2-SIGMA HIGH THRUST DISPERSION (W/THRUST UPDATE).

This case assumes 2σ bad inert weight and fuel loading error RSSed for a margin trend of -3.4 fps/min (at the deadband). On top of this, a $+2\sigma$ cluster thrust dispersion is modeled by distributing the dispersion equally among all SSMEs. Although the PBI thrust update algorithm is optimized for this case, the manual method does not handle it as well. As in the previous case (same overall cluster thrust value), the margin slope is about +13 fps/min after which a manual thrust update is input to lower the margin trend to the positive deadband. One engine is failed at 5:00 MET (PTA), leaving two dispersed engines running. ARD throttles are set to 104.00 percent by the safing task, which zeroes out the thrust update from TMEOUT onward.

The manual thrust update does fix a good deal of the mass error until it is taken out. After this, the mass error increases at a greater rate-making the ARD heavier over time since its thrust value is lower than that of the vehicle (i.e., ARD flowrate is too low relative to the high-thrusting engines onboard). This ARD prop-heavy configuration results in optimistic ΔV available computations, causing the ARD to over-predict vehicle performance. Therefore, FPR is necessary to provide protection for early abort boundary calls. Figure 6-9 shows ARD weight error due to SSME thrust error vs. MET again. The thrust error is covered until 7:40 MET, after which time the weight error due

to the thrust error exceeds thrust FPR protection. Indicated SE press from the HP9000 occurs at 8:46 MET (526 sec), with the thrust error causing 110 fps ΔV margin error at this time. Total FPR protection provided by the SE press bias is 140 fps, but from Figure 6-4, total FPR required at 526 sec is about 3700 lb or 170 fps. Therefore, 1.7σ protection is provided in this case.

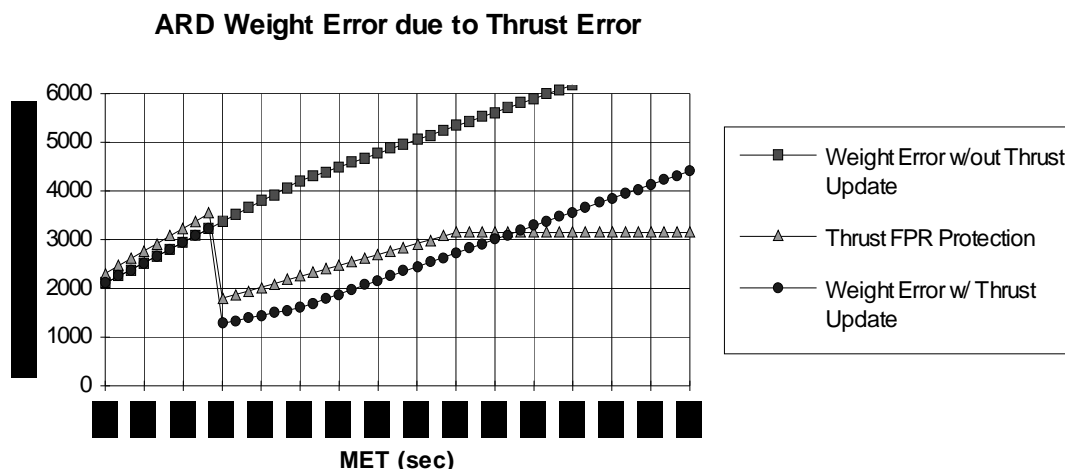


Figure 6-9. ARD weight error due to SSME thrust error vs. MET

Note that this situation could be improved with a re-input of the thrust dispersion on the two remaining engines. This would occur only if the ARD was observed to be misconfigured. This particular case, however, might not be perceived as a bad configuration because the weight error and trend would remain relatively small (<0.5 sec TMECO delta at 8:00 MET). Thus it is possible that the thrust update would not be re-input. However, if it was re-input, the thrust ΔV error (about 75 fps) would be covered by its FPR component at SE press (occurs a bit later at 8:51 MET or 531 sec, Figure 6-10). Overall FPR requirements, however, still would not be met.

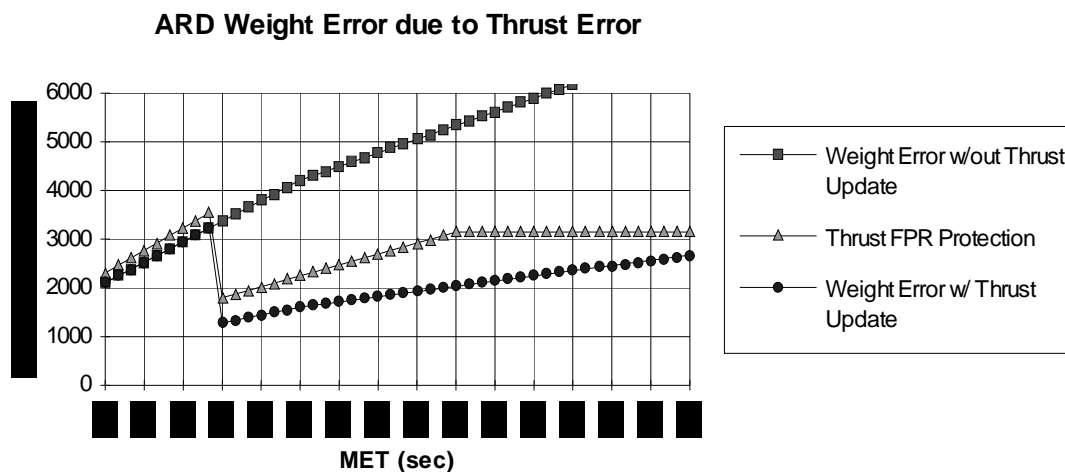


Figure 6-10. Thrust ΔV error

Note that if this case had been handled with a PBI thrust update, then the same results would have been achieved as for re-input of a manual thrust update above (Figure 6-10 again).

CASE 4 - SSME FAIL AT 5:00, ATO, WORST-CASE DISTRIBUTION OF 2-SIGMA LOW THRUST DISPERSION (W/THRUST UPDATE).

This case assumes 2σ bad inert weight and fuel loading error RSSed for a margin trend of -3.4 fps/min (at the deadband). On top of this, a -2σ single engine thrust dispersion is modeled (103.22 percent). This combination lowers the margin slope to about -13 fps/min, which triggers a thrust update to bring the margin trend back up to the negative deadband. The one dispersed engine fails at 5:00 MET, leaving two nominal engines running. The PBI thrust update performed at 4:00 MET provides a much better mass track than if no action had been taken; nevertheless, the ARD does develop a mass error after the bad engine fails since its thrust value is lower than the vehicle's (i.e., ARD's flowrate is too low). This ARD prop-heavy configuration results in optimistic ΔV available computations, causing the ARD to over predict vehicle performance. However, the weight error builds slowly enough that the thrust portion of FPR is sufficient to cover the thrust weight error, even out at SE press (about 9:45 MET or 585 sec). Figure 6-11 illustrates this. FPR required at 580 sec is 4600 lb or 210 fps, while only 140 fps is provided for in the SE press bias; therefore, 1.3σ protection is provided. This was the worst scenario found for low thrust combinations.

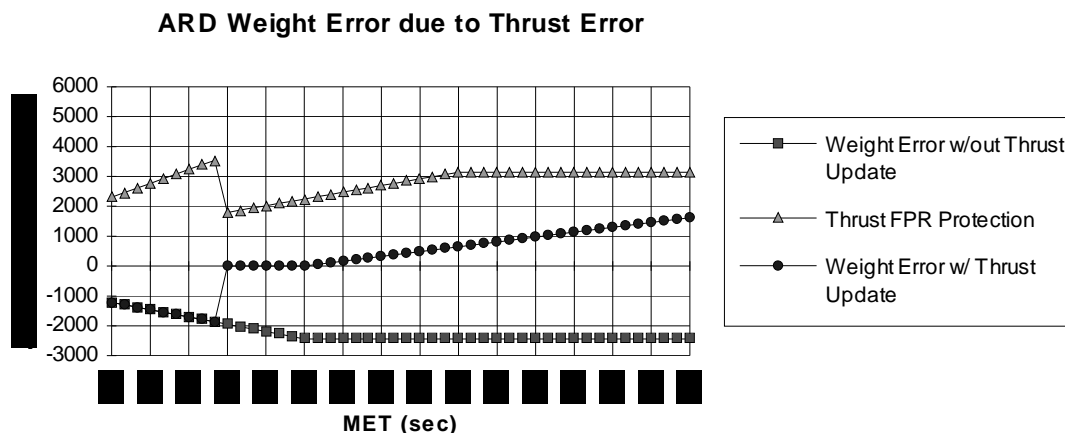


Figure 6-11. Thrust portion of FPR covers thrust weight error

A manual thrust update would have provided more accurate modeling for this case, since failure of the low thruster returns the remaining cluster to a nominal (104.00 percent) thrust value. Since manual updates are reset to 104.00 percent at TMEOUT (due to the safing task) in the throttle table, this would exactly model the onboard. Figure 6-12 shows this mass error plot. This case generates the most difference between manual and PBI thrust update mass track, and is the most favorable manual thrust update case compared to a PBI update. Note, however, that weight error for the PBI case (Figure 6-12) is within FPR limits.

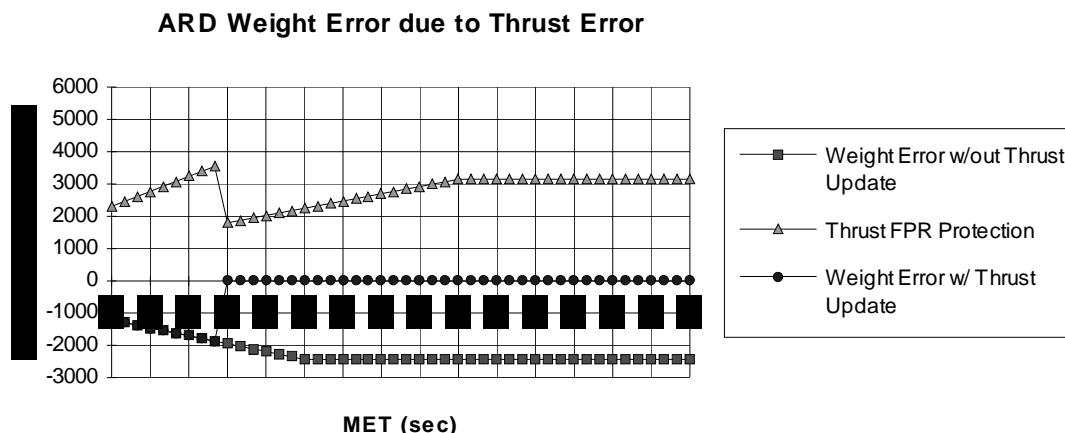


Figure 6-12. Weight error for PBI case

SSME ISP and MR dispersions and LOX loading errors were not addressed in this analysis for two reasons. First, ISP dispersions and LOX loading errors are self-correcting dispersions when applied on top of the deadband since thrust updates partially correct mass track errors for these dispersions. Second, since inert weight, LH2 loading errors, and thrust errors were already present in specific combinations, with worst-case uphill engine failure times, it was reasoned that any additional dispersions on top of this would be beyond a “2 σ bad day”. If deadband components are left out and only SSME ISP, MR, and LOX loading errors analyzed with thrust errors, it is found that the thrust update does a more effective job of reducing mass track errors than in deadband cases above. In spite of this rationalization, strict adherence to FPR buildup techniques does dictate about 210 fps coverage for the worst-case sequential SE press time (see figures 6-4 and 6-5). (Worst-case meaning earliest uphill first engine-out time to push out SE press MET). This is about 50 percent more than is currently protected for via the simo press bias buildup.

Since FPR requirements grow exponentially towards MECO (regardless of ARD thrust modeling technique), protecting for full 2 σ at the latest possible SE press time requires about 70 fps more FPR than is currently provided for simo press (4600 lb vs. 3100 lb). This delta holdback at low margin rates for late SE press (< 10 fps/s) would push back SE press time even more. A nominal STS-50 case was ran on the HP9000 with first engine out at 5:00 and PTA. FPR was increased to 4600 lb in the ARD and single engine press was not achieved at all. (The ARD was about 10 fps short of SE press 109 percent by the time fine count was achieved). This case would have required gap closure (exposure to manual-MECO TAL to ACLS, followed by press on AOA-SH) for single engine coverage. Thus, providing FPR coverage for worst-case SE press times increases exposure to 109 percent throttles and manual-MECO TAL to the ACLS for late press cases. Once the negative ACLS Vi is reached, press is effectively reached anyway, since gap closure commits us to uphill on AOA-SH and 0 σ if required. Thus the trade off of protecting full vs. partial SE press FPR for worst-case engine failure

scenarios is to press uphill with gap closure after manual TAL exposure or to press uphill with between 1.3σ and 2σ confidence.

CONCLUSIONS

The above results can be summarized as follows:

- None of the cases analyzed provided full 2σ FPR protection at SE press.
- Thrust dispersion cases with and without thrust updates were found that exceed thrust FPR component protection at SE press.
- First engine-out at PTA results in latest SE press time (no dispersions), with FPR requirements at about 4600 lb or 210 fps.
- Worst-case low thrust dispersion scenario (case 4) also results in late SE press time. PBI thrust update performed for this case keeps thrust weight error within current thrust protection limits. 1.3σ overall FPR protection is provided at SE press.
- Worst-case high thrust dispersion scenarios (cases 1-3) result in earlier SE press times, decreasing overall FPR requirements. Required FPR is about 3700 lb or 170 fps. PBI thrust update for case 2 results in weight error that exceeds thrust-component FPR protection limits at SE press. 1.7σ overall FPR protection is provided at SE press.
- Thrust updates improve ARD mass track (compared to no action) regardless of dispersion distribution and which engine fails. Manual and PBI updates both have scenarios where one is slightly preferable to the other, however the difference in accuracy between the two is not sufficient to warrant developing procedures to switch from one to another in realtime based on post-engine out ARD health.
- The most critical cases occur with an early failure of the first engine. This pushes out SE press very late, thus providing more time for mass errors to build due to thrust flowrate error. Flights with extremely early PTA times (e.g., 4:00 MET) were analyzed and showed very similar results to the above cases with PTA at 5:00 MET.

It is recommended that PBI thrust updates be performed as planned, and that no action be taken following an engine failure to attempt to remodel the dispersion unless the Booster Officer can provide further information.

It is recommended that the current philosophy for SE press FPR design be retained. The current holdback does provide about 1.3σ protection for worst-case scenarios (early first engine failure, $\geq 0.88\sigma$ low thrust dispersion, 2σ RSSed heavy vehicle weight, etc.). Since FPR is a function of MET, and SE press time is very sensitive to first engine-out time as well as dispersions, providing full 2σ coverage for the worst-case press time would result in gaps for this and many other cases. 0.7σ exceedances of

critical underspeed after proceeding uphill on an ATO typically result in about 70 fps excessive underspeed. This can usually be covered with AOA-SH, which would have been selected after manual-MECO TAL to ACLS for gap closure anyway, assuming worst-case first engine failure time. For non-worse cases where the first engine-out time is well past two-engine press, sequential SE press will occur earlier, thus decreasing FPR requirements. Therefore, it is more likely that full 2σ FPR requirements will be met with the current 3100 lb holdback. It may be appropriate to verify and document these findings in the Flight Rules.

Table 6-2. ARD FPR buildup



Table 6-3. ARD thrust update margin profile/mass error computer (case 1)

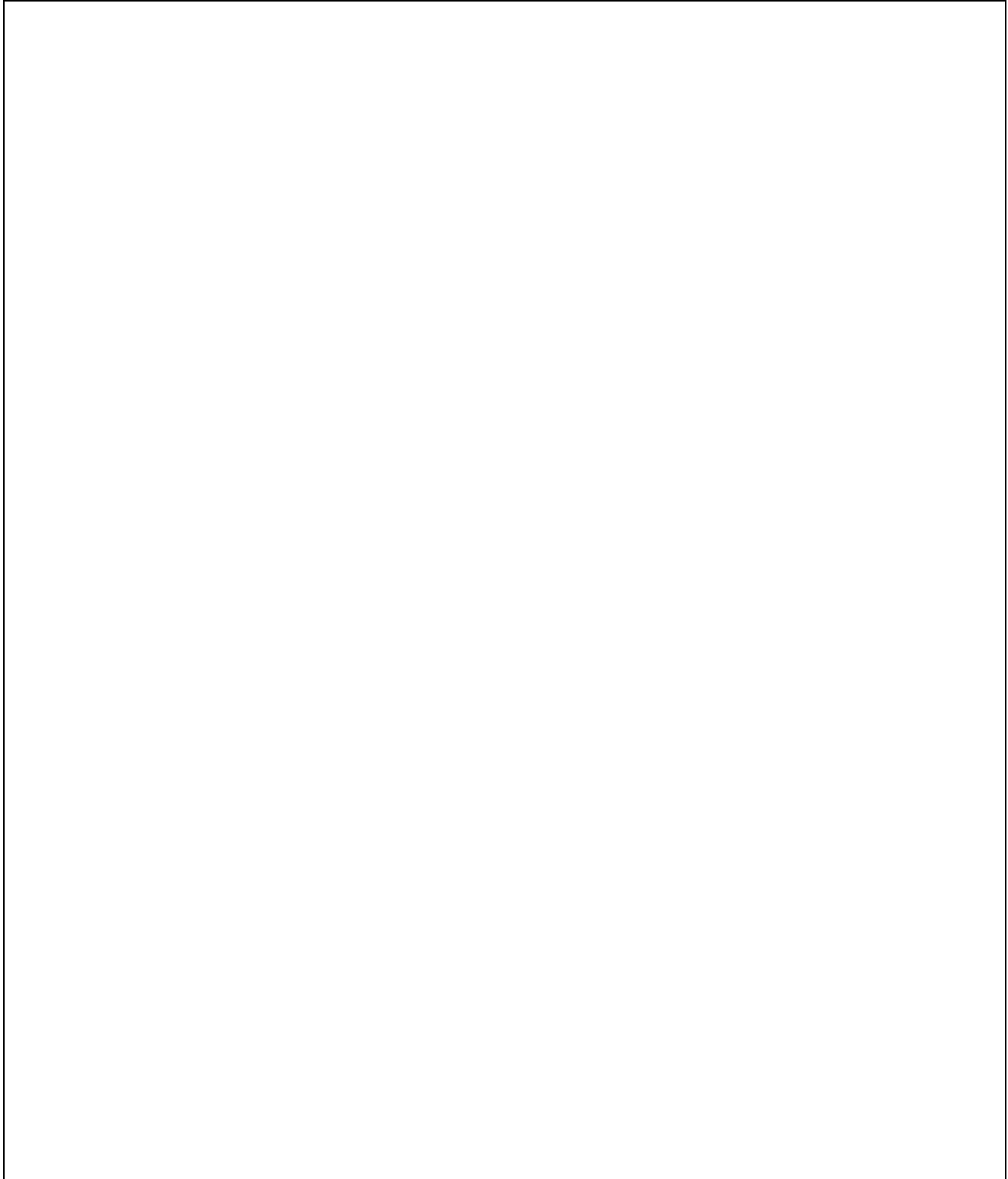
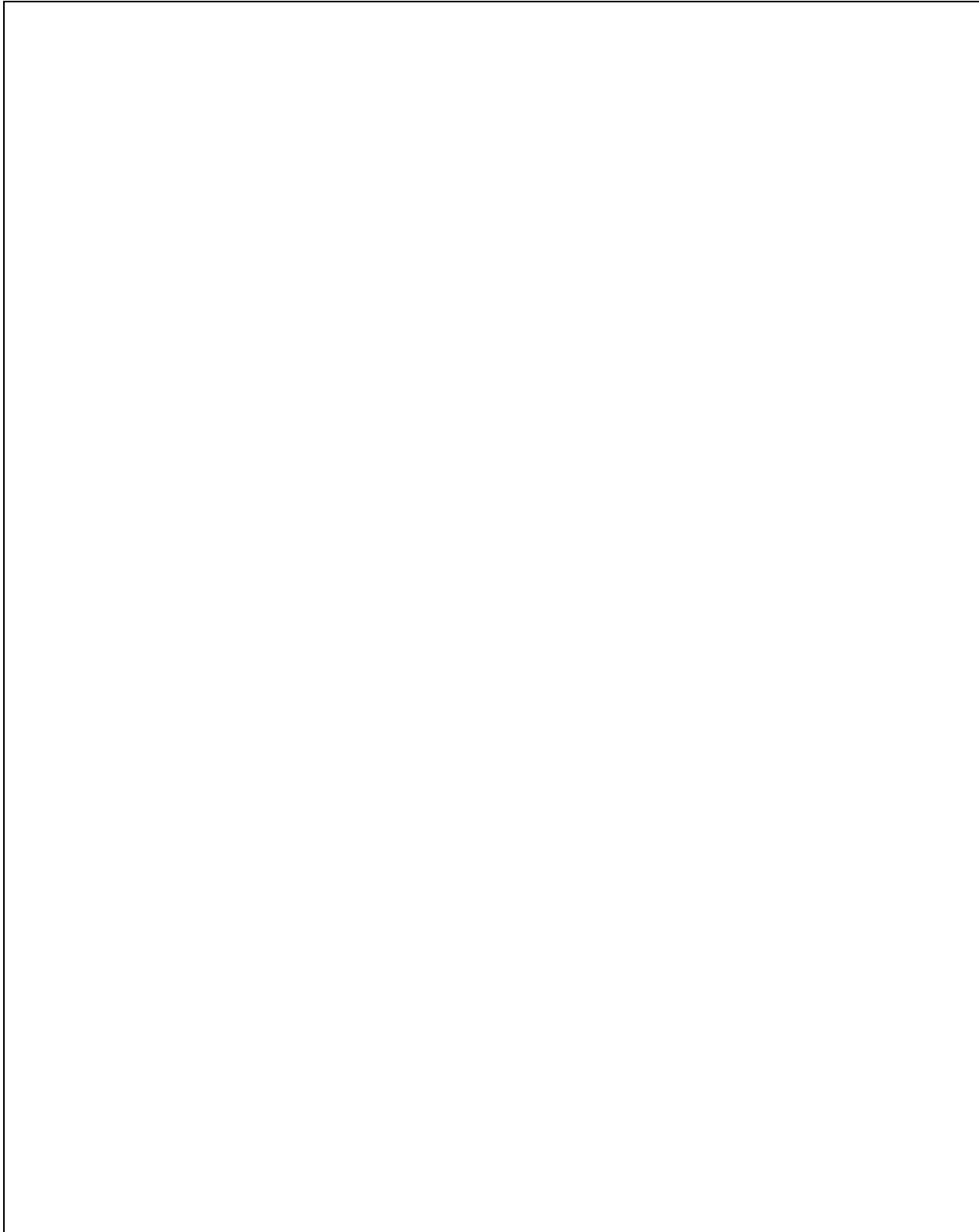


Table 6-4. ARD thrust update margin profile/mass error computer (case 2)



*Table 6-4. ARD thrust update margin profile/mass error computer (case 2)
(concluded)*

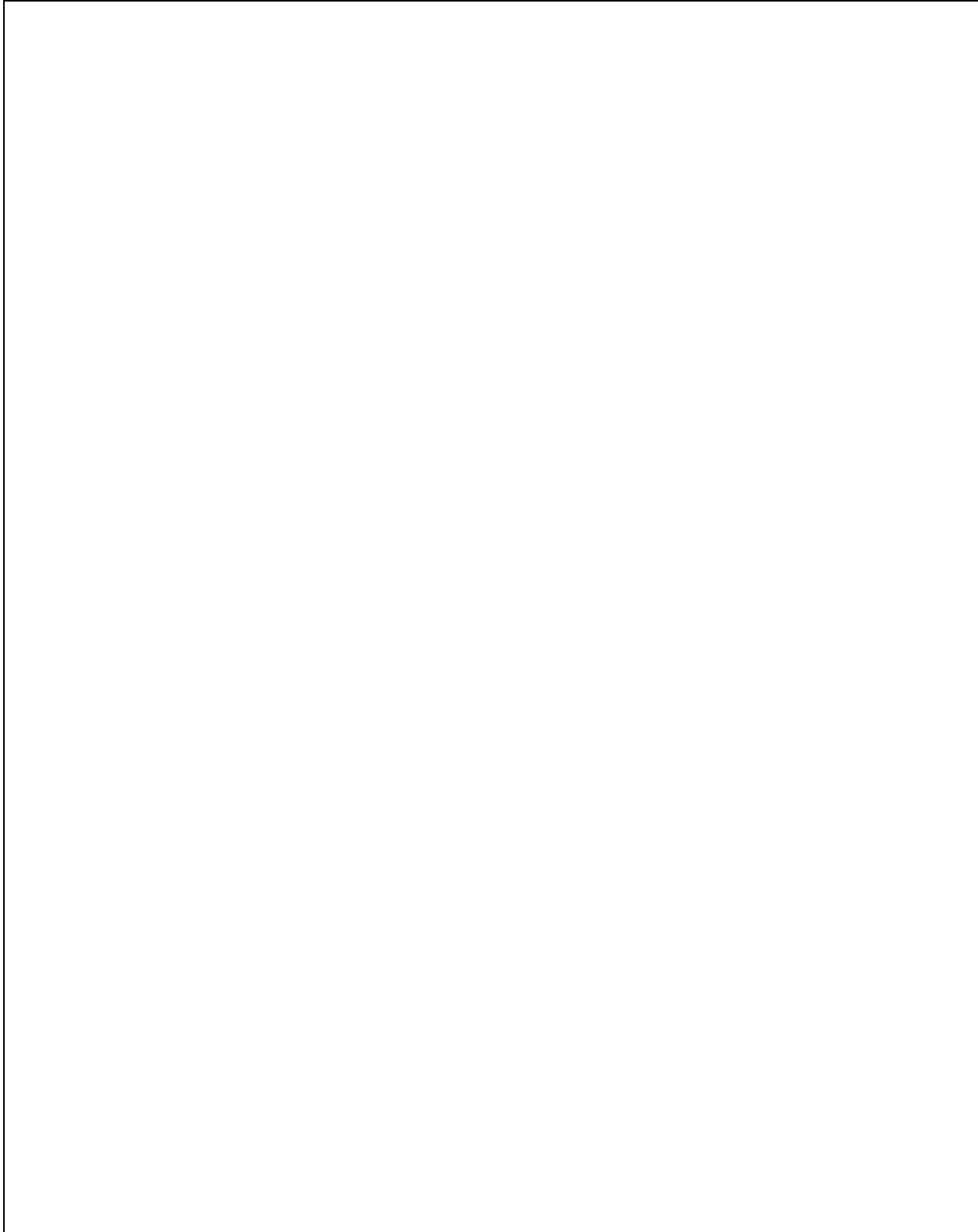
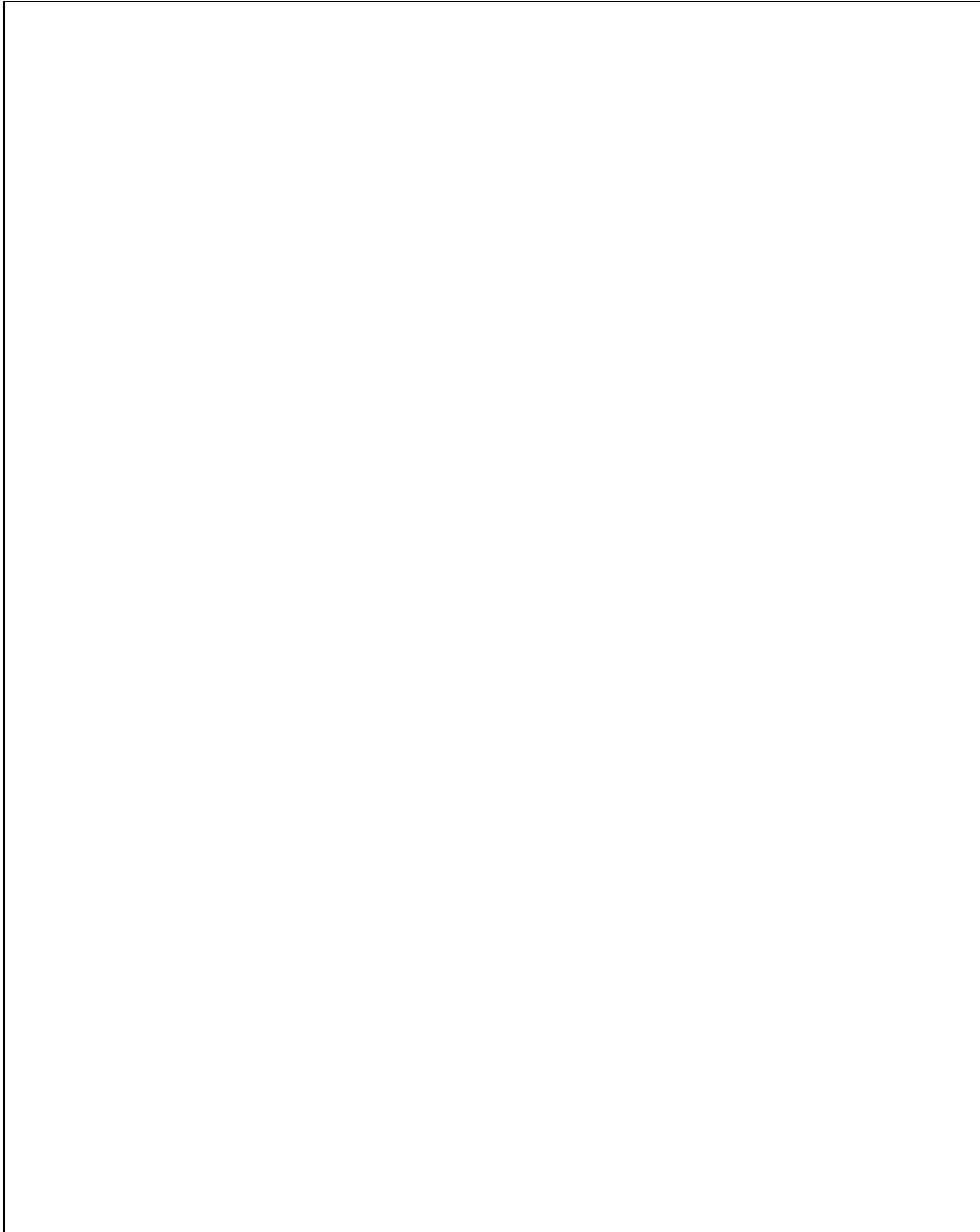


Table 6-5. ARD thrust update margin profile/mass error computer (case 3)



*Table 6-5. ARD thrust update margin profile/mass error computer (case 3)
(concluded)*

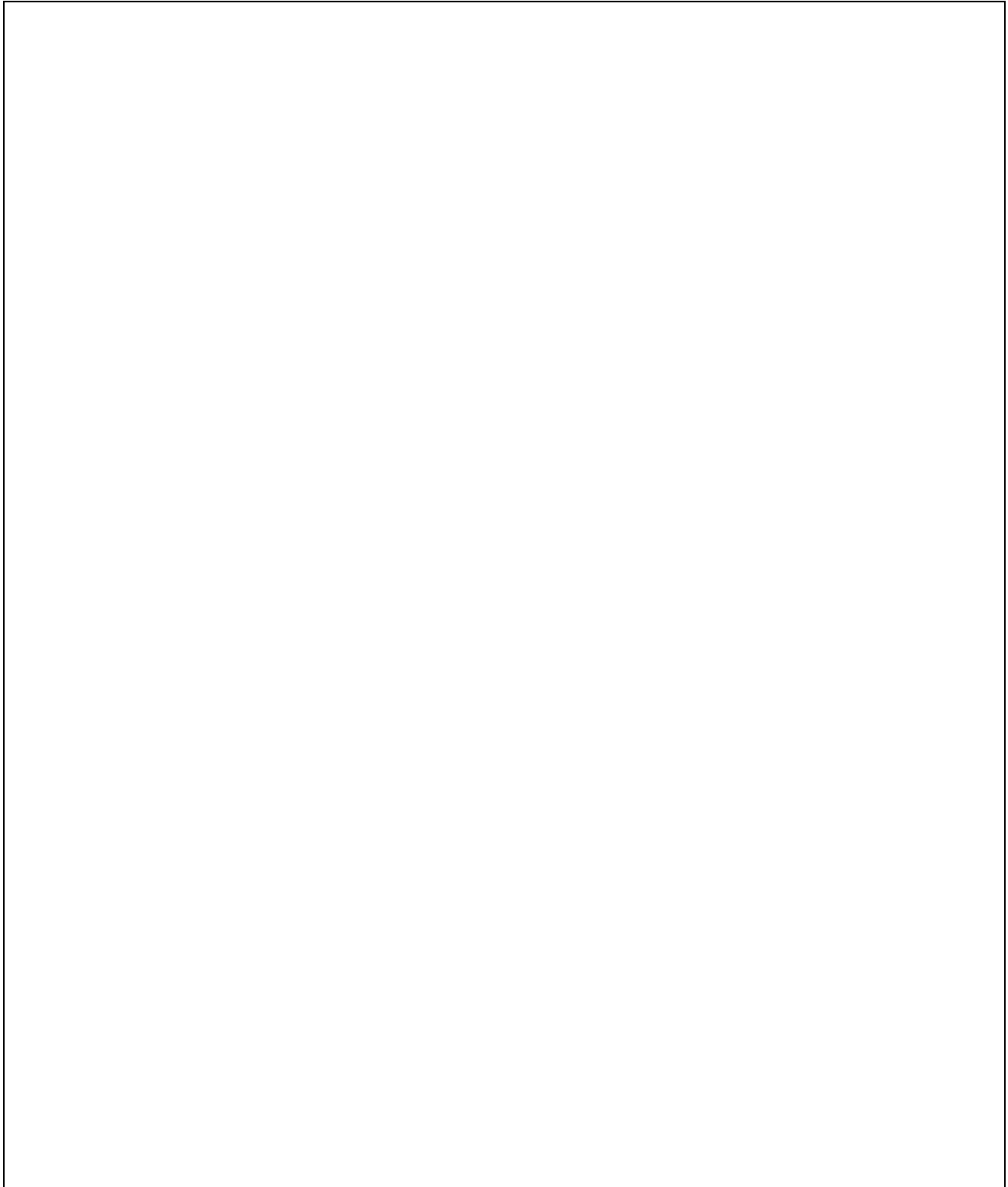
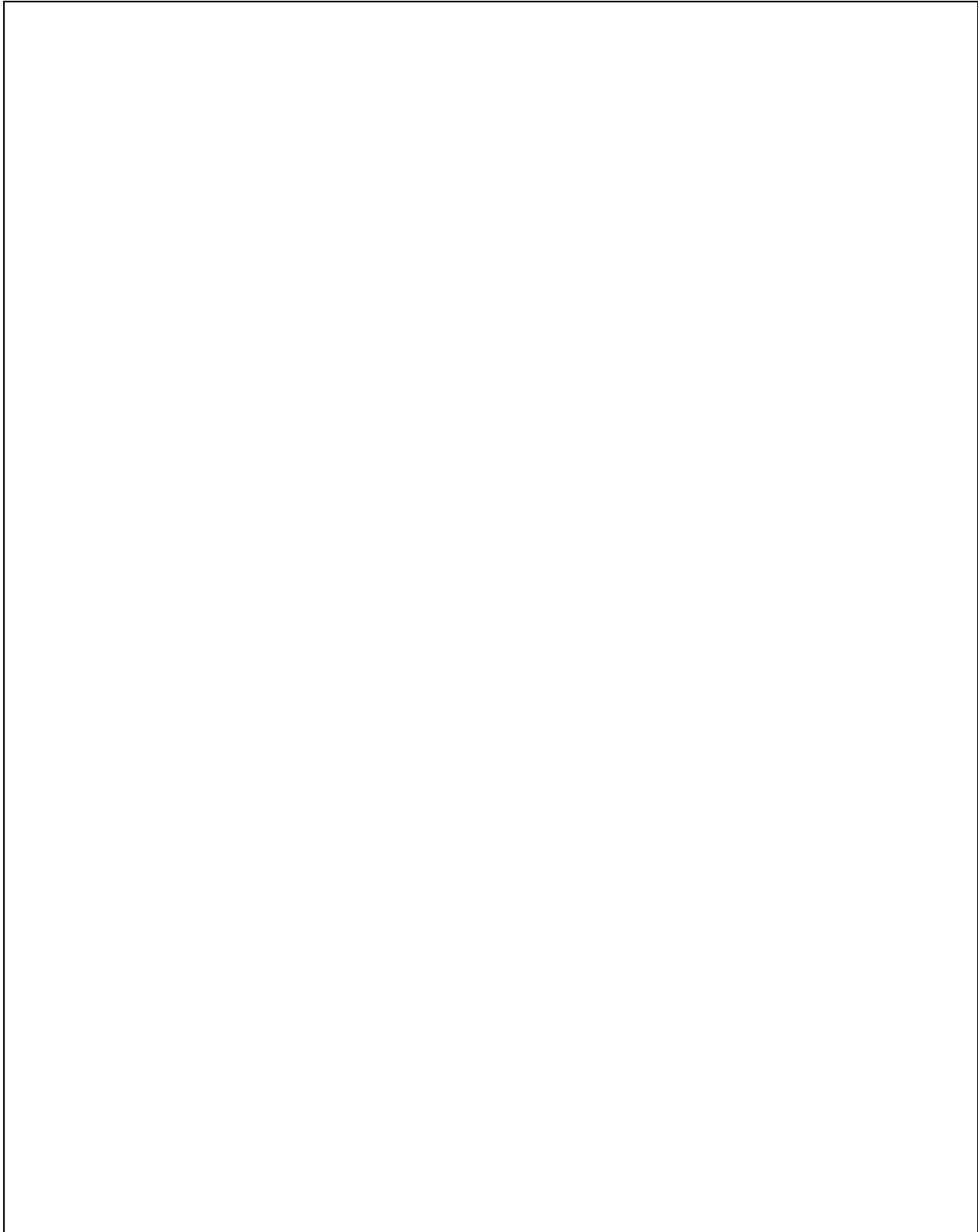
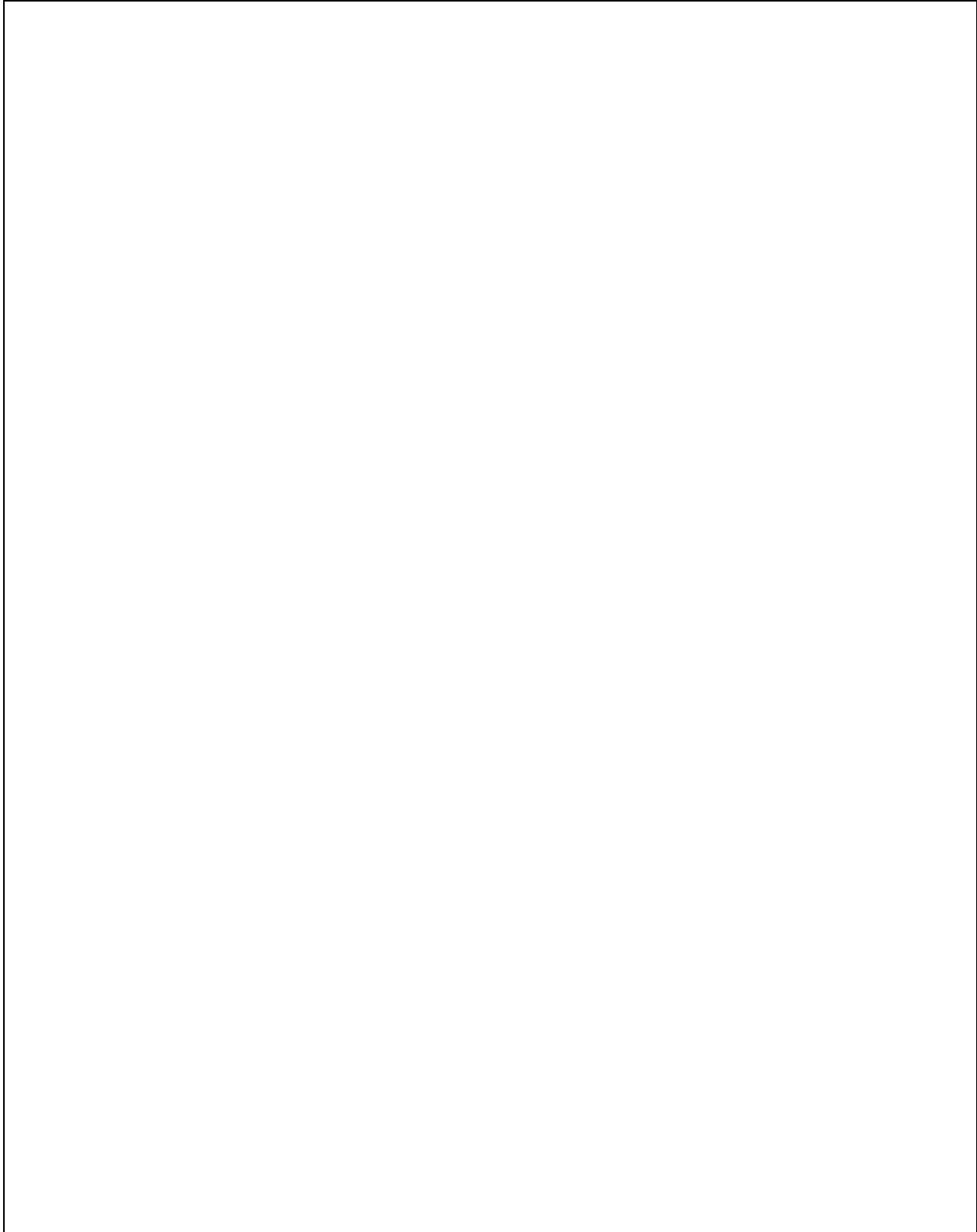


Table 6-6. ARD thrust update margin profile/mass error computer (case 4)



*Table 6-6. ARD thrust update margin profile/mass error computer (case 4)
(concluded)*



6.3 ARD MASS TRACK

Besides utilizing the input state vector, the ARD must track the current vehicle mass and propulsive masses during powered flight. This is done by maintaining a nominal throttle history table, the initial propulsive and non-propulsive masses, and the dry component masses for the entire stacked vehicle. The ET propellant history table is a large array that contains timetags and corresponding MPS fuel quantities. It is built in realtime by the ARD, starting from the knowledge of how much usable propellant was loaded at engine start. The stacked vehicle consists of the dry orbiter, dry ET, SRB casings, and SRB/ET/OMS/RCS propellant masses.

Each cycle, the ARD looks to see what its throttle settings should be (by looking them up in the throttle tables at the current SV time). By knowing the throttles and ISPs (also from the throttle table or ISP system parameters table) the ARD can compute prop flowrate, which is decremented over the computational cycle from the last known value. Hence, the ARD always knows how much propellant it has onboard or had at some previous time. In this way, errors in the mass track can be corrected by fixing the throttle table and “recycling” the ARD to some time when the mass was known to be good (usually lift-off time).

Since all other vehicle components are essentially fixed in weight, the ARD can then deduce total weight by simply summing up all the components. This weight and the ARD’s understanding of total thrust are used to compute acceleration, which feeds the guidance simulation that computes ΔV s. So you can see that proper maintenance of engine characteristics is imperative to proper ARD performance.

The best method of learning more about the theory and sensitivities of the ARD mass track is to study Section 6.10, ARD Questions and Answers. It will give you insight into many of the problems encountered during realtime operations. Although some of the topics discussed are varied, most of them relate to maintaining an accurate ARD mass track.

6.4 PEG GUIDANCE

To be supplied.

6.5 BENCH ARD

To be supplied.

6.6 ARD IMBALANCE MODELING ERRORS REFERENCE MATERIAL

This additional material is presented in its original form as references and to preserve the documents. Future PCNs to this section will combine all the information into a more conventional writeup.

BACKGROUND

While performing flowmeter analyses for the Booster Section, DM46/B. Clarke noted discrepancies between HP9000 ascent program ARD and vehicle performance (this was in Spring 1992). Underspeed differences occurred on these SSME performance case simulations (low MR). The source of these errors was eventually traced to ARD imbalance output (fuel or oxidizer bias), which differed from vehicle imbalances at MECO.

R16B/S. Vyvial and DM42/C. Edelen were actionees on TATR number 92-0388 to determine the extent of the modeling errors, and come up with realtime workarounds for the cases in which these errors occur. This memo documents the analysis results. DM46/B. D. Perry and B. Clarke provided significant assistance.

The current understanding of the problem is that approximately 0 to 50 fps worth of error may occur in the ARD nominal MPROP channel with a single-SSME MR from 6.041 to about 5.800 (with two other nominal engines). This is the MR range from nominal engine operation to the usual point at which uphill capability is lost. The direction of error is ARD-pessimistic. This error could potentially result in TAL aborts if on the edge of uphill capability (even though uphill performance is actually available), or similarly, slightly excessive ATO OMS dumps to regain uphill capability. Also, realtime excessive FPR updates based on pessimistic imbalance output could further degrade calculated uphill capability.

RESULTS

Imbalance errors occur for SSME performance cases in which the engine is throttleable (i.e., biased-throttle), but the ARD throttle setting is locked. (All SSME performance cases are modeled as "locked" cases in the ARD to preclude the engine-out safing task from erasing the input power level in the event of a separate engine failure.) These types of cases include Pc shifts, fuel flowmeter shifts, etc. The ARD over-predicts unusable propellant at MECO (imbalance) which effectively increases the inert weight at MECO and decreases ΔV available. This results in pessimistic ΔV margin. The errors mainly occur because the ARD is assuming a constant throttle setting (and thus constant imbalance buildup), while in reality the SSME throttles through the 3-g profile and into fine count (which results in a lower imbalance buildup). Other factors contribute to the errors as will be shown below. These cases will be referred to as "biased-throttle cases."

Significant imbalance errors also occur for locked-throttle cases in which the SSME is shut down at 23,000 fps V_i (this occurs for a locked engine coupled with low performance, which is usually the case for low MR scenarios). Here the errors primarily

occur because the ARD assumes the MR hit is present all the way out to MECO, when in reality the engine will be shut down at 23k (about 8:00 MET, or 30 seconds prior to the ARD's expected nominal TMECO). In addition, a combination of stuck throttles, low performance, and a good engine-out require the locked engine to be shut down at 24,500 fps. Imbalance errors are present for this case as well. These lockup cases will be referred to as "manual shutdown cases."

ARD requirements concerning imbalance calculations were tailored to locked engine cases, and are not accurate for biased-throttle or man shutdown cases. From inspection of the requirements, it is possible to determine errors for a particular case. Several simulations were performed on SVDS/Bench ARD and the ascent trainer to verify the requirements-derived errors matched actual errors (this was performed for biased-throttle cases only; HP9000 runs were performed to verify manual shutdown imbalance errors).

REQUIREMENTS ERROR COMPONENTS

Once the thrust limiting (K69) flag is set, the following errors occur for low as well as high MR cases. The errors are only appreciable for low MR cases (as shown below); therefore, these descriptions concentrate on the low MR scenario:

- 1) Tgo Error/Manual Shutdown Error - The general velocity margin subtask calls the fuel oxidizer ratio model to obtain LOX (or LH2) flowrate error (i.e., non-6:1 flowrate). This flowrate error is integrated over time to obtain the predicted imbalance at MECO caused by the MR hit. However, Tgo is used as the flowrate error integration timespan rather than time to low-level cutoff (or time to 23k shutdown, or time to 24.5k shutdown), which is really when the flowrate error will cease. For cases in which a depletion cutoff (or 23k or 24.5k shutdown) is expected (rather than burn to TMECO), some error will be incurred by the ARD applying the flowrate error for an excessive time.

$$\text{biased throt: } \delta \dot{M}_{\text{lox}} * (\text{Tgo} - \text{Time to LLCO}) * \%P.L.$$

$$\text{main shutdown: } \delta \dot{M}_{\text{lox}} * (\text{Tgo} - \text{Time to s/d}) * \%P.L.$$

with

$$\text{Tgo} - \text{Time to LLCO} = \text{pred u/s} / \text{accel}$$

$$\text{Tgo} - \text{Time to s/d} \approx 30 \text{ sec (23k occurs about 8:00 MET for 3-engine case)}$$

$$\approx 15 \text{ sec (for 24.5k shutdown; case-dependent)}$$

$$\%P.L. = \text{SSME case power level (locked in ARD)}$$

$$\begin{aligned} \delta \dot{M}_{\text{lox}} &= MR * \delta \dot{M}_{\text{th}_2} * (1 - MR_{\text{nom}}/MR) \\ &= MR (T/ISP) / (1+MR) * (1 - MR_{\text{nom}}/MR) \end{aligned}$$

(This is the non-6:1 flowrate component due to the off-nominal MR. Integration of $\delta \dot{M}_{\text{lox}}$ over the remaining burn time yields imbalance once the original Fuel Bias is factored in.)

- 2) 3-g Throttle Error - Each cycle the fuel oxidizer ratio model calls the valve limit model to obtain current power level, ISP, and MR. These parameters are applied over the remainder of the powered flight profile (i.e., Tgo seconds) for imbalance computations. This is correct if the SSME is truly locked (and will not be shut down); however, for biased-throttle cases, the SSME will experience 3-g throttling. The fuel oxidizer ratio model does not account for the reduced flowrate error that occurs during 3-g throttles. The error is given by the difference between the ARD's computed imbalance (with engine locked) and the true imbalance assuming an average throttle setting over the 3-g throttle delta time. This component is not relevant for locked SSME cases (the engine does not throttle down) or engine-out cases (3-g's not reached).

$$\delta \dot{M}_{\text{lox}} * 3g \text{ throt delta time} * (\%P.L. - \text{Avg } 3g \text{ throt}\%)$$

with

3g throt delta time \approx 49 sec (not including fine count; this time obtained from ascent trainer runs, pretty generic)

%P.L. = SSME case power level (locked in ARD)

Avg 3g throt% = average throttle setting during 3g throttle-back profile

\approx 87 percent

- 3) Fine Count Error - This rationale is similar to the 3-g throttle error. The difference is the timespan over which the flowrate error is applied (10 sec for nominal MECO or 10 sec - u/s / accel for a low level cutoff case), and the throttle setting difference (the locked power level - 67 percent for the three-engine case). The error is given by the difference between the ARD's computed imbalance (with engine locked) and the true imbalance calculated using the fine count throttle setting. This is not applicable to locked engines where a 23k shutdown is performed.

$$\delta \dot{M}_{\text{lox}} * \text{fine count delta time} * (\%P.L. - \text{fine count } \%P.L.)$$

with

$$\text{fine count delta time} = 10 \text{ sec} - \text{u/s accel}$$

$$\%P.L. = \text{SSME case power level (locked in ARD)}$$

$$\text{fine count } \%P.L. = 67\% \text{ for three-engine case (act mode)}$$

$$= 91\% \text{ for two-engine case (hyp mode)}$$

- 4) Bucket Error - SSME performance cases that occur prior to completion of the throttle bucket have their throttle setting locked in the ARD at 1:07 MET. This is to avoid “wiping out” the ARD throttle bucket in the throttle table. However, the degraded ISP and MR are modeled at the correct time. Since x is computed for 100 percent RPL and then multiplied by the power level in the throttle table, there will be an error because the nominal power setting is the multiplier rather than the actual power level prior to 1:07 MET (67 sec). This induces a slight flowrate error in the fuel oxidizer ratio if the biased-throttle setting is significantly differently from 104 percent. This is not applicable to locked engines since ARD procedures call for this to be locked at the correct time in the ARD (not 1:07 MET). The error is as follows:

$$\delta \dot{M}_{\text{lox}} * \text{delta time} * \text{delta } \%P.L.$$

with

$$\text{delta time} = 67 \text{ sec} - \text{time of perf. case}$$

$$\text{delta } \%P.L. = \text{actual } \%P.L. - \text{nominal } \%P.L. \text{ (about constant throughout bucket)}$$

- 5) Fuel Bias Error - ARD is loaded with AOA Fuel Bias (944 lb for this study), since the ARD is set up with an engine-out propellant inventory. For uphill calls, the nominal Fuel Bias (983 lb) should be used in computing imbalance. The difference is 39 lb of LH2, which normally is negligible as far as imbalance is concerned (ΔV is accounted for in the nominal and uphill biases). However, it does matter for low MR cases where all of the Fuel Bias is burned. About 230 lb more LOX will be burned with the 39 extra lb of LH2 on a no-engine-out day. This error ramps in when the AOA bias has been consumed, and is fully in effect after the nominal bias of LH2 has been consumed by the MR upset (the ramping is almost negligible since the difference between biases is only 39 lb; the Fuel Bias is completely consumed by an MR of about 5.97). The ARD’s imbalance should be decremented by an amount dependent on the off-nominal MR:

- a) If AOA (944) bias not consumed (i.e., LH2 bias predicted):

$$\text{bias error} = 0$$

b) If nominal (983) is completely consumed (i.e., >230 lb LOX bias predicted):

$$\text{bias error} = (\text{Nom bias} - \text{AOA bias}) * \text{OBMR}_{\text{cluster}}$$

with

$$\text{Calc. Imp} = \delta \dot{M}_{\text{lox}} * \Delta \text{time} * \% \text{P.L.}$$

$$\% \text{P.L.} = \text{SSME case power level (locked in ARD)}$$

$$\Delta \text{time} = \text{sec that performance case is active}$$

Note that item 5 is not applicable to engine-out cases since AOA bias is correct in that circumstance.

The above formulas were incorporated into an Excel spreadsheet as a means to evaluate multiple cases. For given SSME performance case inputs, the above components are summed together and an equivalent ΔV error is determined. The attached spreadsheets (figures 6-13 and 6-14) illustrate inputs for typical low MR performance cases for biased and stuck throttle, respectively.

IMBERR.XLS

ARD IMBALANCE MODELING ERRORS

OFF-NOM ISP	453.570	sec	NOM FUEL BIAS	983	lb
OFF-NOM MIXTURE RATIO	5.800	mru	AOA FUEL BIAS	944	lb
OFF-NOM POWER LEVEL	100.6	%P.L.	NOM TRADE FACTOR	22.54	lb/sec
LOCKED ? (1=yes 0=no)	0		NOM THRUST (100%)	470636	lb
NOM MPROP	-285	fps	NOMINAL MIXTURE RATIO	6.041	mru
			NOM ISP	452.96	sec
			NOM-AOA UNUSABLES	1082	lb
					lb/fps
COMPONENT	ACT MODE	HYP MODE			
BIAS ERROR:	232	0	ACT U/S MECO DELTIME	-2.82	
TGO ERROR:	104	126	HYP U/S MECO DELTIME	-3.39	
3g THROTERROR:	245	0	DISP LH2 MDOT	152.59	
FINE COUNT ERROR:	89	23			
BUCKET ERROR:	84	84			
23K S/D ERROR:	0	0			
TOTAL IMB ERROR:	754	233			
DELTA-V ERROR:	-32	-10			
			ARD PESSIMISTIC		

NOTES:

HPOT Eff. Loss level 5

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Figure 6-13. Imbalance modeling errors for the HPOT case

IMBERR.XLS

ARD IMBALANCE MODELING ERRORS

OFF-NOM ISP	453.520	sec		NOM FUEL BIAS	983	lb
OFF-NOM MIXTURE RATIO	5.831	mru		AOA FUEL BIAS	944	lb
OFF-NOM POWER LEVEL	104	%RPL		NOM TRADE FACTOR	22.54	lb/sec
LOCK w/man S/D? (1=yes 0=no)	1			NOM THRUST (100%)	470636	lb
NOM MPROP	-285	fps		NOMINAL MIXTURE RATIO	6.041	mru
				NOM ISP	452.96	sec
				NOM-AOA UNUSABLES	1082	lb
						lb/fps
COMPONENT	ACT MODE	HYP MODE		ACT U/S MECO DELTIME	-2.82	
BIAS ERROR:	0	0	lb	HYP U/S MECO DELTIME	-3.39	
TGO ERROR:	0	0	lb	DISP LH2 MDOT	151.92	
3g THROT ERROR:	0	0	lb			
FINE COUNT ERROR:	0	0	lb			
BUCKET ERROR:	0	0	lb			
MANUAL S/D ERROR:	995	498				
TOTAL IMB ERROR:	995	498	lb			
DELTA-V ERROR:	-43	-21	fps	ARD PESSIMISTIC		

NOTES:

Elec Lockup level -3 @ 104%

J_24541_053

Figure 6-14. Imbalance modeling errors for electrical lock case

BIASED-THROTTLE SIMULATION AND SPREADSHEET COMPARISON

Several sample biased-throttle cases were picked to determine the extent of the imbalance problem, and simulations were performed to verify that observed errors could be explained by requirements errors (stuck throttle cases to be addressed below). Requirements errors were calculated by the spreadsheet using case specific inputs. SVDS/bench ARD runs were performed by S. Vyvial using T. Starkweather's SSME performance case input menu. Similar HP9000 Ascent Program runs were made by C. Edelen using the standard thrust limiting menu. The biased-throttle results are compared in Figure 6-15. HP9000 simulations were zero-σ, and SVDS runs were performed at nominal -3σ (unusables direct from TDDP). No ATO dumps were performed, in order to keep the study "simple."



Figure 6-15. Imbalance modeling errors analysis results

Looking first at cases 1, 2, and 5 (LOX imbalances at MECO rather than LH2), the sims confirm imbalance discrepancies between ARD and vehicle. Column 2 (VEH IMB) shows the imbalance from the vehicle simulations. SVDS results show lower LOX bias than the HP9000 even though slightly worse MRs were present (SSME performance case menu for SVDS is slightly off on MR from trainer). A possible cause for this is that SVDS nominal engine MR tags were 6.041, while the trainer used 6.0391, which would have diluted the bad MR effects somewhat. Column 3 (ARD IMB) lists the ARD imbalance predictions. The imbalance output for bench and trainer ARDs disagree by about 100 lb. The bench ARD imbalance comes in lower than the trainer probably because the bench ARD database is configured with 6.041 in the throttle table for the two nominal engines, and 6.0391 for FORNOM (NOMMXRT). Again, this slightly high MR configuration for the two nominal engines partially offsets the effects of the single bad engine in the fuel oxidizer ratio model. Thus the bench comes in slightly smaller even though the bad engine has a slightly lower MR than that modeled in the trainer ARD.

Column 5 (ACT IMB ERR) lists the ARD imbalance error with respect to the vehicle simulation. Column 6 shows the ARD ΔV margin error due exclusively to this imbalance error (inert weight error), with a positive number denoting ARD pessimism.

Actual underspeeds are listed in column 10 (DEL U/S) (note that different sigma levels were used for SVDS and HP9000). The observed underspeed differences in column 10 match fairly well with the underspeed error strictly due to imbalance errors (column 6). This indicates that ARD imbalance prediction errors are responsible for the majority of the underspeed discrepancies observed for these cases.

Imbalance errors calculated by the spreadsheet (derived from requirements errors) are listed in column 7. For HP9000 runs, they are about 100 lb short of observed errors

(i.e., known requirements errors account for about 90 percent of observed imbalance error). For SVDS/bench ARD the spreadsheet under-calculates by about 200-475 lb (i.e., 70 percent to 80 percent of the error is accountable). This indicates that additional, unidentified requirements errors may be present that are contributing to the imbalance errors. Alternately, it may indicate that some errors exist in spreadsheet calculations or assumptions, or that propellant inventory accounting methods are not accurate to this level of detail.

Cases 3 and 4 show that ΔV errors are negligible for high MR cases (LH2 biases). Imbalance error estimates were not conducted since the spreadsheet is configured for low MR cases only. Note that underspeed errors still occur despite the small imbalance differences, indicating (to no one's surprise) that simulation "noise" on the order of 10 fps is to be expected for these runs.

STUCK-THROTTLE SIMULATION AND SPREADSHEET COMPARISON

Four HP9000 runs were performed to verify the manual shutdown (23k or 24.5k fps Vi) error component (item 1 above). The following table summarizes the results and verifies that the ARD imbalance is pessimistic and the error can be calculated by the spreadsheet:

Table 6-7. ARD FPR buildup

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CONCLUSIONS

Simulations performed in support of this analysis task confirm that ARD imbalance errors do exist for low MR SSME performance cases. For scenarios in which uphill capability is being evaluated, this error may be from about 30 to 50 fps in the ARD-pessimistic direction.

For biased-throttle cases, known requirements errors account for about 80 percent of the observed imbalance difference. The remainder may be due to additional requirements errors, simulation propellant inventory bookkeeping problems, or errors in calculating the requirements error amount. Since the simulations indicate imbalance errors at least as great, and possibly greater than what the spreadsheet indicates, the currently identified requirements errors should be accounted for on console. The conservative course of action is to accept the spreadsheet and possibly underestimate the imbalance error by 100 lb or so. Biased-throttle errors are not significant for engine-out cases (i.e., hypothetical mode) since the major components disappear (3g throttling, Fuel Bias). Therefore, this error is applicable only to the uphill call, and performance nominal/low call.

Manual shutdown cases are simpler to calculate and HP9000 simulation results agree well with the spreadsheet. These errors apply to both three-engine and two-engine stuck-throttle cases (i.e., two or one good engines with one stuck). This requires correction to both the actual mode (AM) and hypothetical mode (HM) output. For the three-engine case, correction to the AM is required for the uphill call. For the two-engine case, the locked engine will be shut down at 24.5k Vi, which is about 15-20 sec prior to the two-engine MECO time. Correction for this delta time applies to the AM for the two-engine case. HM correction of the same amount on a three-engine case is required for the same reason (press calls).

Realtime implementation of these results was examined. Use of the spreadsheet on console probably requires too many inputs. An easier alternative is to use a plot of imbalance error vs. MR, since MR is the predominant factor in the error (Figure 6-16).

Biased throttle curve - In addition to MR, the other major independent variables are underspeed and power level. The underspeed is assumed to be design since the correction is intended for the uphill call. Imbalance error is not very sensitive to power level, so the power level is assumed to be 104 percent for this curve. (A biased engine at 96 percent (the lowest throttle on the main engine tables) alters the ΔV error from 104 percent only a couple of fps.)

Lockup curves - Two curves are plotted—one for a 104 percent lockup with a 23k shutdown, and one for a 67 percent lockup with a 23k shutdown. The 67 percent curve also approximates the errors expected for a 104 percent lockup with good engine out. This case would require the stuck engine to be shut down at 24.5k. Errors are unlikely for a 67 percent stuck-throttle case with a 24.5k shutdown (about half of the previous curve).

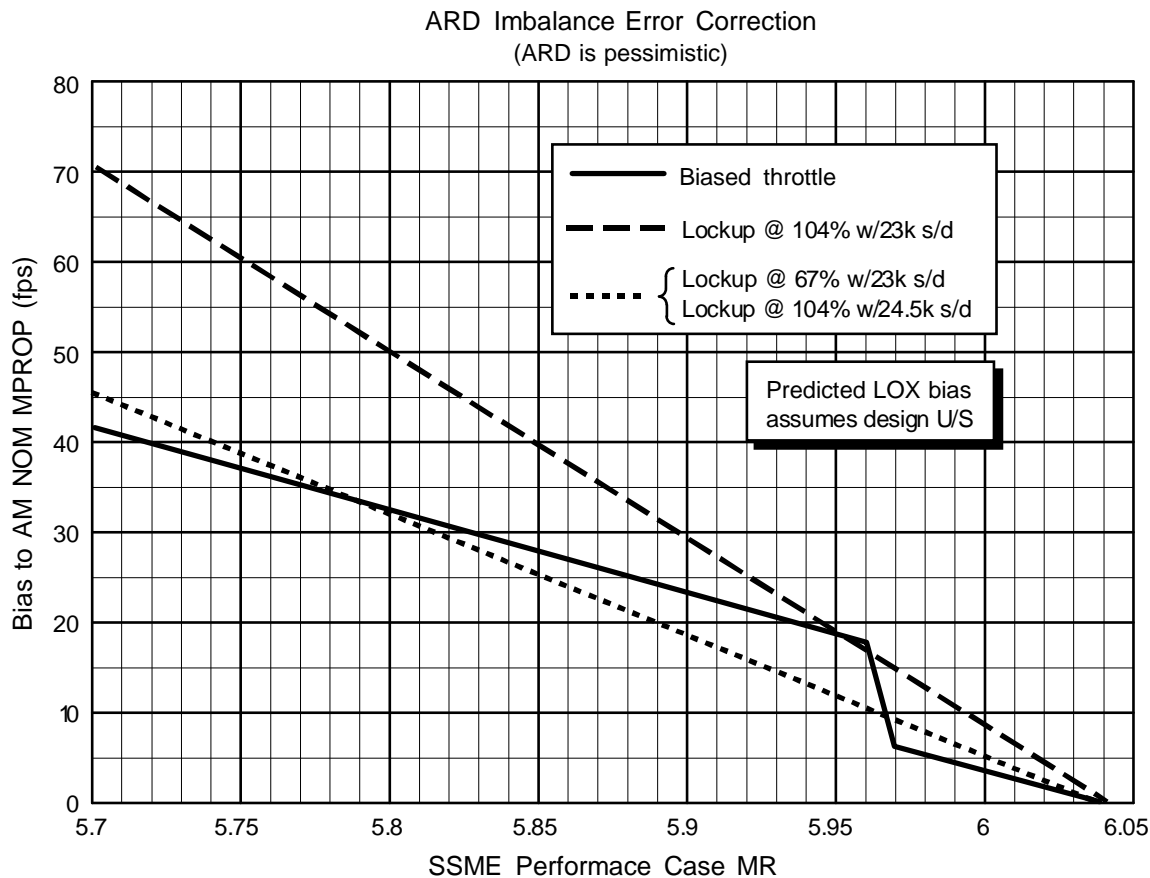


Figure 6-16. ARD imbalance error correction chart

For biased as well as stuck-throttle cases, these errors are primarily experienced during the last minute of powered flight. Therefore, if a low MR bias-throttle case occurs prior to 3-g throttling, then the error will be present. For lockups, if the engine is to be shut down manually (and it is a low MR case) then these errors will be present. The value from the chart represents a positive bias applied to the ARD ΔV margin output.

Realtime procedures worked out with DM46/E. P. Gonzalez, M. R. Abbott, and R16/M. West (STS-50 controllers) are as follows: In the event of a low MR scenario, ARD Support will pass the MR and performance case type (either “biased-throttle” or “stuck-throttle @ xx%”) to Abort Support. Using the pertinent curve, Abort Support will adjust the uphill bias in the more negative direction (i.e., better uphill capability), and inform the FDO. An alternate procedure is to add the bias to the actual mode nominal MPROP and tell the FDO what the corrected margin is. Stuck engines between 67 percent stuck throttle curve should be used for this; it is also labeled “Lockup @104% w/24.5k s/d.” This bias should be subtracted from the press to ATO and press to MECO biases in order to correct the ARD pessimism.

FURTHER WORK

Booster Officers are currently evaluating how much LOX imbalance is sufficient to guarantee NPSP requirements in the event of a stuck throttle and low performance. If the ARD can be used to assist in the realtime evaluation of this, then it may be possible to avoid shutting down a stuck engine/low performance at 23k for low MR cases. This would eliminate most of the imbalance error for the stuck throttle case and make correction of the ARD output unnecessary. (This would not alter procedures for biased-throttle cases.) Booster Officer data will be assessed once that study is complete.

The imbalance errors documented here could be rectified with an ARD SR, which could also include drifting modeling enhancements. Simplification of console procedures as a result of an SR would reduce potential for controller error and enhance flight safety.

6.7 DRIFTING THROTTLES REFERENCE MATERIAL

This additional material is presented in its original form as references, and to preserve the documents. Future PCNs to this section will combine all the information into a more conventional writeup.

Recent test stand data indicates time variant (drifting) SSME parameters will likely occur for hydraulic lockups. An analysis on the FDO trainer showed current flight average engine modeling procedures for the ARD may result in inaccurate uphill assessment abort boundaries. A new procedure has been developed that features interpolated engine parameters in the ARD and a correction console program to provide accurate trajectory modeling.

PROPOSAL FOR ARD MODELING OF DRIFTING SSMEs IN HYDRAULIC LOCKUP

OVERVIEW

Recent engine test stand data and information from Booster Officers has re-emphasized the likelihood of drifting (time-variant) SSME performance in the event of hydraulic lockup. An analysis of actual test stand SSME-drift data indicates that current flight average performance procedures result in large ARD mass track errors throughout most of the ascent profile. This causes erroneous assessment of uphill as well as abort capability. DM46/J. C. Edelen, C. W. Sparks, and W. D. Clarke developed an alternate method for modeling drifts that eliminates many shortcomings of flight average modeling. This method is outlined in detail along with proposed changes to console procedures.

BACKGROUND

An SSME was run under simulated hydraulic lockup at Stennis Space Center (SSC) on April 10, 1992, with increased clearances on the fuel preburner oxidizer valve. This was part of an evaluation of higher tolerance actuators, which is being conducted to reduce the hazard of valve binding during pneumatic shutdowns as well as increase actuator acceptance from vendors. Simulated lockup occurred at 20 sec during the test, and the engine drifted from 6.04 to 6.67 in MR (level 1 to 9), 104 percent to 96 percent in thrust, and finally shut down on a temperature redline exceedance at 370 sec. It was learned at the FDO/BSE Tagup that drifts are considered likely, with high MR cases occurring about 9 out of 10 times. This is better for performance than low MR cases, but increases the hazard of shutdowns due to temperature limit exceedance with an oxidizer rich combustion.

When vehicle performance capability was evaluated with this test stand data for the SSME Project Office, ARD problems were noted. With flight average predictions in the HP9000 ARD, up to about a 9000 lb mass error was present. This error is due to constant ARD engine tags trying to model a drifting real-world SSME. The mass error starts at zero, becomes ARD-heavy over time since the actual thrust is higher than average (in ARD), then trends back towards zero as the actual thrust decreases below

the average. Figure 6-17 shows this “rainbow curve” effect for flight average modeling with both MECO and the predicted engine-out time as endpoints for Booster average-determination. The flight average level 7 curve shows current modeling results; i.e., assuming the engine will run to MECO and obtaining a time-average level. Flight average level 5 curve is an example, assuming the BOOSTERS predict when the engine will shut down and use that time point to obtain an improved estimate of average performance. It turns out they do not actually have capability to give us accurate engine-out MET predictions in realtime, thus engine-out flight averages could be subject to large errors.

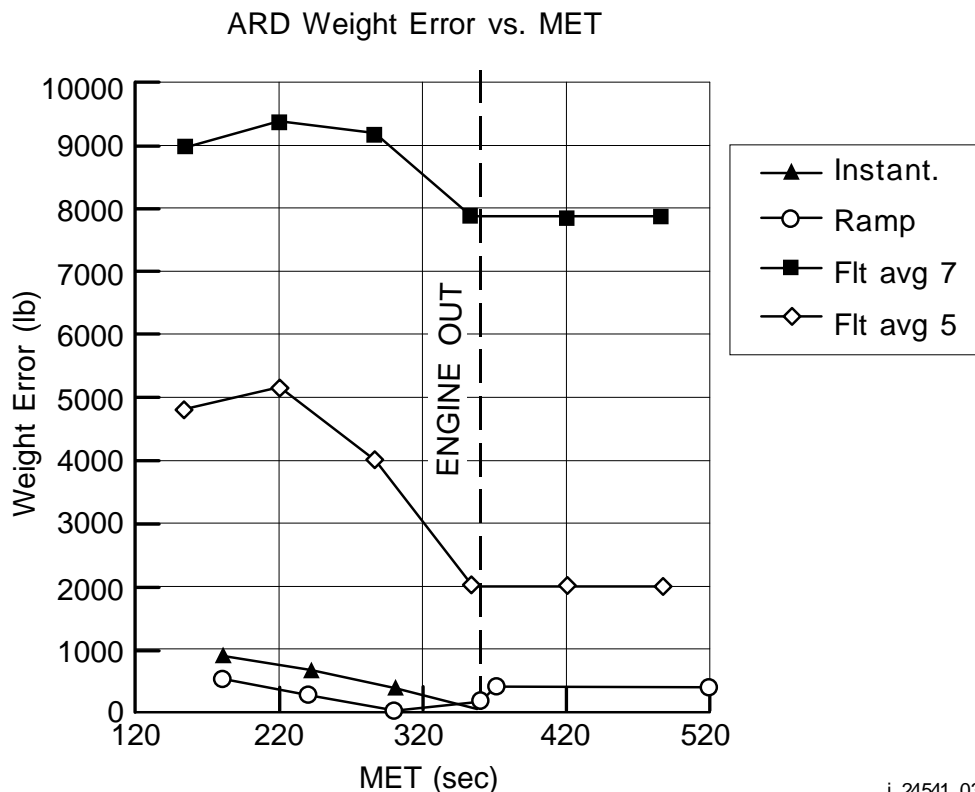


Figure 6-17. ARD weight error vs. MET

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From the plot, it is clear that current procedures (flight average) are not satisfactory for a drift of this magnitude. Flight average modeling may produce large weight errors that could be present at the time of engine failure, just when we need an accurate ARD the most. Alternatives to this method were pursued that would meet the following criteria (somewhat mutually exclusive as will be seen later), all of which rely on the first:

- Provide an accurate mass track at all times
- Provide accurate 3-engine uphill assessment
- Provide accurate bad engine-out abort boundaries
- Provide accurate good engine-out abort boundaries or uphill assessment following engine failure

RESULTS

Two methods were pursued in detail to evaluate the number one priority, accurate mass track. The instantaneous curve shown above assumes an updated instantaneous level from BOOSTER every minute. This kept weight differences small until the error exploded to 22,000 lb when throttle table lines ran out and the ARD erased previous entries to accommodate the engine failure. One other problem is that the ARD uses current ISP, thrust, and MR to extrapolate performance to MECO via ARDPEG and the imbalance model, rather than future average engine data. This produces a trending nominal margin that muddies uphill assessment (significant trend in AM nominal MPROP; see Figure 6-18) and also introduces errors into the good engine-out calls. Note that bad engine-out calls are okay since the ARD is extrapolating two constant-performance engines to MECO from an accurate mass track starting point. The principal disadvantage to instantaneous modeling is the hazard of running out of entries for lockups occurring at or before about 2:00 MET (assuming one update/ min and no other manual throttling or other engine out; two step nominal bucket profile will also suck up extra lines in the table).

The ramp curve on the plot shows a procedure that DM46/C. W. Sparks suggested. The procedure ramps the engine parameters in the ARD using consecutive throttle table entries and the linear interpolation routine. The initial level at time of lockup is input in the ARD with a K69 lock, and the next throttle table entry consists of MECO-predicted engine specs provided by BOOSTER (they have this capability). Bill Clarke determined that the second MED can be performed easily using the throttle table line number in the K69 menu rather than an "L" for a lock (this prevents the ARD from "stepping" the entry). The ARD interpolates between the entries every cycle to obtain current engine parameters, thus maintaining a good mass track. The throttle table for the SSC test run is shown below.

Table 6-8. Throttle Table for the SSC Test Run

Line	AM THRTL	PET	ISP	PET	MR	PET	Comment
1	0.00	-0:04	450.98	-0:04	6.0391	-0:04	
2	1.00	-0:02	452.51	-0:02	6.0391	-0:02	
3	1.00	0:03	452.51	0:03	6.0391	0:03	
4	1.04	0:04	452.96	0:04	6.0391	0:04	
5	1.04	0:08	452.96	0:08	6.0391	0:08	
6	1.035	0:10	452.72	0:10	6.075	0:10	K69 LOCK

Line	AM THRTL	PET	ISP	PET	MR	PET	Comment
7	0.925	8:32	448.33	8:32	6.911	8:32	K69 LINE No.
8	1.035	16:40	452.72	16:40	6.075	16:40	

It is clear from Figure 6-17 that this method provides a good mass track, satisfying the first priority that is a prerequisite for the others. The third criteria (accurate bad engine-out calls) is also satisfied since two constant-performance engines are being propagated to MECO. For good engine-out calls, as with instantaneous level updates, the ARD uses current drifting SSME data to predict future performance rather than future flight average as it should. A similar problem is encountered with propagation of three-engine data for three-engine uphill calls (again, same problem as with instantaneous updates). This results in the trending three-engine nominal MPROP seen in Figure 6-18 prior to the bad engine-out. (After the engine failure, the margin flattens out to an accurate number, since the drifter is gone.) These difficulties are addressed next.

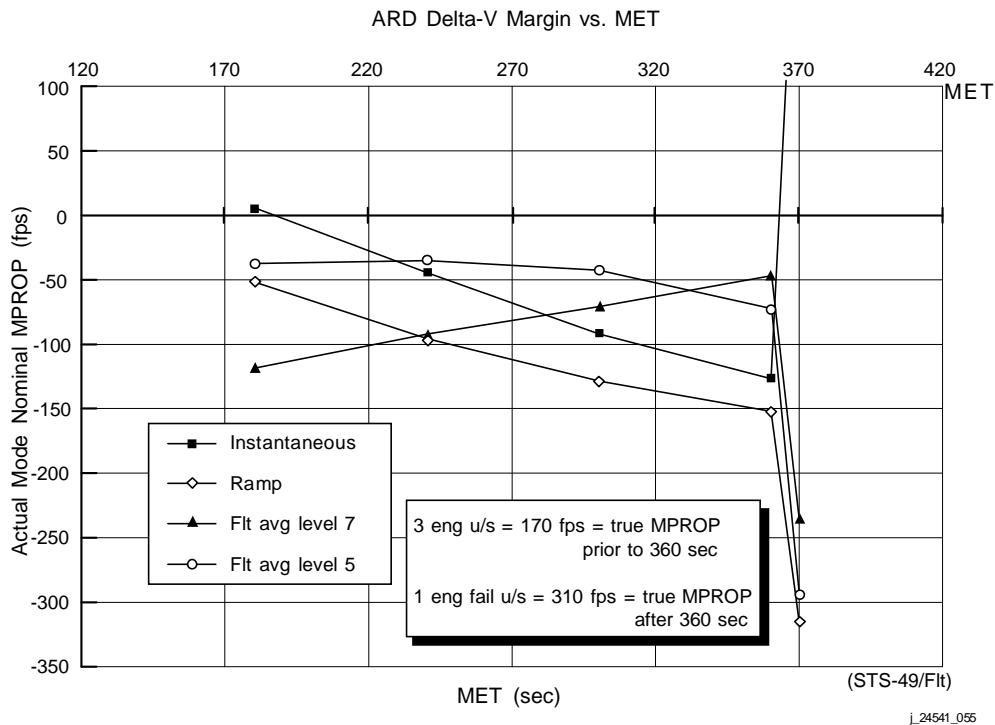


Figure 6-18. ARD ΔV Margin vs. MET

For drifting throttles, maintenance of an accurate masstrack is inconsistent with propagation of future average throttles for two reasons. First, there is only an AM MR and ISP table, unlike throttles that have AM and HM slots. This prevents simultaneous modeling of current engine data in the AM and future average data in the HM. To

further complicate matters, future average engine parameters change continuously since the AM interpolation is changing continuously. For example, the future average throttle (or MR, or ISP) value at any given time = (current + MECO predicted)/2). This is what the ARD should be using in its PEG ΔV available predictions that feed into the velocity margins; this MR value should be used to predict the propellant imbalance remaining at MECO. The time-variant nature of MR, ISP, and power level make modeling good engine-out and three-engine calls extra difficult. This is not a negligible error --- the AM nominal MPROP used for uphill assessment trended -100 fps and -200 fps for the high and low MR cases evaluated, respectively.

After exploring several options (including, for example, ramped thrust limiting on one engine in the AM (say right), 208 percent on the left, and 0 on the center; and future average thrust limiting on the HM center, 0 percent on the right, and 104 percent on the left--pretty messy), a potential workaround was developed to provide accurate uphill assessment as well as good engine-out evaluation capability. It features the ramped thrust limiting profile outlined above for good mass track, and includes spreadsheet-calculated correction biases to account for future engine degradation. (No satisfactory solution was found for making this work internally to the ARD.) The goal is for the sum of ARD nominal MPROP plus correction bias to be time-constant, and reflect true ΔV margin (satisfying the second priority outlined above). The bias would be manually applied in realtime to the AM nominal MPROP to correct the trending ΔV margin in order to assess uphill capability, and could be checked periodically to ensure constant value. For good engine-out boundaries, no satisfactory method was found to correct the hypothetical mode errors. However, after a good engine failure and ARD modeing to two engines running, the spreadsheet may be quickly reconfigured to correct the AM nominal margin for two-engine uphill determination similar to how it is done for three engines.

The spreadsheet in Figure 6-19 computes correction factors over second stage. The inputs obtained from BOOSTER are initial performance case level, power level and time, followed by predicted performance case level and power level at 8:30 MET. (Their processors currently compute flight average specs, so some BOOSTER procedural changes will be necessary to calculate MECO (8:30) predictions from this data.) The spreadsheet then calculates linear interpolated specs for each minute of second stage (same as what the ARD will be propagating at each minute). Future flight average data is also computed for each minute (what the ARD should be propagating). ARD errors for MR, ISP, and power level are determined based on the difference between what the ARD propagates and what it should propagate. Finally, the errors are summed and converted to fps error in the ΔV margin output.

An extrapolator column is also available to handle good engine-out cases. The spreadsheet is configured by inputting the new MECO time in the extrapolator for new MECO predictions (assuming same linear equation). This data is then inserted into the MECO column for readjustment of the future flight average calculations. Calculations are performed as above except for two engines rather than three.

HIGH MR RESULTS

The spreadsheet in Figure 6-19 is set up for the test stand engine drift. MR error leads to an optimistic ARD imbalance prediction since the ARD is propagating optimistic ramped data rather than more pessimistic future flight average. The flowrate error is determined and a delta imbalance calculated with the same equations used in the ARD fuel-oxidizer ratio subroutine, ARDFOR. The rocket equation is used to convert this dry weight error into a ΔV available error. ISP error corrupts exhaust velocity which is used in ΔV available calculations (rocket equation). Once again the rocket equation is used to determine the error and convert this into fps. (Carson found that Vex errors in ARDPEG influence V_{go} minimally; this is not accounted for in this algorithm or FPR incidentally). Power level error also introduces ΔV margin errors since the performance hit due to future thrust degradation is not being modeled. Carson Sparks performed a trade study a few years ago to determine ΔV margin error vs. thrust error, and the time-variant data was incorporated with a curve fit. Results were double-checked against R. Schmidgall's performance-hit back-pocket number of 1000 lb performance hit/1 percent throttle-back/3 engines from the 100 percent study. They compare well. See the appendix for a detailed explanation of these calculations.

HYDR. LOCKUP DRIFT MODELING CORRECTIONS								
	Initial		Extrapolated		MECO			
Level	-1		-5		-4			
Throttle	102.50		93.35		95.50			
MR	5.957		5.719		5.775			
ISP	453.21		453.76		453.63			
MET(s)	120		630		510			
Actual Mode SSMEs		3						
MET	120	180	240	300	360	420	480	540
Current Throt	102.50	101.42	100.35	99.27	98.19	97.12	96.04	94.96
Current MR	5.957	5.929	5.901	5.873	5.845	5.817	5.789	5.761
Current ISP	453.21	453.27	453.34	453.40	453.47	453.53	453.60	453.66
Future Ave Thro	99.00	98.46	97.92	97.38	96.85	96.31	95.77	95.23
Future Ave MR	5.866	5.852	5.838	5.824	5.810	5.796	5.782	5.768
Future ISP	453.42	453.45	453.48	453.52	453.55	453.58	453.61	453.65
ARD LOXMDOT	911	901	891	880	870	860	850	839
ARD LHZMDOT	153	152	151	150	149	148	147	146
Current WT	1561487	1367953	1175098	982923	791427	600611	410475	221017
Imb Error	5205	3687	2441	1460	737	262	29	28
MR ΔV Error	-226	-161	-107	-64	-32	-11	-1	-1
ISP Error	3	3	2	1	1	0	0	0
Throt Error	-37	-21	-11	-5	-2	0	0	-1
Tot ΔV Error	-260	-179	-116	-68	-33	-11	-1	0

Figure 6-19. Hydr. Lockup Drift Modeling Corrections (level 12)

The correction bias (Tot ΔV Error) is added (subtracted in this case) to the ARD AM nominal MPROP to obtain true ΔV margin. Figure 6-20 shows how the trending ARD margin plus the correction bias curve, sum to a constant value, which should be the actual ΔV margin. When the high MR test stand data is run to MECO on the trainer without an engine failure (STS-46/FLT), actual -2 sigma underspeed for three engines to MECO is 115 fps, while the corrected ARD comes out to 70 fps u/s with nominal unusables factored in. The difference indicates some unexplained pieces to the puzzle may remain, or runs need to be performed with higher fidelity drift modeling (40 sec steps were used in the trainer). When the engine is failed at 6:10, as observed on the test stand, the ARD MPROP equals 2220 while the -2σ underspeed attained is 250 fps; again this difference is not understood. The spreadsheet-computed imbalance

correction closely matched the true imbalance. Actual was 6300 lb of LH2 (assuming the engine ran drifting to MECO) with ARD plus correction at a constant 6100 lb.



Figure 6-20. Hydr. Lockup Drift Modeling Corrections

R16B/S. Vyvial has found some differences between SVDS and bench ARD for fixed lockup cases. The 30-40 fps errors are currently unexplained, and it is not known whether this is an SVDS or ARD problem. A TATR has been submitted to resolve this discrepancy. It may be related to the above differences seen between the trainer environment and the ARD.

Low MR Results - Figure 6-21 shows a hypothetical low MR case that drifts from level -1 (MR 5.96) to level -4 (MR 5.78) at MECO. This was chosen to illustrate an approximate worst-case situation with average MR of 5.8, which is around the limit of uphill capability for a typical mission. No shutdown was modeled since SSMEs are supposed to run cool at low MRs and power levels, according to BOOSTERS.

Note that ARD errors are bigger in this case due primarily to the imbalance error from the optimistic ARD MR values that are being propagated out to MECO. For both the high and low MR cases the errors tend to go asymptotically to zero around 6:00 MET,

so at some point the ARD error can be deemed negligible. For early assessment of uphill capability though, the correction factor should not be neglected.

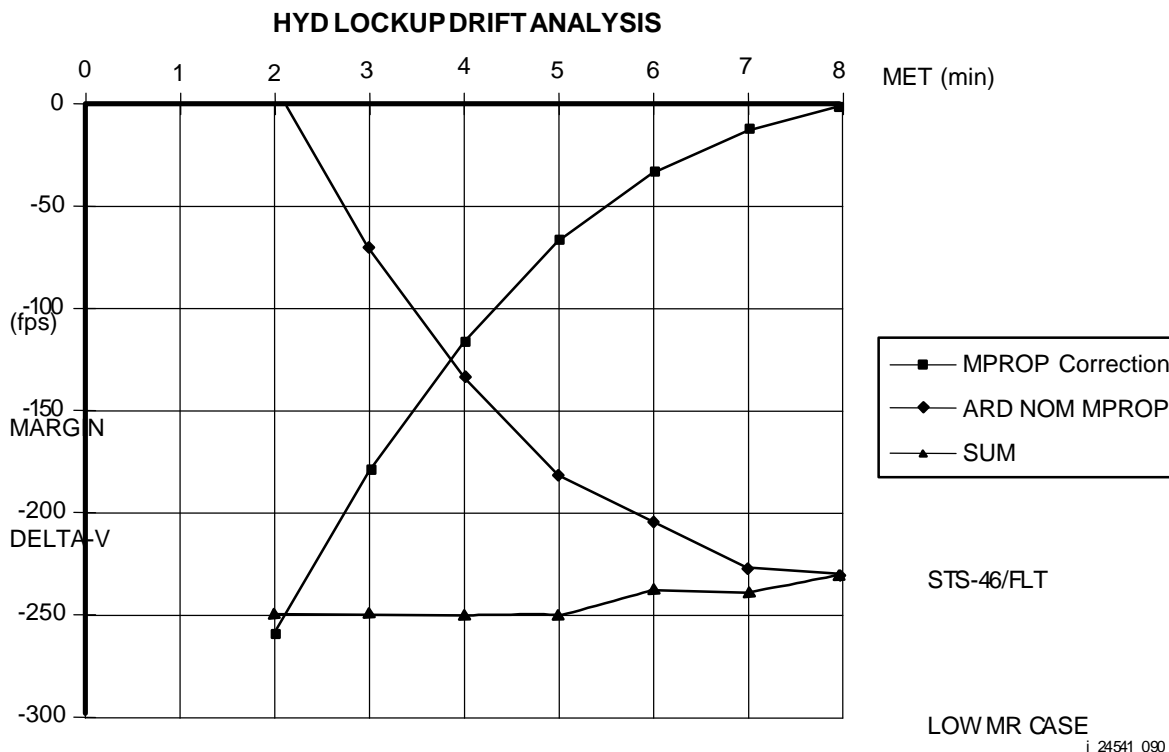


Figure 6-21. HYD Lockup Drift Analysis (level 4)

Figure 6-21 illustrates ARD AM nominal MPROP trend along with the ΔV error and their sum. The actual -2σ underspeed attained was 208 fps while ARD with nominal unusables predicted around 215 fps. The actual imbalance was 4300 lb of LOX, compared to ARD plus imbalance correction of 4300 lb.

CONSOLE PROCEDURES

The proposed console procedures were developed by DM46 personnel.

- 1) After APU fail, SSME is locked in ARD at level 0 when lockup is confirmed (same as current procedures).
- 2) Initial performance level and throttle from BOOSTER are input (overwrites level 0 lock if different) as lock along with FPR weights.
- 3) ARD Support determines throttle table line number for entry immediately after initial lock and passes this to TRAJ.
- 4) Bad engine-out is set up in HM.
- 5) Predicted MECO (i.e., 8:30) level and throttle from BOOSTER are input with K69 MED using throttle table line number rather than "lock" (AM only).

- 6) ARD Support evaluates FPR based on sum of ARD MECO imbalance prediction plus error from the spreadsheet and passes new FPR to TRAJ if necessary; passes FDO predicted nominal MPROP for uphill evaluation (ARD nominal MPROP plus correction bias from spreadsheet).
- 7) FDO makes boundary calls based on bad engine out; uphill evaluation is made with nominal MPROP behavior and ARD Support's estimation of where it is heading. TAL aborts should be delayed as long as practical to allow the margin maximum time to settle out.

If a good engine shuts down early, the following should be done if the failure occurs close to PTA:

- 1) Base uphill capability on the critical underspeed and no ATO dump.
- 2) ARD Support enters new MECO time in the "good engine out" spreadsheet option. This provides a new correction curve for the ARD nominal MPROP, and the corrected MPROP ΔV margin is voiced up to the FDO for a heads up on where the margin is heading for uphill consideration.
- 3) Delay abort decision until the last TAL or ACLS capability in order to minimize the ARD prediction error.
- 4) If abort boundaries are required after 8:30 (e.g., single-engine press), then the throttle table must be modified with new TMECO engine predictions in order to maintain a good mass track past 8:30. This is obtained by ARD Support by extrapolating BOOSTER data from the initial and 8:30 inputs to the new MECO time (spreadsheet performs this function). This data should be input in the line immediately following the 8:30 predictions.

CONCLUSIONS AND FURTHER WORK

It is recommended that the ARD throttle table interpolation scheme and correction spreadsheet outlined above be incorporated into console procedures. This will provide a significant flight safety improvement over current procedures due to a better ARD mass track, which is essential for realtime trajectory evaluation. With the throttle table ramp, bad engine-out abort boundaries and post-engine fail uphill evaluation will be as accurate as normal ARD operations. Three-engine uphill and good engine-out performance assessments will require use of the correction spreadsheet if errors in the ARD solution are to be minimized prior to late in second stage. Initial spreadsheet results compare fairly well for the two cases examined, considering modeling difficulties. Differences between ARD and vehicle simulation underspeeds should be investigated and may result in modifications of the ARD correction spreadsheet. It is recommended that SVDS simulations be performed to resolve discrepancies between the correction spreadsheet and trainer underspeeds.

APPENDIX - DETAILED FORMULATION

The sections below refer to letters on the attached ARD correction spreadsheet (Figure 6-22).

- 1) Initial and 8:30 main engine performance specs obtained from BOOSTER are input here with the "Load Data" button. For a good engine-out case, the new TMECO is entered in the interpolation column, which linearly interpolates the initial and MECO data to determine new MECO specs. The "Good EO" button prompts the user for this new MECO time, transfers the interpolated MECO data to the MECO column to be used by the spreadsheet, and sets the AM number of engines to two.
- 2) Current engine parameters obtained from linearly interpolating between initial and MECO power level and performance level. This is calculated for each minute, and is identical to the engine parameters the ARD is using at the same points in time.
- 3) Future flight average engine parameters obtained from current engine data (B) and MECO data (A). This is calculated for each minute, and represents what the ARD should be using in its ΔV margin computations for future performance. Power level, ISP, and MR are all computed similarly:

$$\text{Future Flight Avg} = [\text{Current interpolated}(B) + \text{MECO predicted}(A)] / 2$$

- 4) ARD LOXMDOT and ARD LH2MDOT are LOX and LH2 flowrates the ARD is assuming for imbalance computations, thus they are based on current SSME data (B). Current WT is total weight (post-SRB sep) that is calculated assuming previous minute "current" SSME flowrates (B) for the locked engine and nominal flowrates for the remaining one or two engines.

$$\text{LH2MDOT} = \text{NOMTHR}/\text{ISP}(B) * \text{POWLEV}(B)/100 / (1 + \text{MR}(B))$$

$$\text{LOXMDOT} = \text{NOMTHR}/\text{ISP}(B) * \text{POWLEV}(B)/100 / (1 + \text{MR}(B)) * \text{MR}(B)$$

- 5) Imbalance error is the difference between what imbalance the ARD will calculate with current engine data (B) and what it would calculate if it used the future average predictions (C).

a) If low MR:

$$\begin{aligned} \text{IMB ERR} &= [\text{ARD LOXMDOT} * (1 - \text{NOMMR}/\text{MR}(B)) \\ &- \text{LOXMDOT}(C) * (1 - \text{NOMMR}/\text{MR}(C))] * (\text{Tmeco} - \text{Tcurr}) \end{aligned}$$

b) If high MR:

$$\begin{aligned} \text{IMB ERR} &= [\text{ARD LH2MDOT} * (1 - \text{MR}(B)/\text{NOMMR}) \\ &- \text{LH2MDOT}(C) * (1 - \text{MR}(C)/\text{NOMMR})] * (\text{Tmeco} - \text{Tcurr}) \end{aligned}$$

$$\text{LOXMDOT}(C) = \text{NOMTHR}/\text{ISP}(C) * \text{POWLEV}(C)/100 / (1 + \text{MR}(C)) * \text{MR}(C)$$

$$LH2MDOT(C) = NOMTHR/ISP(C) * POWLEV(C)/100 / (1 + MR(C))$$

- 6) MR ΔV Error is the ΔV margin error due to the imbalance error (E), and is given by the difference between the rocket equation using different inert (burnout) weights:

$$MR \Delta V ERR = Vex * 1n[MECOWT / (MECOWT + IMB ERR(E))]$$

MECOWT = nominal vehicle burnout weight

- 7) ISP Error is the ΔV error due to ISP difference between (B) and (C). This is also given by the rocket equation:

$$ISP \Delta V ERR = Vex * (ISP(B) - ISP(C)) * 1n[Current WT / MECOWT]$$

- 8) Throt Error is the performance hit due to future thrust degradation. It is determined from curve fit of a previous study by C. Sparks that calculates ARD ΔV error as a function of thrust error.

$$THROT ERR = (THR(B) - THR(C)) * (8.381 * 1n(MET) - 50.65)$$

- a) Similar results are obtained with a trade factor obtained from DM23/R. A. Schmidgall from the 104 percent vs. 100 percent power level study. The rule of thumb is about 4000 lb performance hit between the two, or about 1000 lb/percent throttle. A “WAG” of this trade factor for our purposes yields the following equation:

$$THROT ERR = (THR(B)-THR(C))*(1000/TF/3 SSMEs)*(Tmeco-Tcurr)/510 sec$$

TF = ascent performance trade factor (about 22 lbs/fps)

(Tmeco-Tcurr)/510 sec = fractional portion of ascent profile

remaining over which the thrust hit applies

- 9) The individual error components (F, G, and H) are added to obtain total ΔV error, negative meaning the ARD output is optimistic. For example, a negative ΔV Error is subtracted from MPROP to obtain predicted ΔV margin.

DRIFT. XLS

HYDR. LOCKUP DRIFT MODELING CORRECTIONS

LOAD DATA
(CTRL+0)
GOOD EO
(CTRL+G)
RETURN
(CTRL+R)
FLOT
(CTRL+)

	Initial	Interpolated	MECO
Level	0	-2	-2
Throttle	104.00	104.00	104.00
MR	6.041	5.885	5.901
ISP	452.96	453.41	453.36
MET (s)	0	570	510

(a)

Actual Mode SSME's

3

MET	120	180	240	300	360	420	480	540
Current Throt	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00
Current MR	6.008	5.992	5.975	5.959	5.942	5.926	5.909	5.893
Current Isp	453.05	453.10	453.15	453.20	453.24	453.29	453.34	453.38
Future Ave Throt	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00
Future Ave MR	5.955	5.946	5.938	5.930	5.922	5.913	5.905	5.897
Future Ave ISP	453.21	453.23	453.25	453.28	453.30	453.32	453.35	453.37
ARD LOXMDOT	926	926	925	925	924	924	923	923
ARD LH2MDOT	154	155	155	155	156	156	156	157
Current WT	1561551	1367059	1172574	978096	783625	589160	394702	200251
lmb Error	3023	2107	1339	722	257	-54	-211	-210
MR DV Error	-132	-92	-59	-32	-11	2	9	9
ISP Error	3	2	1	1	1	0	0	0
Throt Error	0	0	0	0	0	0	0	0
Tot DV Error	-129	-90	-57	-31	-11	3	9	0

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

i_24541_037

Figure 6-22. ARD Correction Spreadsheet

6.8 HANDLING SIGMAS - THRUST AND ISP DISPERSIONS REFERENCE MATERIAL

This additional material is presented in its original form as references and to preserve the documents. Future PCNs to this section will combine all the information into a more conventional writeup.

SSME THRUST AND ISP DISPERSIONS (WHAT THEY ARE, HOW THEY ARE HANDLED, AND HOW THEY AFFECT THE ARD FPR)

The mystical world of Dispersions and FPR can be very confusing. I find that a lot of it is due to not understanding the terms used, and the improper usage of those terms. Poorly labeled charts, lack of derivations, and few references also cloud the picture. This document will attempt to clear up some of the confusion.

One of the first things that I found confusing was the use of the word “dispersion.” There are two flavors of dispersions. First, there is a dispersion, mechanical or environmental, in the performance of a system or in its operating environment. Then there is the effect, or “dispersion” this off-nominal condition has on something else, such as propellant consumption. For example, a 3σ ISP dispersion may be 2.3 seconds. But it may cause a 3σ propellant consumption delta of 3000 pounds. Confusion can arise if you hear the phrase “the 2σ ISP dispersion is 4000 lb.” It is not clear what the 2σ applies to. Does it apply to the ISP dispersion on the engine or does it apply to the resulting effect of the propellant (prop) consumption dispersion? What they mean is an ISP dispersion (value not stated) caused a 4000 lb change (increase) in propellant consumption. (The change could have been negative.)

In this document we will discuss specification (SPEC), and flight-derived (FD) dispersion values. SPEC values are usually higher. They were set at the beginning of the STS program and are therefore very conservative. FD values are based on actual flight experience. They are usually updated after about eight flights. All mathematical manipulations to dispersions are performed the same way, no matter whether you are using SPEC or FD values.

One of these manipulations is converting between sigma levels. This is done by multiplying the 3σ value by $2/3$ to get the 2σ value, and by $1/3$ to obtain the 1σ value. Conversely, if you are given the 1σ value, you can calculate the 2σ and 3σ values. The example below shows this:

- 3σ thrust for 1 engine = 4593 lb,
- 2σ thrust for 1 engine = $4593 * 2/3 = 3062$ lb, and
- 1σ thrust for 1 engine = $4593 * 1/3 = 1531$ lb.

Another manipulation is converting a single engine dispersion to an equivalent dispersion on a system of two or three engines. This is done by applying the formula:

$$\sigma_{total} = \sigma_A + \sigma_B + \sigma_C + \sigma_D$$

Refer to any statistics book for a rigid, detailed application. For dispersions that are additive, like thrust, we get:

$$\sigma_{total} = \sigma_A + \sigma_B + \sigma_C + \sigma_D$$

and if $\sigma_A = \sigma_B = \sigma_C = \sigma_D$:

$$\sigma_{total} = 4\sigma_A$$

We will refer to this technique as the RSS method. For dispersions that are not directly additive, like MR and ISP, the approach is slightly different:

$$\sigma_{total} = \sqrt{\sigma_A^2 + \sigma_B^2 + \sigma_C^2 + \sigma_D^2}$$

and if $\sigma_A = \sigma_B = \sigma_C = \sigma_D$:

$$\sigma_{total} = \sqrt{4\sigma_A^2} = 2\sigma_A$$

We will refer to this technique as the RMS method. These are statistical methods that account for the probability that each engine (in a system of two or three engines) will have the full dispersion on it. Obviously, the probability that two engines will each have a 3σ dispersion on it is lower than the probability of one sick engine, but we still have to protect for it. So, we do not multiply the single engine dispersion by a factor of two, but rather by the square root of 2, thanks to the RSS method. Likewise, for a system of three engines, we multiply by the square root of 3 rather than by 3. This can be seen in the following example:

$$\begin{aligned} \text{RSS} &= \sqrt{\sigma_A^2 + \sigma_B^2 + \sigma_C^2 + \sigma_D^2} \\ &= \sqrt{4\sigma_A^2} = 2\sigma_A = 2 \times 3957 \\ &= 7955 \text{ lb.} \end{aligned}$$

Thrust can be measured directly on the test stand, whereas ISP requires a calculation (thrust/mdot). Thrust is also additive; i.e., the total thrust of the system is the sum of the individual thrusts. ISP is different in this manner also. The total ISP of the system is not the sum of the individual ISPs, but it is the total thrust divided by the total flow-rate. This is important because ISP dispersions are treated slightly different statistically. They use the RMS method. The difference is that you take an average value after squaring the sum, as shown below:

Given 3σ ISP for 1 engine = 2.3 seconds:

$$\text{RMS} = \sqrt{\frac{2.3^2 + 2.3^2 + 2.3^2}{3}} = \sqrt{\frac{15.87}{3}} = \sqrt{5.29} = 2.3$$

= 1.328 (3σ for three engines).

The result of the math averaging is that you end up dividing by the square root of the number of engines rather than multiplying by it. To statistically combine the two- or three-engine ISP dispersions, you still multiply by the square root. But the extra step is to then divide by the number of engines. Therefore, multiplying by the square root of a number and then dividing by the number is the same as dividing by the square root! Not knowing this can lead to a lot of confusion. When people first see that ISP is divided by the square root, they think “it is handled the opposite of thrust.” That is not quite true. In overall math manipulation, it is true. But in those math steps, and in theory, it is not true. It is not opposite, just slightly different. Another way to look at it is (numerator to statistically combine)/(denominator to average over three engines):

$$\frac{2.3 \times \sqrt{3}}{3} = 1.328$$

= 1.328 (3σ for three engines).

We have discussed how to change sigma levels and how to figure sigma values for one, two, or three engines. Now, let us walk through some calculations. Start with thrust. As shown in Figure 6-23, the 3σ thrust dispersion SPEC value for a single engine is 6000 lb. Simple division shows us that the 2σ and 1σ values are 4000 and 2000 lb, respectively. To find the 3σ thrust dispersion value for two engines, we RSS two engines at 6000 lb to obtain:

$$\text{RSS} = \sqrt{6000^2 + 6000^2} = 8485$$

= 8485 lb.

Likewise, for a system of three engines:

$$\text{RSS} = \sqrt{6000^2 + 6000^2 + 6000^2} = 10392$$

= 10392 lb,

or:

$$RSS = 10392 \text{ lb (} 3\sigma \text{ for three engines).}$$

The total 3σ thrust dispersion for the system of three engines is 10392 lb. Now, to model this in a simulation, one of the ways would be to divide 10392 by three engines running. This yields 3464 lb per engine. (Remember, thrust is additive.) This is how it is usually done. You do not put 6000 per engine!

Note that dispersion-wise three engines at 3464 have the same overall effect as one engine at 6000:

$$RSS = \boxed{} = 6000 \text{ lb,}$$

$$RSS = \boxed{} = 6000 \text{ lb.}$$

Likewise, you can work through the numbers for the 2σ (4000 lb) and 1σ (2000 lb) cases. When you finish that, you can see that the FD numbers are handled the same way, they just start with different values. Recall that the FD thrust dispersion values are reconstructed postflight.

The FD ISP values are not broken down per engine. The postflight reconstruction can only determine the ISP for the entire three-engine cluster. So, our starting point for calculations is now a cluster dispersion value instead of a single-engine dispersion value. A ton of confusion can happen right here! We will see that the cluster dispersion value is also the value you apply to each engine! This is simply due to averaging! For instance, the FD 3σ ISP cluster value is listed as .91:

Given 3σ ISP for cluster = .91 seconds. But if:

- SSME 1 = .91,
- SSME 1 = .91, and
- SSME 1 = .91,

then: cluster value = $(.91 + .91 + .91)/3 = .91$ seconds.

However, this cluster dispersion value is the only one we really need. We can calculate the rest. We know that we need to use the RMS method since ISPs are averaged. We do the calculation in “reverse”; i.e., what do three engines at .91 RMS to? The answer is: Given 3σ ISP for cluster = .91 seconds:

$$\begin{aligned} \text{RMS} &= \boxed{} = \boxed{} = \boxed{} \\ &= \boxed{} = \boxed{} = \boxed{} * (.91) = \\ &= 1.58 \text{ seconds (} 3\sigma \text{ for one engine).} \end{aligned}$$

Or, if you are given $1.58 = 3\sigma$ for one engine, then:

$$1.58 * \boxed{} = \boxed{} = .91 \text{ seconds (} 3\sigma \text{ for three engines).}$$

Notice that the system impact for three engines (.91) is less than that for one engine (1.58)! Recall that for thrust, the system impact for three engines is worse than that for one engine. Now that we have the 3σ ISP value for one engine, we can convert to the two-engine system value by the method described earlier; i.e., multiply by the square root of the number of engines and divide by the number of engines, which effectively is dividing by the square root of the number of engines:

Given $1.58 = 3\sigma$ for one engine:

$$1.58 * \boxed{} = \boxed{} = 1.12 \text{ seconds.}$$

Notice that the two-engine value (1.12 seconds) is not found this way:

$$\begin{aligned} \text{RMS} &= \boxed{} \\ &= 1.824 \text{ seconds (two engines dispersed),} \end{aligned}$$

or, per engine:

$$= 0.91 \text{ seconds (two engines dispersed).}$$

Rather, we use the same method as the three-engine case, knowing in advance that the answer we want is 1.58. Solving for X yields

$$\begin{aligned} 1.58 &= \boxed{} = \boxed{} = \boxed{} = \boxed{} = \boxed{} \boxed{} = \boxed{} X \\ X &= \boxed{} = 1.12 \text{ seconds.} \end{aligned}$$

We really do not use this value for anything except the two-engine running PEG VEX error in the ARD ISP reserve buildup. The main point is not to get confused between 1.824 dispersion on two of three engines running and 1.12 dispersion on two of two engines running. The 1.12 value is from having an engine out! The 1.824 value has three engines running, two of which are dispersed! Spiffy!

We can also show how the per engine value (.91 seconds) applies whether or not we have one, two, or three engines running dispersed.

$$\text{RMS} = \boxed{} = 0.91$$

$$\text{RMS} = \boxed{} = 1.824 \text{ or } .91 \text{ per engine}$$

$$\text{RMS} = \boxed{} = 2.736 \text{ or } .91 \text{ per engine}$$

Amazing!

Converting between sigma levels is handled the same way as thrust. Likewise, there is no difference in handling between SPEC and FD values.

Once we have these dispersions, they are modeled in a simulation to see what effect they have on propellant consumption. A system dispersion, such as ISP, can be positive or negative (± 2.3 seconds.). This flavor of dispersion is usually presented this way --- symmetrical about zero. The effect the dispersion causes may not be symmetrical. For example (hypothetical), a +2.3 second ISP dispersion may cause a +4000 lb increase in prop usage, but a -2.3 second dispersion may only cause a 670 lb decrease in prop consumption. This can be a confusing point. In the world of FPR, we want to protect against high prop usage cases.

Analysis is done to quantify these dispersion effects on prop usage. The dispersions are randomly chosen and combined using Monte Carlo techniques. Basically, "they" make a kazillion computer runs and note how the prop usage changed for each dispersion. From this data, they figure out a mean and standard deviation of prop consumption for each. The FPR and ARD FPR people need these numbers to know how large to make the FPR. The basic idea behind FPR is insurance! You want to carry enough extra gas to ensure that you do not run out before you reach the MECO target, even if you have some performance dispersions. But, being a rocket scientist, you want to minimize this amount, since it means less payload off the pad. If you have a completely nominal ascent, you would have carried along the entire FPR (usually 3000 - 4200 lb) to MECO for nothing! But, that is the price you pay in the big space program. The basic equation on which FPR is built is:

$$\text{FPR} = \boxed{} + \boxed{} + N \boxed{}$$

where:

- $\boxed{}$ = sum of all prop consumption means caused by 6:1 dispersions
- $\boxed{}$ = sum of all prop consumption means caused by NON 6:1 dispersions
- N = desired level of sigma protection. Flight design = 3.0, ARD = 2.0
- $\boxed{}$ = sum of all prop consumption standard deviations caused by 6:1 dispersions

- σ_{prop} = sum of all prop consumption standard deviations caused by NON-6:1 dispersions

The FPR equation is optimized by choosing a Fuel Bias that minimizes the total of FPR + bias.

As you can see, we further breakdown system dispersions into 6:1 and NON-6:1. The 6:1 dispersions affect prop consumption in a ratio of 6 to 1 between LOX and LH2. Therefore, no imbalance is built up due to these dispersions. You simply use more or less prop to reach your MECO target. Examples of 6:1 dispersions are thrust and ISP. We assume any change in the thrust or ISP is caused by something other than a MR change. Inert weight is also a 6:1 dispersion. Any change in the vehicle non-propulsive mass will cause the prop consumption to change. This also means that any error or uncertainty in the way we track the vehicle inert weight will cause a change in prop consumption from the expected nominal. Since any weight measurement will have some kind of inaccuracy in it, we must protect for it in FPR.

NON-6:1 dispersions are ET Loading and MR. The NON-6:1 dispersions affect prop consumption in an “unbalanced” way. Translated, ET Loading means that if the LOX and LH2 tanks are loaded in the wrong ratio, there will naturally be an imbalance, even if the flight goes perfect. The MR means if the engine valves/computer cannot maintain the proper MR, an imbalance will of course build up. More or less LH2 may be used for the nominal quantity of LOX, and vice versa. Since our vehicle is loaded with six parts of LOX for each part of LH2 by weight, this off-nominal MR will cause an imbalance of either LOX or LH2. The low MR cases are real performance killers, since not only does the imbalance become unusable prop to reach the MECO target, but you are carrying it along the trajectory as dead weight. Since the LOX weighs six times as much as the LH2, the LOX imbalance cases really hurt!

The current FD data for prop consumption due to certain dispersions are listed in Figure 6-24. This can be done for three different trajectories, Nominal, RTLS, and AOA. The ARD uses the AOA data. This reference is the current standard for building up ARD FPR. You can see this by looking at Figure 6-25, which shows the ARD FPR buildup, part of product ASCT 22A. The mean and 2σ values are directly input into the buildup. Aha, you say, what about ET Load and MR? Where are they? They can be found from Figure 6-26, if you enter the chart with a Fuel Bias of 944 lb. Looking up the mean and 2σ values yields 215 and 1692 pounds respectively. These are NON-6:1 dispersions, and they are a function of Fuel Bias. This chart allows you to look up mean and standard deviation of the cumulative effect of ET Load and MR for any reasonable Fuel Bias without having to make those kazillion computer runs. A lot of effort goes into the chart, and we will not try to explain the black magic behind it all here.

What about ISP and thrust? Their means match, but not their 2σ values. Why? Well, the answer is found in figures 6-27 and 6-28, which show the ARD-specific buildup for these components. We have these buildups, called ISP and Thrust Reserves for the ARD because the ARD does not know its mass perfectly. Notice that the last line in each buildup says if the calculation yields a value less than the 2σ value, then use the

2σ value. This hardly ever happens. If an ISP or thrust dispersion is present (non-thrust limiting), the ARD will be using an incorrect value to compute its flowrate, or \dot{m} . Since the ARD uses this \dot{m} over time to figure out how much it weighs, an error will build up. So, the ARD estimate of the ΔV available in the ET will be wrong. The Weight Error reserve calculations take this into account. Likewise, with dispersions present, PEG will incorrectly compute the ΔV remaining to reach the MECO target velocity because the ARD V_{ex} value will be off due to dispersions (ISP mainly), with thrust almost negligible. Think of it like this; the ARD is always computing a ΔV margin based on:

$$\Delta V \text{ Margin} = (\Delta V \text{ available}) - (\Delta V \text{ required})$$

The weight error affects the ΔV available portion, and the V_{ex} error affects the ΔV required part from PEG. If you were building FPR for something other than the ARD, or if the ARD had a perfect mass track and perfect PEG inputs, then you would use the FD 2σ values, and not the Reserve calculations.

Let's take a further look at the buildups. They have two components. Each component is based on the PTA point, the call for which the ARD is tailored to protect. The Weight Error component occurs because the ARD flowrate is wrong. Thus, for the high thrust case, the ARD will buildup a chunk of prop from lift-off to PTA that has not been burned yet, when compared to the vehicle. This makes the ARD "heavy", and falsely improves the ARD estimate of vehicle performance. The ARD thinks it has more prop, hence more ΔV , in the tank than it really does. For you ARD types, this shows up as an increasing nominal ΔV margin. This is also the case we want to protect for, since it could result in early Press calls. That is why the calculations use positive thrust and negative ISP dispersions - they both cause this upward shift. The Weight Error reserve is computed as a weight and then converted into a delta velocity via the rocket equation. This ΔV represents the error in velocity at the PTA point due to carrying the chunk of prop along instead of burning it. This ΔV is then converted to an FPR weight of prop via a trade factor.

The second component is called the PEG Prediction Error, which is due to the V_{go} error. This error occurs from PTA (or the call you are interested in) to MECO. The simple way to think of is that PEG needs accurate information to solve its guidance equations and reach the MECO target velocity. It uses the parameter V_{EX} , or exhaust velocity of the SSME gases, to figure out how well it will accelerate - how much "oomph" it is getting from the engines. Since there is no realtime feedback for ISP to PEG, it will be using an incorrect V_{EX} , and incorrectly calculate the time (velocity) needed to reach MECO. This requires more or less prop (ΔV), depending on the direction of the dispersion. We protect the high prop usage case. Because of the PEG error, the ΔV required computed by ARDPEG is not accurate. The vehicle uses an additional chunk of prop that we must account for. Notice that for thrust dispersions, the PEG Error reserve is small and is ignored, while for ISP, it is half of the total reserve. Also, note that the PEG Error reserve is calculated in terms of a ΔV and then converted to an FPR weight of prop via a trade factor.

The last thing to note in Figure 6-25 is the TOTAL. You can see that the mean values are added, and the 2σ values are RSS'ed and then added to the means, just as our FPR equation indicates.

The trade factor is a way (via rocket equation) to see how much ΔV a given amount of prop is worth. This is mainly a function of time, since as the vehicle flies longer, it gets lighter, and the remaining prop can give the vehicle a bigger kick. The point we use to compute the trade factor is the PTA time. It is also a function of MECO weight, but this is not a large driver. The trade factor will vary slightly from flight to flight, but it is usually around 22 lb prop/fps.

A word about "thrust limiting." We really misuse this term in the FDO world. The phrase "performance case" is really more accurate. The BOOSTERS use "thrust limiting" to mean a very specific kind of performance case. Anyway, these are pre-defined cases of SSME performance shifts that provide adequate cues on the ground for the BOOSTER officer (BSE) to be able to determine what is happening. The BSE can then relay the new thrust (throttle), ISP, and MR for input into the ARD. The ARD is then "smart" about the situation, and should model the mass track and performance accurately. FPR protection is not for performance cases. It is for dispersions in the noise compared to anomalies, or for those cases where a dispersion causes a performance impact, but does not quite meet the criteria for a performance case. There is a special procedure we have to do with the ARD FPR when this occurs. Most performance cases have an off-nominal MR, thereby creating an imbalance, either LOX or LH2, that can be thought of as a new Fuel Bias. (A LOX imbalance is actually a negative Fuel Bias.) Recall that earlier we stated that the NON-6:1 dispersions are a function of Fuel Bias. So, now that performance case has created a new Fuel Bias, we must recalculate the NON-6:1 components of FPR and RSS them with the other components to get the new FPR! Since it is not possible to do these calculations quickly on the fly, the well prepared ARD Support uses a function on the laptop application called ARDTools. This is done on the fly in powered flight. As a backup, he has also made up a chart preflight that shows what FPR adjustment is required as a function of the new MR. This chart and the plot of it are shown in figures 6-29 and 6-30. The adjustment to the ARD is made by the FPR slot on the K67 MED. This sets gas aside from usable gas to "unusable" FPR (or vice versa). Of course, this is for one engine running at an off-nominal MR. If you get more than one, it gets a little more complicated, but the basic idea is the same.

WDC 7-8-91

FLIGHT DERIVED THRUST VALUES

7-5-91

3 SIGMA FOR ONE ENGINE = 4593
 3 SIGMA FOR TWO ENGINES $4593 * \sqrt{2}$ = 6495
 3 SIGMA FOR THREE ENGINES $4593 * \sqrt{3}$ = 7955

PER ENGINE = $7955/3$ = 2652

2 SIGMA FOR ONE ENGINE $4593/3 * 2$ = 3062
 2 SIGMA FOR TWO ENGINES $3062 * \sqrt{2}$ = 4330
 2 SIGMA FOR THREE ENGINES $3062 * \sqrt{3}$ = 5304

PER ENGINE = $5304/3$ = 1768

1 SIGMA FOR ONE ENGINE $4593/3$ = 1531
 1 SIGMA FOR TWO ENGINES $1531 * \sqrt{2}$ = 2165
 1 SIGMA FOR THREE ENGINES $1531 * \sqrt{3}$ = 2652

PER ENGINE = $2652/3$ = 884

SPEC THRUST VALUES

3 SIGMA FOR ONE ENGINE = 6000
 3 SIGMA FOR TWO ENGINES $6000 * \sqrt{2}$ = 8485
 3 SIGMA FOR THREE ENGINES $6000 * \sqrt{3}$ = 10392

PER ENGINE = $10392/3$ = 3464

2 SIGMA FOR ONE ENGINE $6000/3 * 2$ = 4000
 2 SIGMA FOR TWO ENGINES $4000 * \sqrt{2}$ = 5657
 2 SIGMA FOR THREE ENGINES $4000 * \sqrt{3}$ = 6928

PER ENGINE = $6928/3$ = 2309

1 SIGMA FOR ONE ENGINE $6000/3$ = 2000
 1 SIGMA FOR TWO ENGINES $2000 * \sqrt{2}$ = 2828
 1 SIGMA FOR THREE ENGINES $2000 * \sqrt{3}$ = 3464

PER ENGINE = $3464/3$ = 1154

Figure 6-23. Thrust and ISP values

FLIGHT DERIVED ISP VALUES		7-5-91
3 SIGMA FOR ONE ENGINE		= 1.58
3 SIGMA FOR TWO ENGINES	$1.58 / \sqrt{2}$	= 1.12
3 SIGMA FOR THREE ENGINES	$1.58 / \sqrt{3}$	= .91
	PER ENGINE	= .91
2 SIGMA FOR ONE ENGINE	$1.58/3 * 2$	= 1.053
2 SIGMA FOR TWO ENGINES	$1.053 / \sqrt{2}$	= .744
2 SIGMA FOR THREE ENGINES	$1.053 / \sqrt{3}$	= .61
	PER ENGINE	= .61
1 SIGMA FOR ONE ENGINE	$1.58/3$	= .527
1 SIGMA FOR TWO ENGINES	$.527 / \sqrt{2}$	= .373
1 SIGMA FOR THREE ENGINES	$.527 / \sqrt{3}$	= .304
	PER ENGINE	= .304

SPEC ISP VALUES

3 SIGMA FOR ONE ENGINE		= 2.3
3 SIGMA FOR TWO ENGINES	$2.3 / \sqrt{2}$	= 1.626
3 SIGMA FOR THREE ENGINES	$2.3 / \sqrt{3}$	= 1.328
	PER ENGINE	= 1.328
2 SIGMA FOR ONE ENGINE	$2.3/3 * 2$	= 1.533
2 SIGMA FOR TWO ENGINES	$1.533 / \sqrt{2}$	= 1.084
2 SIGMA FOR THREE ENGINES	$1.533 / \sqrt{3}$	= .885
	PER ENGINE	= .885
1 SIGMA FOR ONE ENGINE	$2.3/3$	= .767
1 SIGMA FOR TWO ENGINES	$.767 / \sqrt{2}$	= .542
1 SIGMA FOR THREE ENGINES	$.767 / \sqrt{3}$	= .443
	PER ENGINE	= .443

Figure 6-23. Concluded

AOA LEG

DISPERSION	MEAN	2-SIGMA	CONTRIBUTION
SRB BURNRATE	96.10	620.63	238.16
SRB ISP	29.56	824.05	200.01
SRB THRUST SHAPE	1.44	168.68	11.93
SSME THRUST	19.38	510.16	115.36
SSME ISP	0.00	629.85	146.31
SSME CLIMBOUT	0.00	68.33	1.72
COLLECTOR	41.05	254.90	64.87
INERT WEIGHT	-3.74	1655.24	1006.74

Figure 6-24. AOA LEG dispersions

ARD AOA FPR TABLE

STS 43- CYCLE --FRI

FPR ITEM	PRE-MISSION 2.0 SIGMA FPR VALUE	TO GET ARD 2.0 SIGMA, MULTIPLY BY	ARD 2.0 SIGMA MPS FPR	CONTRIBUTION TO ARD FPR	% CONTRIBUTION TO ARD FPR
ET LOAD & MR	215. + 1892.	1.000	215. + 1892.	215. + 979.	33.5
SSME ISP (1.78 SEC/SSME)	0. + 1156.	1.000	0. + 1156.	0. + 457.	156
SSME THRUST (4589.93 LB/SSME)	19. + 1244.	1.000	19. + 1244.	19. + 529.	18.1
INERT WEIGHT	-4. + 1655.	1.000	4. + 1655.	4. + 937.	32.0
SSME CLIMBOUT	0. + 68.	1.000	0. + 68.	0. + 2.	1
COLLECTOR	41. + 254.	1.000	41. + 254.	41. + 22.	.8
RESULTS			279. + 2925.	279. + 2925.	

TOTAL = 3204

L24541_041

Figure 6-25. ARD AOA FPR table

AOA LEG
 PARABOLIC FIT ANALYSIS

BIAS	FPR	FPR+BIAS	NON 6:1 ET LOAD & MR	
			MEAN	2-SIGMA
0	7973.3	7873.3	1986.0	4673.9
50	7500.3	7558.3	1815.0	4459.8
100	7155.7	7255.7	1643.9	4246.5
150	6826.6	6966.6	1502.6	4036.2
200	6492.0	6692.0	1361.0	3826.8
250	6102.7	6432.7	1228.9	3622.6
300	5889.7	6189.7	1106.2	3423.4
350	5613.6	5963.6	992.5	3238.4
400	5355.0	5755.0	887.6	3044.4
500	4891.9	5391.9	702.9	2697.5
550	4687.9	5237.9	622.3	2538.1
600	4502.9	5102.0	549.0	2389.2
650	4334.2	4984.2	482.7	2251.2
700	4183.9	4883.9	422.9	2124.7
750	4050.3	4800.3	369.1	2010.0
800	3923.0	4732.8	321.1	1907.3
850	3030.4	4600.4	278.2	1816.6
900	3741.8	4641.8	240.2	1737.6
950	3666.0	4616.0	206.6	1670.0
1000	3601.7	4601.7	177.0	1613.1
1050	3547.8	4597.8	151.1	1566.1
1100	3502.9	4602.9	128.4	1528.1
1150	3465.9	4615.9	106.8	1498.2
1200	3435.7	4635.7	91.8	1475.2
1250	3411.4	4661.4	77.1	1458.1
1300	3391.9	4691.9	64.5	1445.8
1350	3376.6	4726.6	53.8	1437.6
1400	3364.6	4764.6	44.6	1432.5
1450	3355.3	4805.3	36.9	1429.8
1500	3348.3	4848.3	30.4	1428.9
1550	3343.1	4893.1	24.9	1429.4
1600	3339.3	4939.3	20.3	1430.7
1650	3336.6	4986.6	16.5	1432.7
1700	3334.7	5034.7	13.4	1434.9
1750	3333.4	5083.4	10.8	1437.3
1800	3332.6	5132.6	8.7	1439.7
1850	3332.2	5182.2	6.9	1442.0
1900	3332.0	5232.0	5.5	1444.2
1950	3332.0	5282.0	4.4	1446.2
2000	3332.1	5332.1	3.4	1448.0
2050	3332.2	5382.2	2.7	1449.6
2100	3332.4	5432.4	2.1	1451.0
2150	3332.6	5482.6	1.6	1452.1
2200	3332.8	5532.8	1.3	1453.1
2250	3333.0	5583.0	1.0	1454.0
2300	3333.1	5633.1	.8	1454.7
2350	3333.3	5683.3	.6	1455.3
2400	3333.4	4733.4	.4	1455.8
2450	3333.5	5783.5	.3	1456.1
2500	0000.0	5000.0	.3	1456.5

Figure 6-26. Parabolic fit analysis

STS 43 CYCLE--FRI

ARD AOA FRP TABLE
 THRUST RESERVE

FOR 3 SSMEs OPERATING, THRUST DISPERSION:
 $D\text{-THRUST-3SSME} = 4589.9/\text{SQRT}(3) = 2650.0 \text{ LBS/SSME}$
 $D\text{-WDOT-3SSME} = ((470637.9 + 2650.0) * 1.04)/452.656 - (470637 * 1.04)/452.656$
 $D\text{-WDOT-3SSME} = 6.09 \text{ LBS/SEC/SSME}$

WEIGHT ERROR AT TIME OF SSME FAILURE 303.0 SEC
 $WT \text{ ERROR} = \text{TIME SSME FAILED} * 3 \text{ SSMEs} * D\text{-WDOT-3SSME} * 5534.4 \text{ LBS}$
 $VEHICLE \text{ WT AT } 303.0 \text{ SEC} = 964398.2 \text{ LBS}$
 $\Delta\text{-V WT ERROR} = \text{EXHAUST VELOCITY} * \text{ALOG}((\text{WT AT TEO} + \text{WT ERROR AT TEO})/(\text{WT AT TEO}))$
 $\Delta\text{-V WT ERROR} = (32.174049 * 452.656) * \text{ALOG}((964398.2 + 5534.4)/964398.2) = 83.3 \text{ FPS}$

THE PEG PREDICTION ERROR DUE TO THRUST ERROR IS SMALL COMPARED TO THE $\Delta\text{-V WT ERROR}$ AND IS IGNORED

TOTAL THRUST RESERVE = 83.3 FPS (FOR 3 SIGMA)
 TOTAL IN LBS = 1866.1 LBS
 FOR 2.0 SIGMA, THRUST RESERVE = 1244.1 LBS

NOTE: IF THIS NUMBER IS LESS THAN THE INPUT THRUST FPR OF 510.2 OBS, THE INPUT WILL BE USED

Figure 6-27. Thrust reserve

STS 43 CYCLE--FRI

ARD AOA FRP TABLE
 ISP RESERVE

TAG THRUST = 470637.9 LBS AT THROTTLE OF 1.00
 TAG ISP = 452.656 SEC AT THROTTLE OF 1.04

FOR 2 SSMEs OPERATING, ISP DISPERSION:
 $D\text{-ISP-2SSME} = 1.78/\text{SQRT}(2) = 1.255 \text{ SEC/SSME}$
 $D\text{-WDOT-2SSME} = (470637.9 * 1.04)/452.656 - 1.255 - (470637.9 * 1.04)/452.656$
 $D\text{-WDOT-2SSME} = 3.01 \text{ LBS/SEC/SSME}$

FOR 3 SSMEs OPERATING, ISP DISPERSION:
 $D\text{-ISP-3SSME} = 1.78/\text{SQRT}(3) = 1.025 \text{ SEC/SSME}$
 $D\text{-WDOT-3SSME} = (470637.9 * 1.04)/(452.656 - 1.025) - (470637.9 * 1.04)/452.656$
 $D\text{-WDOT-3SSME} = 2.45 \text{ LBS/SEC/SSME}$

WEIGHT ERROR AT TIME OF SSME FAILURE 303.0 SEC:
 $WT \text{ ERROR} = \text{TIME SSME FAILED} * 3 \text{ SSMEs} * D\text{-WDOT-3SSME} * 2230.8 \text{ LBS}$
 $VEHICLE \text{ WT AT } 303.0 \text{ SEC} = 964398.2 \text{ LBS}$
 $\Delta\text{-V WT ERROR} = \text{EXHAUST VELOCITY} * \text{ALOG}((\text{WT AT TEO} + \text{WT ERROR AT TEO})/(\text{WT AT TEO}))$
 $\Delta\text{-V WT ERROR} = (32.174049 * 452.656) * \text{ALOG}((964398.2 + 5534.4)/964398.2) = 83.3 \text{ FPS}$

PEG PREDICTION ERROR DUE TO EXHAUST VELOCITY ERROR:
 $\text{ARD MECO WT} = \text{ZERO MARGIN WT} + \text{GUESS AT FPR (+ MPS USED DURING PPD FOR RTLS)} = 326103.7 \text{ LBS}$
 $\Delta\text{ DV VEX ERROR} = \Delta\text{ EXHAUST VELOCITY FOR 2 SSMEs} * \text{ALOG}(\text{WT AT TEO}/\text{ARD MECO WT})$
 $\Delta\text{ DV VEX ERROR} = (32.174049 * 1.255) * \text{ALOG}(964398.2/326103.7) = 43.8 \text{ FPS}$

TRADE FACTOR FOR LBS/FPS:
 $TF = \text{ARD MECO WT} * (1. - \text{EXP}(-1./\text{EXHAUST VELOCITY})) = 22.39 \text{ LBS/FPS}$

TOTAL ISP RESERVE:
 $\text{TOTAL} = \Delta\text{-V WT ERROR} + \Delta\text{ DV VEX ERROR} = 77.4 \text{ FPS (FOR 3 SIGMA)}$
 TOTAL IN LBS = 1734.1 LBS
 FOR 2.0 SIGMA, ISP RESERVE = 1156.1 LBS

NOTE: IF THIS NUMBER IS LESS THAN THE INPUT THRUST FPR OF 629.8 LBS, THE INPUT WILL BE USED

Figure 6-28. ISP reserve

If sick engine shutdown or PC Sensor turned off, check Mass Imbalance task on appropriate channel.

OFF-NOMINAL MR DATA

MIXTURE RATIO	FUEL/LOX BIAS	NOMINAL LOADINGS		
		FINAL FPR VALUES - NOT INCLUDING MASS TRACK ERRORS	DELTA FPR	
5.75	20260	(LOX)	5800	
5.76	19340	(LOX)	5800	
5.77	18430	(LOX)	5800	
5.78	17510	(LOX)	5800	
5.79	16600	(LOX)	5800	
5.8	15690	(LOX)	5800	
5.81	14780	(LOX)	5800	
5.82	13870	(LOX)	5800	
5.83	12970	(LOX)	5800	
5.84	12060	(LOX)	5800	
5.85	11160	(LOX)	5800	
5.86	10250	(LOX)	5700	
5.87	9350	(LOX)	5700	
5.88	8450	(LOX)	5600	
5.89	7550	(LOX)	5500	
5.9	6650	(LOX)	5400	
5.91	5760	(LOX)	5300	
5.92	4860	(LOX)	5100	
5.93	3970	(LOX)	4900	
5.94	3070	(LOX)	4700	
5.95	2180	(LOX)	4500	-ΔETP
5.96	1290	(LOX)	4300	
5.97	400	(LOX)	4200	
5.98	80	(Fuel)	3600	+ΔETD
5.99	230	(Fuel)	2600	
6	370	(Fuel)	1800	
6.01	520	(Fuel)	1100	
6.02	670	(Fuel)	600	
6.03	810	(Fuel)	200	
6.04	960	(Fuel)	-0	
6.05	1100	(Fuel)	-200	USE ABS VAL
6.06	1250	(Fuel)	-300	
6.07	1390	(Fuel)	-300	+ΔETP
6.08	1540	(Fuel)	-300	
6.09	1680	(Fuel)	-300	
6.1	1830	(Fuel)	-300	-ΔETD
6.11	1970	(Fuel)	-300	
6.12	2120	(Fuel)	-300	
6.13	2260	(Fuel)	-300	
6.14	2410	(Fuel)	-300	
6.15	2550	(Fuel)	-300	

Figure 6-29. Off nominal MR data

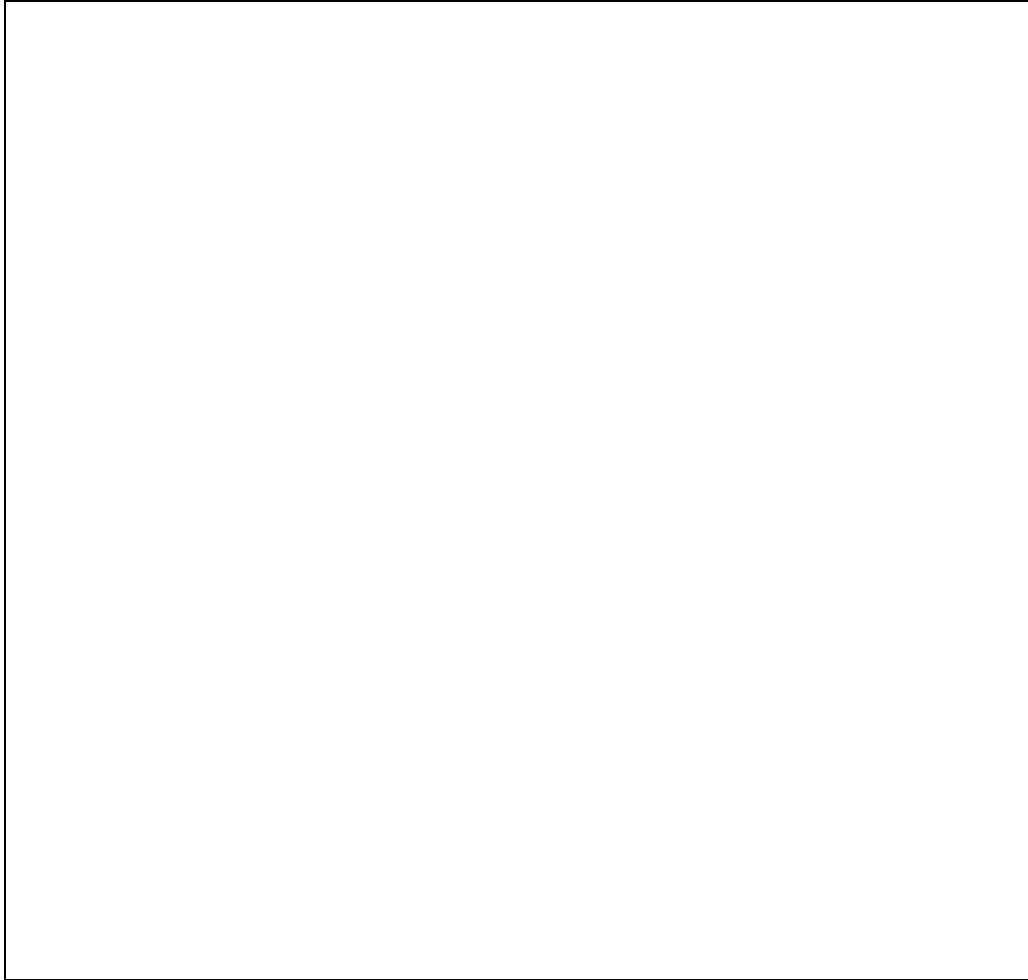


Figure 6-30. FPR delta as a function of Imbalance Output

6.9 BOOSTER UNCERTAINTIES

This section is in development. As of September 1, 1995, the subject is in the decision loop, being reviewed by the management and technical communities. It is not yet mature enough to be incorporated into official procedures, and the decision may be made to not incorporate them. Future PCNs to this document will rework and expand this section into a clearer, more useful, and readable write-up.

In addition to potential dispersions due to preflight tagging inaccuracies, realtime Booster Officer errors in performance case assessment may occur. These Booster Officer uncertainties in MR, ISP, and thrust can be attributed to engine instrumentation accuracy and rounding error between levels. Therefore, the throttle setting, MR, and ISP passed to TRAJ for incorporation into the ARD are not as accurate as actually input. This introduces modeling errors into the ARD and affects the FPR buildup substantially. To maintain required 2σ confidence in ARD calls, these uncertainties must be accounted for in FPR updates. Booster Officer ISP uncertainty is greater than flight-derived uncertainty only for nozzle leaks, so this is the only case where extra ISP holdback is required. Generically this is considered to be worth about TBD lb extra FPR and should be added to the nozzle leak FPR adjust table manually. Do not forget to include this if the laptop or FPR adjust curves are used in realtime, since they are not set up explicitly for nozzle leaks.

Booster Officer MR uncertainty has a large impact on FPR adjust quantities. For each case, total MR uncertainty is determined by combining Booster Officer MR uncertainty with flight-derived MR uncertainty. This value is input in the FPR adjust program to obtain the new FPR adjust curves. The effect of Booster Officer MR uncertainty is a very large upward shift in the Δ FPR curve on the low MR side. This shift becomes a significant portion of the total holdback, since Δ FPR for a low MR without Booster Officer uncertainties is about 5200 lb.

ARDTools on the laptop has the ability to account for these uncertainties and compute the correct FPR called for. However, this feature is not used at this time. It is uncertified and hard-coded to be inoperative.

In early April 1995, the ARD Support office received the official values of Booster (BSE) uncertainties for thrust, ISP, and mixture ratio (MR). These values represent the uncertainty in each of the values passed from the BSE officer to the FDO for use in the ARD. These were contained in a letter from MSFC/Dennis Gosdin to JSC/DF6/Brock Stone dated 3-17-95. The uncertainties stem from 3 sources:

- 1) Hardware sensor uncertainty,
- 2) Engine prediction uncertainty, consisting of at least 3 parts:
 - a) Inherent inaccuracies in the SSME power balance model,
 - b) Uncertainty in the ability to predict the engine characteristics at 200 seconds into flight,

- c) Inability to predict how the engine will rebalance with varying LO2 inlet pressure,
- 3) Error due to table rounding.

Since any error in the values of throttle (thrust), ISP, and MR directly affects ARD computations, and thus the abort mode boundaries, the Flight Performance Reserve (FPR) should protect for them to ensure abort capability exists when the call is made by the FDO. FPR does not currently protect for uncertainties; it does protect for system dispersions quantified by the post-flight reconstruction data. These are referred to as Flight Derived (FD) dispersions.

W.D. Clarke, with the assistance of Carson Sparks, and utilizing the advice of RID/John Wolfe, re-calculated the inputs required and computed the new FPR. With the uncertainties factored in, the FPR increases, and becomes a function of the engine performance case and imbalance. This increase is larger for the low MR cases, and is unacceptably large for cases involving an off-nominal flowmeter. There are three major issues that arise from this:

- 1) The performance loss from the increased FPR means loss of uphill capability (TAL abort required) on many flights if even a mild flowmeter case occurs. More severe cases for other failure modes can also cause this.
- 2) The imbalance created by an off-nominal engine can be large enough such that the low level cutoff protection system is not armed. This could potentially lead to a catastrophic fuel depletion situation.
- 3) If the uncertainties are protected for in preflight FPR, the required increase would mean that payload would have to be reduced.

Several minor issues also arise:

- 1) If adopted, the uncertainties will have to be formally documented, tracked, and updated, similar to the process now used for FD dispersions. Flight Rules will also have to be modified.
- 2) All FPR computations will have to be modified. This includes preflight FPR with its corresponding impacts on ascent performance margin (APM), realtime ARD FPR computational tools, and any Flight Design products involving FPR.
- 3) Many questions would have to be investigated in order to develop procedures for handling engine shutdowns when large imbalance problems arise.

The data and above issues were presented by Mr. Clarke at the Ascent/Entry Flight Techniques meeting #124 held on 6-2-95. DA8/Wayne Hale directed Mr. Clarke to present the issues at the AFSIG, which was done on 6-12-95. At the AFSIG, MS4/Doug Whitehead assigned no actions and made no decisions. However, he said he would talk to MA3/Ron Dittmore personally and elevate the issues. Mr. Whitehead suspected that no changes would be made to the current FPR philosophy, and that further investigation of the imbalance problem would have to be performed. Mr. Clarke

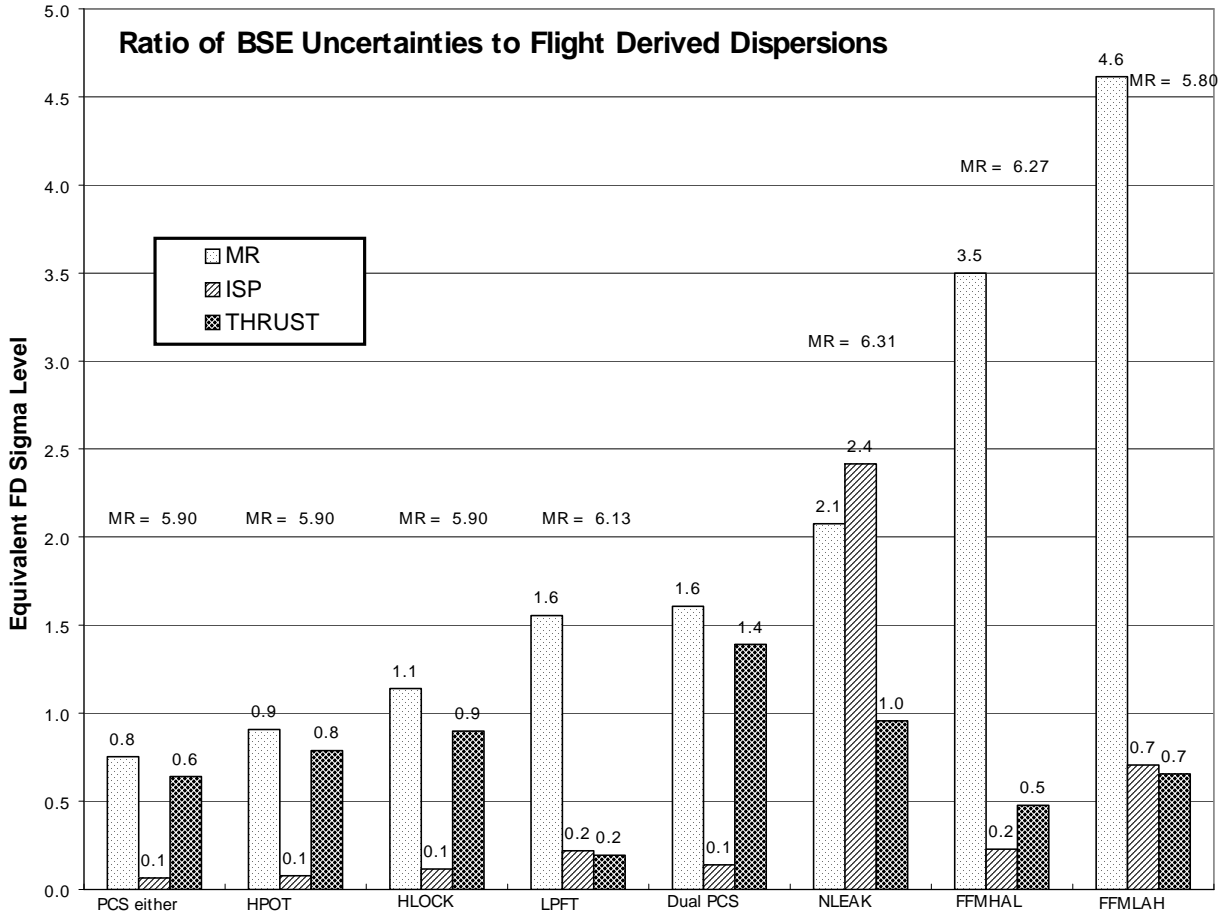
emphasized that the Flight Dynamics and Booster sections both wish to resolve this issue one way or the other, and with the appropriate documentation from an educated management. On 6-15-95, the issue was presented to MS/Lambert Austin and MS/Robert White by Mr. Clarke and Mr. Sparks at a meeting also attended by Mr. Whitehead.

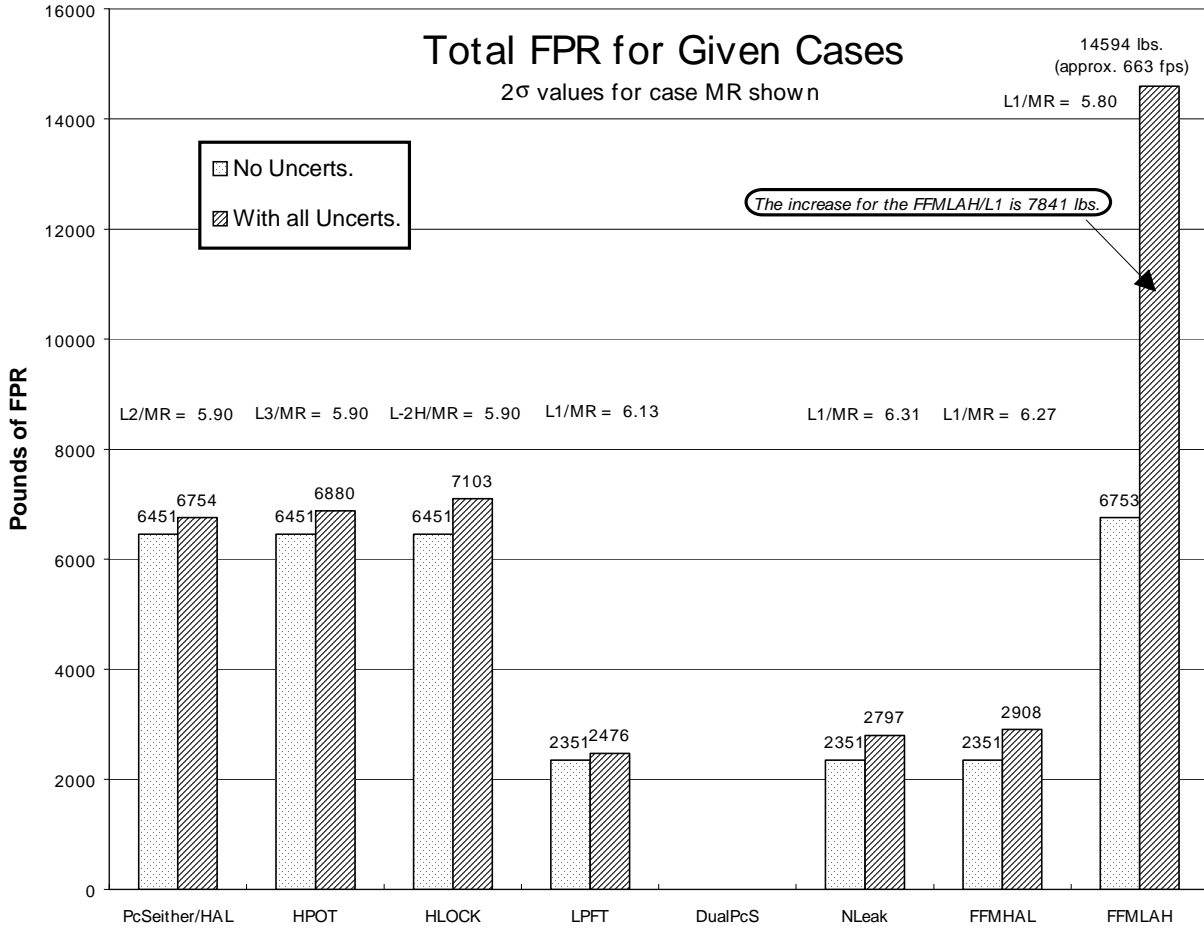
The data was presented again at a special combination AFSIG/PSIG on 7-18-95.

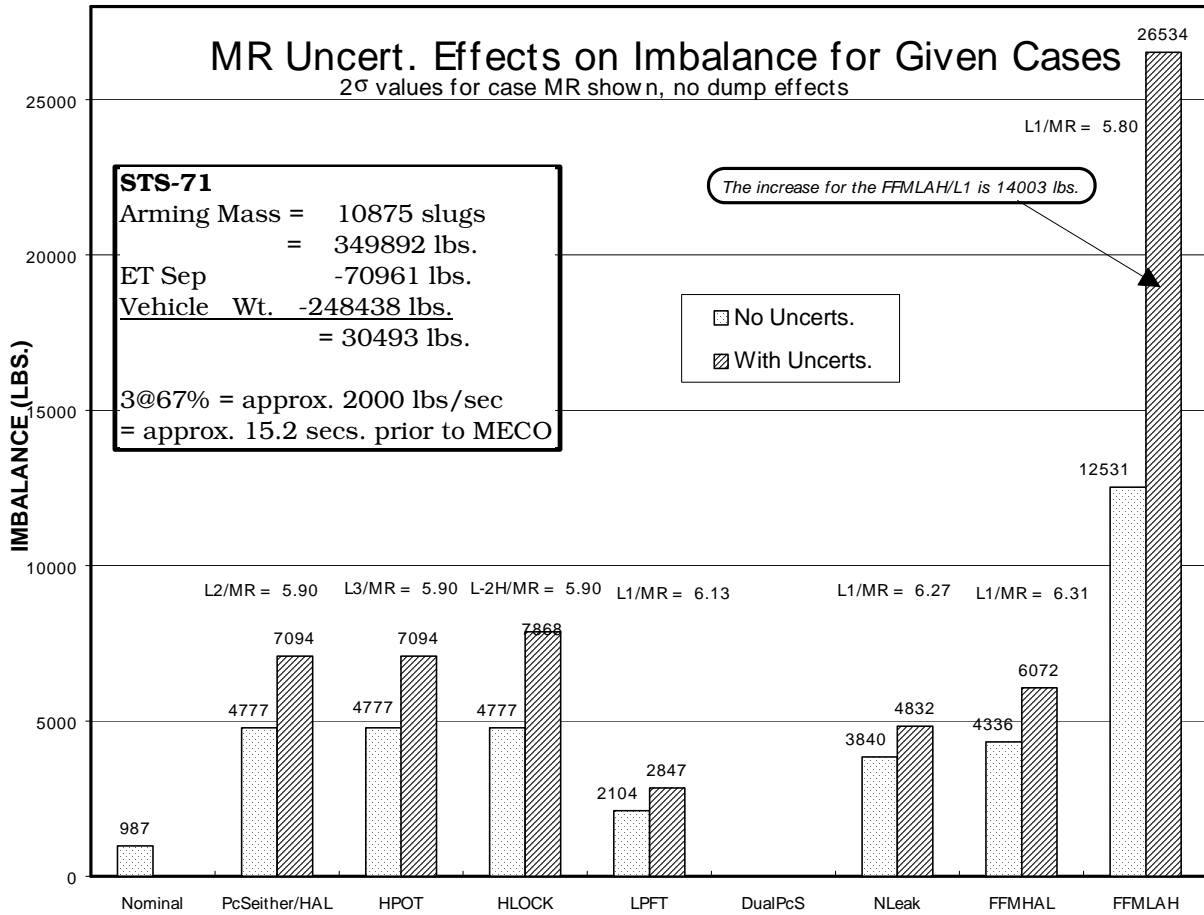
On 8-1-95, the pitch was presented at the ICB, chaired by Lambert Austin. Mr. Whitehead and Mr. Previtt were both in attendance, along with a host of others. After presentations from Ken Dwyer and Bill Clarke, Mr. Whitehead gave his recommendation that the uncertainties not be incorporated into FPR. Mr. Austin seemed to agree overall, but made no official decision. He gave an action to Rockwell Downey to characterize the risk/probability of getting into a Flowmeter case. He also asked them to compute (if it is possible to do) what equivalent sigma level it would take to get all the conditions just right to cause this scenario. RID owes an estimate of the size of this analysis task back to the AFSIG in two weeks. Mr. Austin implied that his eventual decision was going to be to ignore the uncertainties, and that this RID analysis would provide some more background information to support his rationale. Whatever the decision, a "CR" would eventually be written to document it in NSTS 07700, Volume X. Personnel from SR&QA have called Mr. Clarke about the issue and were in attendance at this meeting.

Both sections will wait for further instructions from Mr. Whitehead and/or program management.

The following plots are included for information only. For full explanations, contact the ARD Office. They are not numbered.







There is a folder of material in the ARD Support Office regarding Booster Uncertainties. Contact Bill Clarke at 483-1985 for further information.

6.10 ARD QUESTIONS AND ANSWERS

The following set of questions and answers is an excerpt from the Trajectory Officer Handbook. The handbook is an informal guide handed down through the TRAJ generations and is geared mainly toward TRAJ training. However, there is much useful information here for the ARD Support. Knowing what a TRAJ does and why he does it helps the ARD Support do a better job. After all, the TRAJ and ARD Support must work very closely during operations.

WARNING: Some information in this section is outdated, particularly for OMS-related procedures. Chapter 4 contains all current procedures.

Q: What is the ARD?

A: The ARD is a computational tool which predicts, in a cyclic manner, the capability of the vehicle to achieve the MECO targets for the various abort modes. It does this by computing the ΔV required to meet the targets and comparing that number to the ΔV available from the MPS fuel remaining onboard. The difference between the two is called the MPS ΔV margin. This number is added to any excess OMS fuel available (above what is required for the abort mode in question). All three of these quantities (MPS margin, excess OMS margin, and the sum of the two) are displayed on ARD OUTPUT. The FDO uses these values to make the mode boundary calls. The ARD requires a certain amount of care and feeding to accurately reflect current vehicle configuration and all that has happened propulsion-system-wise in the past (a prerequisite for accurate performance predictions).

Q: What type of care are we talking about here?

A: In the most basic sense, the ARD requires only two types of inputs that are dynamic.

- State vector - This is selected-source driven.
- Propulsion system data - The ARD needs to know the throttle settings for each engine, its ISP and, in some cases, the MR. This data is stored in a table for each engine. When engine anomalies such as engine-outs and stuck throttles occur, the results must be input to the throttle table. Also, we have to correctly track what, if anything, is happening to the OMS quantity. For things such as pre-MECO abort dumps, that is all handled internal to the ARD. Tank leaks, dumps to max blowdown, and others are handled manually.

Q: Why isn't this task automated?

A: Basically, because we have to be able to operate in the blind. Cueing all the things that need to be taken care of off telemetry would require huge amounts of core for problem resolution logic, plus some data just is not available in TM, plus what if

telemetry is lost for some reason? For this task, man-in-the-loop is the best way to go.

Q: How do I know if the ARD is properly configured?

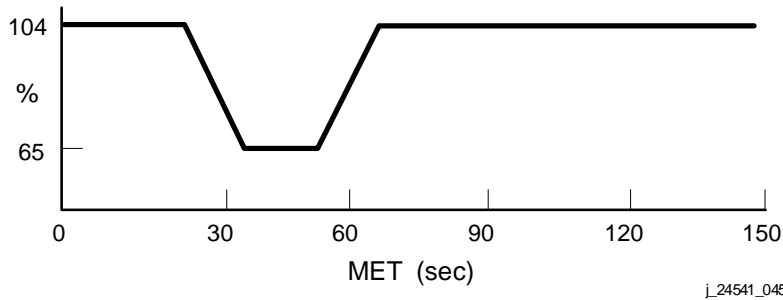
A: By the way the nominal margin behaves. Basically, if the ARD is correctly predicting the way the vehicle is going to behave, then its cyclic prediction of ΔV margin for the nominal targets, or whatever abort mode you are flying, should remain fairly constant (to within prediction accuracy, quality of filter vectors, and others). If the margin trends one way or another, then the real vehicle is accelerating at some rate other than what the ARD expects. This, in turn, boils down to a thrust-modeling error, a mass estimation error, or both. It is up to the TRAJ to figure out which of these causes is the real problem and what to do about it. A secondary cue is the TMECO estimate of the ARD compared to that downlisted by the vehicle.

Q: What is mass estimation?

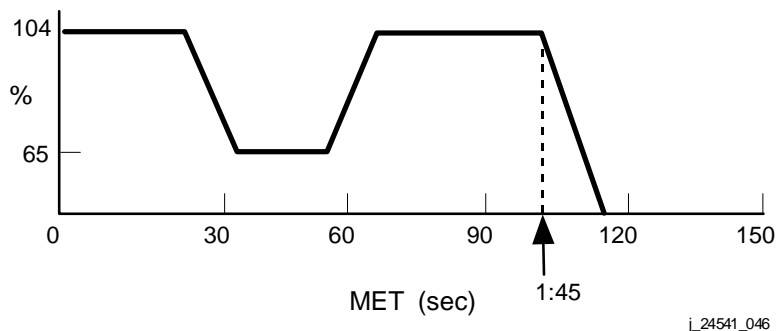
A: As I said, we need to be able to operate in the blind. Hence, the only thing the ARD relies on the outside world for is a state vector. One of the ARD components that is initialized prerun is called the "mass track." This is a big array that contains time tags and corresponding MPS fuel quantities and is built in realtime by the ARD, starting from knowledge of how much usable propellant was loaded at engine start. (This value is the MEP value on ARD/AME INIT.) Each cycle, the ARD looks to see what its throttle settings should be (by looking up in the throttle tables at the current state vector time), and knowing the throttles and ISPs (also from the throttle table), it can compute fuel flowrate, which is decremented over the computational cycle from the last known value. Hence, the ARD always knows how much fuel it has onboard, or had at some previous time. In this way, errors in the mass track can be corrected by fixing the throttle table and "recycling" the ARD to some time when the mass was known to be good (T-0 is usually a safe place to go - ask an experienced ARD Support about the STS-60 ARD NO-GO case.) Since all the other vehicle components are essentially fixed in weight, the ARD can then deduce total weight by simply summing up all the components. This weight plus the ARD's understanding of total thrust (again, based on throttles from the throttle table) are used to compute acceleration that feeds the guidance simulation which computes ΔV s. So you can see, proper maintenance of engine characteristics is imperative to proper ARD performance.

Q: Is it possible to mess up the throttle table somehow? Is it easy to recover?

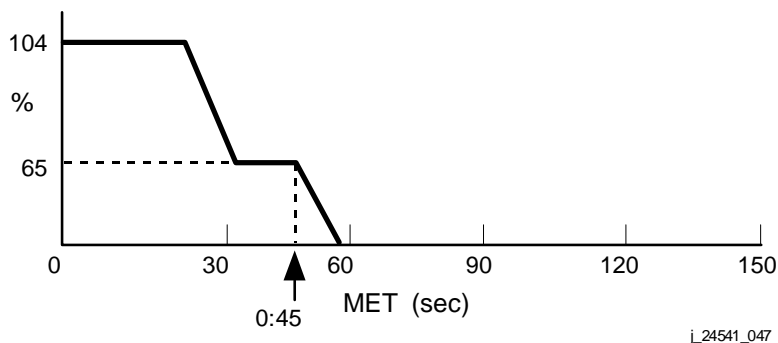
A: Yes and no. Anytime a throttle table update is made, that update goes in at the specified time and then all remaining table entries are redefined with the entry you just made. This can lead to trouble if you enter a time that is earlier than you really wanted. Let us look at an example. Graphically, a throttle table may look like this:



Now, let us say an engine dies at 1:45 and by some magic DYNAMICS accidentally puts in 0:45, or TRAJ accidentally tells him 0:45. Now, the throttle table should look like this:



But instead, it looks like this:

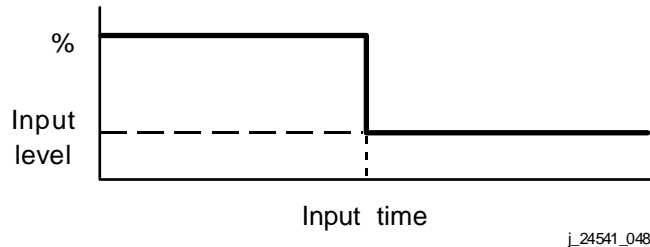


Unfortunately, there is no way to recover from this except to manually rebuild the table which, on the fly, there just is not enough time to do. Now, when the ARD automatically recycles to T-0, the mass track is going to miss a whole minute of flowrate because it thinks the engine died at 0:45 and it really kept going till 1:45. Hence, the ARD will think it has roughly 60,000 lb more gas than it really does.

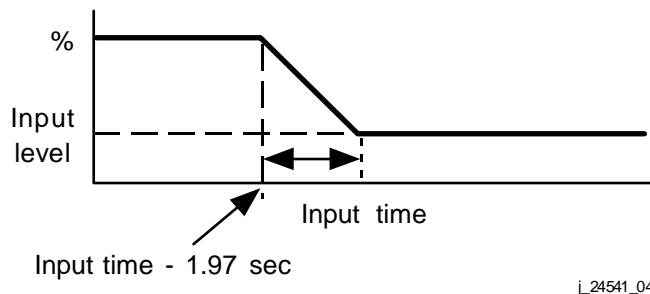
But all is not lost. The capability exists to enter increments to ARD MPS, OMS, and RCS weights (via the K67 MED) and, in this case, a simple Δ WT to the MPS weight of -60K would come very close to fixing the problem. It is up to TRAJ to figure out the right mass adjustment and what component to update. The vernacular for these things is Δ OMS, Δ RCS, Δ ETD (for external tank dry), and Δ ETP (for external tank propellant).

There is one other subtle aspect of mass track maintenance that we can discuss here. Anytime a throttle table entry is made, two changes to the table result. In

effect, the software dislikes instantaneous throttle changes; hence, is designed to always ramp from one level to the next. This is what happens: The ARD takes the input time, backs it up by 1.97 sec (this is a system parameter), and makes its first table entry at that point using the current throttle level. Then the second entry is made using the input throttle level at the desired time. Therefore, instead of getting a table that looks like this:

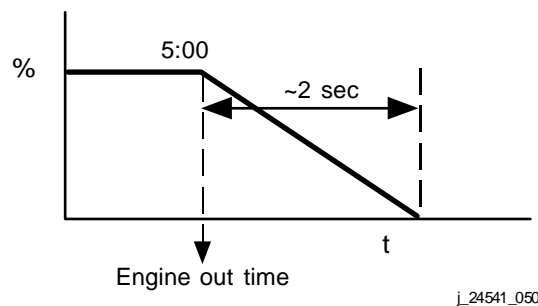


you get this:

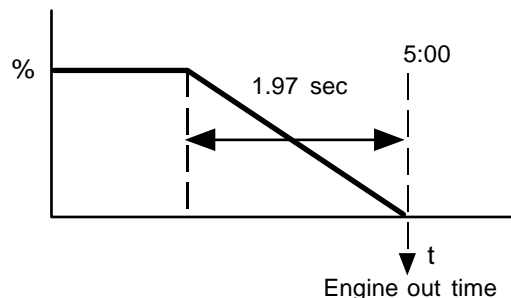


This is a more realistic representation of what is actually happening since it takes a finite amount of time for the engines to throttle or tail off and this affects the mass track.

Now, there is yet another ramification of all this. The ramification has to do with engine failures. Let us say the engine dies at 5:00. (This number is shown to you on the ARD display.) Now, this time is the time that the engine goes into shutdown phase, and it loses about 90 percent of its thrust in the first 2 sec after start of shutdown. Hence, its power curve looks approximately like this:



Now, if you tell the ARD that the engine died at 5:00 etc:



j_24541_051

You can see the problem. The ARD assumes you wanted zero thrust at 5:00 when actually the engine started tail off at 5:00.

Procedurally, the way we fix this is to feed the ARD an engine-out time that is 1 sec earlier than what comes down on telemetry, and then the ARD automatically recycles to T-0 to pick up the flowrate integration through tail off. The 1-sec-earlier engine-out time also accounts for computational delays that bias the downlisted engine-out time. The net result of all this is a correct accounting for roughly 2000 lb of MPS prop that, otherwise, the ARD would think was still available for ΔV purposes. For engine-outs close to mode boundaries, 2000 lb can mean the difference one way or the other.

Q: What is the nominal prelaunch sequence of events?

A: Prelaunch, the TRAJ spends most of the time verifying that the Flight Rules and FDF are up to speed, surveying the database, and updating anything that needs updating prior to final prelaunch checkpoint. At L-1 hr, the DOL ET LOX and LH2 loadings come in and the TRAJ works with ARD Support in recomputing the ARD loading based on the actual numbers. Sometimes the load is good and no change to the ARD is required, and other times it is not.

Q: What do you do, just add up the LOX and LH2 and toss that into the MEP slot?

A: No. Most of the calls for abort boundaries require protection for 2σ low performance. The way it is simulated is to withhold a certain amount of prop from the ARD and put it into the FPR slot, where it is unusable. This “ 2σ bias” is generally on the order of 2500 lb and represents the uncertainty in various systems that could cause performance dispersions. There are several contributors to this but by far the biggest are the uncertainties in ET loading and SSME thrust and ISP. At any rate, if the loadings are off-nominal, new values for the usable MPS fuel, LH2 bias, ARD FPR and dry weight must be computed. We have a program called ARDWTS on the laptop computer for doing this. It is easy to do, but you should know what you are doing first. Things get complicated because the ET is not loaded to the SSME MR (although it is close); extra gas is tossed in for startup and shutdown usages, both of which are at other than the nominal MR, a Fuel Bias to maximize payload capability while minimizing FPR, and 3σ FPR protection.

For the nominal mission mode, the ET loading protects for 3σ dispersions. The ARD, however, is loaded to assume an engine-out at the Press-to-ATO boundary

and 2σ protection after that. So there is some statistical black magic involved in computing the amount of propellant we will allow the ARD to consider as actually usable.

Q: Does the ARD know about LOX and LH2 or just usable prop?

A: Usable prop only. Most of the time this makes things easy, but there are certain engine dispersion cases that result in off-nominal MRs and then the ARD has to invoke some tricky math logic that adjusts the usable for the MR dispersion. It still knows only a usable quantity, but keeps track of and displays for you the imbalance in LOX or LH2; i.e., the current unusable quantity and how much it predicts will be unusable at MECO for the nominal, RTLS, and TAL modes. These dispersed cases we collectively refer to as thrust limiting, which is a misnomer in that it technically applies to only a few specialized engine problems that set the onboard O/B thrust-limiting flag. We, however, have adopted it for use with any off-nominal thrust or ISP/MR engine problem.

So, on to the actual blast-off. At T-0, the TRAJ punches the lift-off PBI. This initiates ARD and plotboard processing.

Next, TRAJ punches SDP DYN and listens for DYNAMICS to state that they copied the lift-off time. They then input it on the D15 MED and ship a K83 MED, which fixes the guidance IY vectors to the correct values (usually rotating EF to M50 unless it is a rendezvous flight) and tells the ARD when lift-off really was.

By the time all this is done, it is time to monitor Adaptive Guidance. At around 20 sec MET, the onboard software computes a number called Tdel_adjust. This is simply a time difference, in seconds, between when the vehicle achieved an I-loaded relative velocity and when prelaunch predictions said it would achieve this velocity. The theory is that in the first 30 sec or so, the only significant performance dispersions could come from the SRBs running either hot or cold. Hence, Tdel_adjust (or simply "Tdel") is a measure of how hot or cold the SRBs are. If Tdel is less than zero, the vehicle is accelerating more quickly than expected and the SRBs may be hot; vice versa for Tdel greater than zero.

Q: What happens with this information?

A: Onboard, two adjustments are made. First, the "depth" of the throttle bucket is adjusted. For hot SRBs, the bucket will be deeper or will be executed in two stages. The objective is to control qbar, optimize first stage performance, and save a little gas, if possible. The amount of throttle adjustment is a direct function of the Tdel magnitude. The direction of adjustment is dictated by the Tdel sign. For cold SRBs, then, the bucket will be shallower, with the same objectives in mind.

The second adjustment is to the I-loaded pitch profile. A pitch bias factor is applied to cause the vehicle to pitch higher or lower than I-loaded, again as a function of

the value of Tdel. For hot SRBs, the orbiter pitches up; for cold SRBs, it pitches down, relative to the I-loaded profile.

The net effect of all this, as far as the ARD is concerned, is that we will have more or less propellant after the throttle bucket, depending on what happened. The ARD does not adjust its bucket, which is part of the throttle table. Instead, by monitoring the value of Tdel and applying some flight-dependent “fudge factors,” it can compute how much more or less propellant will be used as a result of the onboard bucket change. This Δ WT is applied to the ARD mass track and is displayed on the ARD digitals.

Q: I thought you said, “Operate in the blind.” Now you are doing things based on telemetry (TM) data.

A: The ARD gets to play with three values of Tdel. One is from the primary avionics software system (PASS), one from the BFS, and a third is computed by the ARD itself based on selected source velocities. If a TM value is available, it will be used for the ARD Δ weight comp. If not, the ARD-estimated Tdel will be used. A Δ WT will be computed and the value actually feeding the mass track will be displayed under DELWT OVERRIDE on the ARD. Unfortunately, the ARD-estimated Tdel can be grossly in error since the ARD cycles only once every 6 sec while the O/B cycles once every .16 sec. Hence, the ARD Δ WT is usually bad, and on a day without TM you will have to tweak the mass yourself by monitoring margin trends and such.

For the next minute or so, until just before SRB separation, things should be fairly quiet. We do, however, advise the Range Safety Officer (RSO) of any lofting/depression or out-of-plane dispersions so he does not worry that the vehicle is deviating or about to deviate from the nominal trajectory beyond what is reasonable or expected based on SRBs and/or prelaunch winds analysis.

Next, at ~2:00, the crew is supposed to call “Pc less than 50,” meaning SRB chamber pressures have dropped below 50 psi and SRB separation is less than 6 sec away. At this point, the TRAJ punches the VECTOR SAVE PBI, which dumps the next six SS vectors to the online printer for use by the folks who predict SRB impact points so that the retrieval folks either know they are in the right place or know where to go. Sometimes the crew is busy or forgets or we do not have communication or something, in which case we also have a “PC < 50” DDD to tell you when to execute the vector save. If all else fails, 2:05 is a good time to do it.

Now the real work begins. You may or may not have noticed that so far we have not paid any attention to ARD margins.

Q: To tell you the truth, I was just a bit curious. Why is this?

A: First-stage guidance is open loop in the sense that it does not shoot for any particular point in space. It just tries to follow an I-loaded pitch-and-yaw profile, which is a function of Earth-relative velocity. Where the orbiter actually goes is a

fairly sensitive function of SRB performance, winds, and atmosphere. The bottom line is, the ARD does a poor job of modeling first-stage performance because of this sensitivity. And, since second-stage capability is strongly impacted by the staging conditions, the margin predictions pre-staging are virtually useless.

That all changes at staging. With active second-stage guidance, the ARD can predict vehicle performance with a great deal of accuracy, provided that it has a good knowledge of vehicle thrust, mass, and flowrate and a good state vector to work with. It takes 30 to 45 sec for the O/B guidance to converge and all the attitude transients to damp out, and at that point the ARD margins become reliable.

The TRAJ's job at this point is basically to keep the ARD configured to accurately reflect environmental conditions --- the thrust, mass, and flowrate parameters mentioned earlier.

Q: What cues are available?

A: Basically, there are three sources of data to sort out what is going on. The first source comprises the downlisted values of commanded and actual throttle settings, O/B MECO time, and O/B mass estimate. The second source is the margin behavior. The third source is a MECO time as computed by the ARD, which can be compared to the O/B time. Let us discuss these things in more detail.

The downlisted throttle settings are fairly straightforward. The commanded setting is the value specified by guidance, and the actual settings for each engine are a derived value from a BOOSTER comp that factors in engine P_c , discharge temperatures, valve settings, and other factors. In general, your desire is that the ARD throttles match the O/B throttles. For some of the thrust-limiting cases, however, the BOOSTER comp is unreliable, and instead we adjust the ARD to a power level obtained from a table BOOSTER supplies to us. As long as the ARD throttles are configured properly, the thrust and flowrate maintenance are generally taken care of.

The O/B MECO time is computed by GUIDANCE and is nearly always reliable to within a second or so once it is properly converged. One may observe changes of up to 10 sec if performing a pre-MECO dump, for instance, since the guidance does not know the dump is of relatively short duration; otherwise, the time should be very stable. By itself, the MECO time does not tell you much, though. You must compare it to an independent source; i.e., the ARD, in order to back out really useful data.

The O/B mass estimate is also displayed on the ARD, along with the time tag for which it is valid. Unfortunately, the time tag does not display correctly and the O/B mass estimate is typically good only to ± 3000 lb; therefore, this parameter is good only for very coarse comparisons. Sometimes, in fact, it is useless and the reason lies in the way it is computed. The O/B is initialized with a mass that represents the total vehicle weight, less SRBs, at lift-off. During the first stage, this mass is

decremented each guidance cycle by a canned 100 percent power level flowrate times commanded power level times the Δt for one guidance cycle. This is okay as long as all three engines are at the commanded level, but if you have one stuck somewhere because of hydraulic lockup or something, the O/B mass goes down. In second stage, the O/B estimate is based on the mass estimate at staging, updated every guidance cycle by an approximation to the rocket equation, which in turn uses a derived exhaust velocity based on sensed acceleration, engine tag thrust, and flowrate and a fudge factor based on the difference between expected and observed acceleration. So you can see, the O/B mass estimate is to be taken with the appropriate grain of salt.

There is another mass estimate. The BOOSTER group has a comp which solves $F = ma$ based on tag thrust, throttle settings, and sensed acceleration. This comp and its time tag are also displayed on the ARD and generally provide a reasonable cut at the vehicle weight. The points to be aware of are (1) the time tag is displayed only to the nearest second, introducing a potential error of roughly 2000 lb in any one time-synched compare, and (2) the comp is not under our control and, hence, is no better than the data with which the BOOSTER group has configured it.

Then, we also display the ARD weight computation and its time tag. It is updated every 6 sec, which is the ARD's comp cycle rate. This weight must be eyeball synched to the same time as either the BOOSTER or O/B weights. If the times themselves do not show up concurrently; i.e., if the BOOSTER comp is at 3:45 and the ARD comp is at 3:43 or something, 1000 lb/sec times the number of engines running is a good flowrate fudge.

Those three weight comps provide a clue to the validity of the mass track.

Another clue is based on the difference between the O/B and ARD-computed MECO times. Since both the ARD and O/B guidance solutions are based on valid vectors (assuming O/B nav is good), they should compute the same MECO time as part of the solution. If the ARD computes a MECO time that is later than what the O/B computes, then the ARD must think the vehicle is not going to be accelerating as fast as the O/B thinks. If you have done your job and kept the throttles configured properly, the only other source of trouble could be erroneous ARD mass. The same thing holds if the ARD-MECO time is earlier than the O/B; i.e., the ARD expects more rapid acceleration than the O/B is detecting. In either case, some kind of mass problem exists, and now you have to figure out not only how large the discrepancy is but in which vehicle component the problem lies and whether it is a constant bias or a time-varying effect.

Q: Is the MECO time difference related to margin behavior?

A: Yes. Basically, you can use the MECO time compare to forecast how the margins are going to behave. For example, let us say that they load 5000 lb less fuel into the tank than they thought they had (5000 lb is not a really credible number (unless you count the STS-61C tank draining incident), but it is okay for this example).

Then, let us say we are just past staging; all the transients have died out and the ARD MECO time says 8:30 while the O/B time is 8:25, and the ARD nominal margin is +100 ft/sec. Since the O/B is going to fly its own solution, the ΔV it achieves over the next guidance cycle should be the same as what it expects to get based on that solution. The ARD, however, is calculating a solution based on a vehicle it thinks is 5000 lb heavier; hence, the ΔV the ARD expects to see is going to be less than what the orbiter is really capable of. So when the next ARD cycle comes around, it will see the vehicle going faster than was predicted, and this "extra" ΔV will show up as extra velocity margin. This situation will repeat itself from ARD cycle to ARD cycle, and the extra ΔV s will accumulate into a very distinct trend in the margin history. Plus, since the ARD is continually seeing more acceleration than expected, the MECO time it computes from cycle to cycle will become earlier and earlier and should eventually converge with the O/B time. Hence, if you see an ARD MECO that is later than the O/B time, you can expect the ARD nominal margin to increase with time. If the ARD MECO is earlier than the O/B, the nominal margin will decrease with time.

- Q: But the nominal margin is just that --- a nominal margin. As long as the orbiter is flying the nominal trajectory, this margin should remain constant, right?
- A: That is right! So if the ARD shows a trending margin, you have trouble. (Note: Weight error is introduced here to illustrate the point. We know that thrust is statistically most likely to be the cause of the problem.)
- Q: Now I know I have a problem, and I have all these mass estimates displayed for me, so I ought to be able to figure out how large the mass error is and whether the ARD is heavy or light. Right?
- A: Essentially. As I said earlier, you have to take the mass computations with a grain of salt. Therefore, you combine the mass compare numbers with your best guesses and estimated factors. For instance, at 3:00 MET, a 1-sec MECO time difference corresponds to a mass error of roughly 4000 lb. At 5:00, it is up to about 6000 lb/sec, and it jumps to roughly 10,000 lb/sec by around 6:30 MET. So, given the current MECO time difference, you can back out an approximate weight factor based on MET.

Your whole goal during all this is to keep the nominal margin history flat on the average; i.e., no trend up or down. I say "on the average" because you can get local variations due to nav filter performance on the order of 5 to 10 ft/sec (worse near staging and low-el solutions) and also because until we get to OI-7 and subsequent OIs, there is some error inherent in the PEG solution itself which can cause some trending. This error is supposed to be nulled to some extent by an empirical correction based on TGO that the ARD computes internally using system parameters MCCIDL and MCC2DL, but even that does not fix all of the problem. OI-7 PEG has an improved prediction scheme in which the solution has only very small errors, roughly 5 ft/sec or so at staging.

Q: When I get trending margins, how do I know it is from a mass error and not a thrust error?

A: You don't. You don't know the truth. The trend could be due to both, neither, or a combination of things. But, you can take a statistical approach and assume that the problem is caused by thrust and not something less likely or extreme. This is what gave birth to the thrust update methodology. That is one reason we carry FPR --- we do not know for sure. That is also why there is a deadband on the thrust update method --- the deadband retains the uncertainty that the trend might be caused by something(s) other than thrust.

Technically speaking, Rockwell guarantees SSME thrust only to be within 6000 lb of spec. We have never, with the possible exception of STS-1, seen an ARD behavior indicative of engine problems anywhere near that bad, however. Prior to thrust update, we would not know what to do with it even if we thought it was a thrust problem, since the engine PCs all indicate 100 percent, 104 percent, or whatever, and then you are reduced to adjusting with the engine tag thrust value, for which you have no real justification, and certainly no license. If the throttles indicate other than 104 percent, then you know you have a problem and you will account for it; that is a separate thing. So, instead of adjusting with the thrust (pre-thrust update days), which in turn also affects the mass, we will simply proceed as if it is just a mass problem.

Q: Okay, ignoring thrust update procedures for now, how do you tell where the problem is? Is it OMS, dry weight, MEP, or what?

A: There is a bit of judgment calling that goes into this. When you can, you try to figure out what the most likely case is, based on what has happened so far. Generally, we start by assuming the problem is in ET propellant and come up with reasons why it should not be there; i.e., we assume that we have good knowledge of the OMS, RCS, and dry vehicle weights based on preflight weighings and assessments. Since the ETP is such a large proportion of total weight, is the last item loaded, is continually replenished until T - 5 min, and is also the only component whose weight changes on the fly, it stands to reason that a mass problem will most likely be found in the ETP accounting.

Now, let us say you see a mass error of 5000 lb, and you cannot come up with any reason for it anywhere. What do you do --- toss it all in the ETP? Toss in part of it and ignore the rest? Half in ETP and half in dry? Ignore it all together?

Q: What do you do in this case, Oh Mighty ARD-Lord (if you do not have thrust update)?

A: I would call my sigmas into play at this point. If you do not know where it is, I would toss up to 2σ ET loading error into the ETP and maybe pitch the rest into ETD if it is not too much. The 2σ ET number is normally 2000 - 3000 lb but varies a little from flight to flight. A safe number is 2500 lb. Δ ETPs larger than that are

very unlikely without some cause that you should be able to sort out. This is another factor that led to the thrust update method.

Q: Is there a difference between positive and negative Δ WTs, philosophically?

A: Yes, this ties back to our discussion of “where is the weight error?”. Let us say that the ARD appears 3000 lb light and you cannot figure it out, so you add +3k into the Δ ETP, then all the MECO times agree and the margin trend settles out. But what have you done? If the weight problem turns out to be a ton of water in the tiles from rain the night before and 20 extra getaway special (GAS) canisters, then you made the weights match up by effectively deleting the ARD FPR! Remember, we said the ARD 2σ FPR was normally 2 - 3 klb. So now, all the FDO’s calls are providing no protection for low performance and you did the wrong thing by adding propellant to the ETP.

So let us say now you go the other way and toss the weight into the ETD as a dry weight adjustment. This, in effect, increases your payload weight by the amount of the adjustment. The ratio of Δ payload weight to Δ MPS propellant required to boost to orbit is not exactly one to one, but it is close; hence, every pound of dry weight adjustment reduces your MPS margin by roughly that same amount. As an example, let us say you threw +3 klb into the ETD. That is going to hit your MPS margin by about 3 klb also which equates to about 130 ft/sec of lost capability. This can be a big impact to nominal performance, delays in Press calls and others, and essentially results in over-conservatism since the ARD is already loaded for -2σ protection. So the next option in this case is to split the weight between ETP and ETD which will stabilize the margins with minimal impact to predicted capability. But really, you do not have any more justification for doing that than for any of the other options. (Now the thrust update method provides justification for tweaking the ARD throttles.)

Q: Now what (if no thrust update)?

A: If for some reason you did not have thrust update, or it was inappropriate to implement, use judgment and common sense as best you can. You are very unlikely to encounter a true dry weight error of more than 1000 lb because the 3σ weighing uncertainty is less than that. I think the best approach is to use (-) Δ ETP for ARD-heavy cases and do nothing for ARD-light (ARD light, sit tight). Remember, the ARD is already loaded to cover 2σ dispersions, of which MPS loading and SSME thrust and ISP are the major factors. Be aware of what your options are and the impacts and implications of using them.

Q: This business is not pure rocket science, is it?

A: No, there is some art.

Q: How small a weight error can you detect?

A: On a really good day, $+2\sigma$ or so, we think we can see 1000 lb, but it is a good trick. With all the other factors that figure in, like filter noise and prediction accuracy, 2000 lb is more realistic; 3000 lb is obvious. The ARD sensitivity to mass errors increases dramatically with MET. Even 1000 lb is evident by 3g throttling time, but by then all your calls are made and it is too late to care. You really want a good first cut at any mass problem by 3:00 to 3:30 or so, so you can fix it prior to the Negative Return call. After that, you have another minute or so to fine-tune things before the Press calls. After the Press calls, we normally will not play with ΔWTs or thrust update unless there is some gross error that has not been corrected and will seriously impact the single-engine calls.

Q: Is there anything else I need to know about the mass track?

A: I guess the only other thing I want to say about it is that TRAJ gets a lot of help with this task from the backroom. Historically, it has been ARD Support's job to recommend ARD thrust and weight updates. Nowadays, it is a concurrent agreement thing; that is, the TRAJ and ARD Support work together to sort out and fix ARD thrust/mass problems.

Q: Now what happens in the typical, nominal profile?

A: After the FDO makes the Press-to-MECO call, TRAJ has to reconfigure the ARD for single-engine calls. At this point, I probably should discuss actual and hypothetical modes, because we have not touched on that yet.

The ARD calculates velocity margins for two different modes: actual and hypothetical. The AM is maintained to reflect real vehicle capabilities. The HM is generally configured to reflect the next lower MPS failure configuration; i.e., if you have three engines running, the HM will be configured with one engine down such that the ARD HM margins then reflect what capabilities you have if you were to lose an engine at current time. The abort boundary calls are all made from the HM. The plotted nominal margin, whose trend we monitor for thrust/mass error purposes, is computed by the AM. The HM is always a "what happens if" tool and can be configured however you want; the important thing to remember is that it always starts from current conditions (i.e., mass and state vector) and then computes capability based on how the HM throttles are configured.

Normally the HM is initialized (via throttle table) with the left engine out and the center and right at 104 percent. After the Press-to-MECO call, which is based on a single-engine out, the HM must be reconfigured to compute margins for single-engine capability. The first single-engine capability achieved is that to the TAL site at 104 percent; Droop 109 calls can be based on either 0, 0, 109 in the HM or velocity. To reconfigure, TRAJ calls DYNAMICS and says

"OK, DYN, 0, 0, 104"

They are cued for "0, 0, 104." In a few seconds, the HM left and center throttles will be 0, and the right will be at 104.

Q: Then what?

A: After the SE calls are made, roughly at MECO - 1 min, TRAJ has some book-keeping chores to do. At MECO the ARD computes the current OMS, RCS, and dry vehicle weights and hands these values across to the post-MECO OMS capability tool, which is called the Abort Maneuver Evaluator (AME). But, the way the formulation is written, these handover weights are arrived at by summing various component weights, including whatever Δ WTs you put in on the fly. Then the orbiter weight is obtained by taking this total weight and subtracting the dry ET weight, leaving whatever Δ s were entered as additions to the orbiter weight. Obviously, this is wrong for any Δ ETP values, including Adaptive Guidance's DELWT Override, since any ET propellant remaining goes away with the tank. Starting with ARD-1B, all of this is handled automatically.

Q: What if we do not have comm or TM and cannot see MECO?

A: You have a couple of cues. First, you know when MECO should occur because the ARD-computed time has been on the display in front of you for quite a while. Second, you can watch the V_i on the FDO Launch Digitals and when it gets to the target velocity, it will start oscillating around the target (rather than increasing) when MECO occurs. The oscillation will continue until NAV gets the free-flight filter configured.

Q: Talk about off-nominal problems.

A: Let's take an easy one, like a stuck throttle that is not drifting. A stuck throttle can occur anywhere in the launch profile, and its effect depends a lot on where and at what level the engine locks up. There are two kinds of stuck throttles: hydraulic and electrical. In the hydraulic case, an APU has gone down or something and you no longer have hydraulics to drive the engine valves. Electrical lockups occur with command path failures where the main engine controller cannot communicate with the GPCs. The APUs are numbered 1 through 3, just like the associated engine, where center = 1, left = 2, and right = 3. So, if APU 1 is down, the center engine goes into hydraulic lockup.

What this means to the ARD is that you have to at least lock the throttle so the software will know that the engine is stuck; you may also have to adjust the power level and/or ISP and MR, depending on where the engine is stuck. If it is locked at full power level, for instance, you only have to lock the throttle and reconfigure the HM to reflect a "good" engine out. From a conservative viewpoint, taking a good engine down reflects "worst case" configuration. If the engine is locked in the bottom of the throttle bucket, you will have to specifically lock it in the ARD at that level, then adjust the ISP and MR if they are significantly off-nominal. If it locks up in the bucket throttle-down or throttle-up transient, the MR dispersions can be huge but, otherwise, are relatively benign. MR must be handled with care because of the way the Fuel Bias is factored into the usable propellant. At any rate, let us take an example. At 40 seconds, APU 2 fails and we are in the bottom of a 70 percent throttle bucket. You would call DYNAMICS and say "In both actual and

hypothetical modes I want to lock the left engine at 70 percent, time of 40 sec. Then, in the hypothetical mode, take the right engine to zero at current time.”

Key points are:

- Mode (actual and hypothetical)
- Engine (left)
- Power level (70 percent)
- Time (40 sec)
- Lock or simple adjust (lock)

Then TRAJ reconfigures the hypothetical to take down a good engine, since after the above input you would have 70, 104, and 104 percent in the HM (remember, it was initialized at 0, 104, 104). What TRAJ did was arbitrarily select the right engine as the dead HM engine to provide next-lower MPS failure evaluation. Then your HM configuration would be 70, 104, 0.

If you had a significant ISP/MR dispersion, TRAJ would get new values from BOOSTER-supplied tables and provide the numbers to DYNAMICS in much the same way as TRAJ provided the throttle data. When everything gets into the machine, TRAJ then verifies against what shows up on the lower right block of the ARD display.

Q: What about an engine-out?

A: Probably the easiest of all. Engine failures are characterized by a rapid drop-off in AM margins, a zero for the affected engine's throttle setting, DDD and PBI feedback, and very obvious calls from the crew, BOOSTER, Guidance, or whoever sees it happen first. The FDO is supposed to punch a PBI at engine failure which automatically kills the appropriate ARD engine, but this provides only an initial guess at engine failure time and velocity. The TRAJ manually corrects the ARD using downlisted engine-out time and velocity, which appear on the ARD display.

Q: I can see where the engine time is important to the mass track, but why do we care about velocity?

A: Because velocity is the parameter used to determine the duration of the pre-MECO ATO OMS dump, the IY vector and R-V-γ targets used for ATO, and the fuel dissipation attitude for RTLS. Hence, if you are past RTLS and you are sure you are not in pre-MECO ATO abort stage, the velocity is not crucial, but fix it anyway, as a good professional procedure.

Now, let's say the center engine just died, and it's 5:00 MET. TRAJ should first make sure the FDO has punched his PBI because your MED updates will not take until he has. Then, TRAJ calls DYNAMICS and tells him he has a TME OUT/VME OUT update, then gives him "Center engine, time of 5:02, velocity [# off the

display].” Note that, per the discussion on throttle table construction and mass track logic, we have subtracted 1 sec from the downlisted engine-out time. This will trigger an automatic mass track recycle to lift-off. Next, reconfigure the HM to reflect the next engine-out possibility. In this case, HM throttles of 0, 0, 104 would be requested in preparation for single-engine TAL capability. This all must be done quickly, particularly if the engine failed very close to a mode boundary. When everything is properly reconfigured, TRAJ goes back to monitoring MECO times and margin trends. Remember, if you get into an ATO abort case with a pre-MECO OMS dump, the ARD and O/B MECO times will not agree until after the dump is complete. The O/B time should be a couple of seconds earlier during the dump.

Q: What do you use for engine-out time if there is no TLM?

A: Using the ΔV Margin history plot, the FDO should be able to find you a fairly accurate time just by observing where the margins begin to drop. If he was quick on noticing the failure, his PBI input time may be as accurate as you get. Uncertainties will result in a messed up mass track, and your best course is to fix it with ΔETP using the techniques we discussed earlier. Any uncertainty in engine-out time provides license to tweak the ΔETP . We are currently evaluating the ELOG tool to estimate engine-out time.

Q: OMS leaks?

A: They are easier than engine failures, at least as far as pre-MECO is concerned. The PROP Officer will call to TRAJ a leak level that represents the amount of OMS expected to be lost by OMS-2 TIG or OMS-1 TIG for standard insertion flights. There are only four levels, and the appropriate ΔOMS number comes from a chart that provides the values on a flight-to-flight basis. PROP gives us this chart. TRAJ simply tells DYNAMICS, “A ΔOMS of minus such-and-such, balanced with RCS”; the such-and-such number comes from the chart. The “minus” is because this value is prop lost, and the reason we “balance with RCS” is that the conservative approach is to assume the OMS fuel is leaking into the pod and is being carried as dead (dry) weight.

Q: What about dumps to max blowdown?

A: Blowdown dumps are harder because now you have to deal with two components, a “prop lost” and a “capability lost,” and balance them in such a way as to keep the mass correct. If the blowdown is done correctly; i.e., for the correct number of seconds, this is not so tough because the prop and capability losses are by definition the same (at least to within a couple of hundred pounds). But let us say that the dump cuts off early. Mass-wise, you may have only dumped half (for instance) of what you needed to in order to maximize blowdown. So you have an OMS tank with a lot of fuel in it that is still there mass-wise but unavailable ΔV -wise, hence the dual-component nature of this problem.

Operationally, the way we handle this is: First, when PROP calls for the dump, TRAJ configures the ARD with ΔOMS equal to the negative of the capability lost quantity. This number and any others referenced here are obtained from another chart provided to us by PROP. The chart provides, as a function of dump time, oxidizer/fuel remaining, propellant dumped, and propellant lost. PROP will provide the correct dump time to maximize the blowdown. So TRAJ goes to that time on the chart, puts (-) the propellant lost number in the ΔOMS , and in the ΔRCS , a number equal to the difference between the propellant lost and propellant dumped numbers on the blowdown chart.

Let us take another example. For STS 51-F, the optimum blowdown dump time was 115 sec for the right OMS pod. Dumping for that amount of time would result in a propellant capability loss of 6779 lb and a dumped quantity of 6323 lb. Basically, this means that 6779 lb of OMS was going to become unusable and dumping for 115 sec would get rid of all that otherwise dead weight except for about 450 lb. So you put -6779 in ΔOMS and you set $\Delta RCS = 450$. At that point you still have a ΔOMS of -6779, which reflects the amount of OMS you cannot use. The total weight Δ , as far as the ARD is concerned, is $6779 + 450 = -6329$, which is essentially what was dumped (6323).

Q: What if the dump stops early?

A: The procedure is basically the same. When TRAJ finds out the dump has stopped, he goes into the table at the actual dump time, puts the $\Delta OMS = (-)$ the propellant lost, and sets the $\Delta RCS = (+)$ (propellant lost-propellant dumped). It is straightforward, really, but there is some bookkeeping going on which you need to understand.

Q: What about pre-MECO ATO abort dumps?

A: Given the proper velocity at engine out, the ARD is smart enough to know how long the dump is, to ramp down the dump duration, if required, and to not dump at all if you are out of the dump region. It is a good idea to double-check the ARD against a chart that indicates the correct dump quantity, however, just to be sure. During an ATO dump, you can see the ARD current OMS quantity on the display. It should decrease from cycle to cycle during the dump.

Q: What if you are doing a three-engine ATO abort? Where does the engine-out velocity come from?

A: For three-engine cases, VMEOU is defined to be the velocity at abort selection in the O/B software. The ARD, likewise, is cued off the ATO abort PBI, which the FDO pushes when the abort selection is confirmed. If he hits the PBI on time, the velocity snapshot will be close but not exact. Thus, TRAJ should have DYNAMICS perform a K61 Abort Proceed MED to update the velocity.

Q: What about Pc sensor shifts?

A: There are a couple of Pc transducers on each SSME, and one of the failure modes is for one of them to have a high or low bias to its output. If one of the transducers shifts high, such that its output indicates a higher Pc than really exists, it is referred to as a "Pc Shift High-Actual Low" or more simply, "Pc Shift High (PCH)."

This high Pc output is averaged with the output from the second (good) transducer; therefore, the final Pc that gets sent as feedback to the main engine controller is only half as high as sensed by the bad transducer. The main engine controller (MEC) sees the error between the actual and commanded Pc and starts adjusting with engine valves to bring the sensed Pc down. Since the actual Pc was correct and just the sensor was bad, the MEC adjustment is going to make the real Pc lower than what you want nominally. So you take a thrust hit right away. On top of that, valve adjustment results in an oxidizer flowrate change that causes the engine MR to be lower than it should be. The MR change is a function of how much the Pc transducer has shifted. Now, look at what has happened. The MR, which is the LOX flowrate divided by the LH2 flowrate, is nominally around 6.03. This results in LOX flowrates of around 925 lb/sec and LH2 flow-rates of 153 lb/sec at 104 percent power level per engine. If we incur a level 3 PCH, the MR for that one engine changes to 5.815, with flowrates of 903 and 153. Hence, we are using up 32 lb/sec less LOX than we should be nominally. If the shift occurs at lift-off and we are flying a 500-sec burn arc, then we are talking a LOX imbalance of 32 x 500 or 16,000 lb of unusable LOX accumulating by MECO. Essentially, this means you have increased your payload weight by 16,000 lb, and you have 16,000 lb less gas to carry it to orbit with. This is a big impact to abort boundaries and even nominal mission capability.

For Pc Shift Low (PCL), essentially the opposite effect occurs, system-wise: The engine actual Pc goes higher than nominal, so you get some thrust increase; the MR goes up, so you use more LOX than you want and, hence, build an LH2 imbalance. The performance capability is not impacted as badly, however, since you have more thrust, and since the vehicle is getting lighter faster (due to the excessive LOX consumption), it accelerates faster. For small PCLs, in fact, like levels 1 to 2, the net impact is close to zero.

Q: How does the ARD handle all this?

A: We tell it what's going on. BOOSTER gives us a set of tables that tells us what the power level, ISP, and MR are for various Pc Shift levels. DYNAMICS puts this on a floppy disk and on the day we have a problem, BOOSTER tells us what level to use and what time it took effect. We pass that data to DYNAMICS, who fetches the data off the floppy for that level, and the ARD reconfigures the appropriate throttle table with the new thrust, ISP, and MR values. Plus, it internally sets a thrust-limiting flag, which tells it that there has been a MR dispersion. It needs to know this, because, as mentioned earlier, the ARD does not care about LOX and LH2 separately; it only knows how much usable gas it has as a single ETP number.

However, that number is not going to do any good because it assumes a nominal MR. So, by telling it what the new MR is and by knowing what the nominal MR was, the ARD can compute a Δ usable quantity, which it then applies to the usable computed in the mass track. We do not have insight into what the Δ usable is, but the ARD also computes what the current and MECO LOX and LH2 imbalance (unusable) is and displays it on the lower right corner of the ARD display next to the ISP and MR values it is using.

Operationally, TRAJ tells DYNAMICS to put the updates into both the actual and hypothetical modes for the appropriate engine and then reconfigure the HM for a good engine out, as we did with the stuck throttle case. Not only that, but TRAJ has to play a little game with the thrust-limiting time. Let us say the Pc Shift occurred at lift-off. If TRAJ tells DYNAMICS to put the adjustment in at lift-off, the power level input will wipe out the throttle bucket for that engine. Remember, we said any throttle table entry overwrites everything after its time tag. Here you are with a bad mass track in a potentially performance-critical case.

But there is a solution. The MED for input of thrust, ISP, and MR allows a separate time tag to be applied to each; therefore, for any power level change that occurs before throttle up, we simply time tag it after the bucket. Generally, a safe time to use is 1:07 MET. Words to DYNAMICS would be like, "Pc Shift High, Level 3, center engine at lift-off, throttles at 1:07, AM and HM."

Q: But now you have flown for up to 1:07 with a bad power level. Does that mess up the mass track?

A: Yes, it does. But ARD Support can compute a correcting Δ ETP as a function of the level of Pc Shift throttle setting. We use ARDTools to do this. We make the adjustment in ETP; we put it in DELWT-OVERRIDE, which is basically the same thing. Plus, it make sense to put it there since it is an adjustment to the bucket mass history. There are two more complicating factors to consider; it is not a simple problem.

When the ARD thrust-limiting flag is turned on, it is allowed to burn the Fuel Bias with any LOX imbalance for purposes of Δ V margin computation. But in fact, we really still want to protect the bias and update the FPR reserves due to the off-nominal MR.

In the past, the original ARD fathers came up with Δ ETP numbers for high and low MR cases which are intended to essentially rebuild the Fuel Bias into the mass track. Now, the ARD Support generates a table of FPR vs. MR. Thus you have an FPR adjustment to perform in addition to the thrust, ISP, and MR update. The FPR adjust is performed with the FPR slot on the K67 MED, while the propellant update for the throttle difference until 1:07 is handled with the Delta-Wt Override slot on the K67 MED.

The next complicating factor arises from the capability to turn off the bad Pc sensor. Depending on what kind of performance is available, which is determined

by the FDO, we may want to shut the sensor off to avoid an RTLS or AOA. The disadvantage of this is that you give up redundancy on that engine since it is down to one Pc transducer; there is a risk of the crew accidentally turning off the wrong channel, which would double the dispersion instead of fixing it. If we do turn the sensor off, then the ARD must again be reconfigured to tell it we have returned to a nominal configuration. To do this, TRAJ first tells DYNAMICS to go back to nominal thrust, ISP, and MR at whatever time the crew flips the right switch. The nominal data is also stored on the floppy. Furthermore, ARD Support determines the final FPR Update based on the ARD imbalance output and the FPR vs. propellant imbalance chart, or using ARDTools.

Q: But what about aborts?

A: Actually, aborts are easy things to do, even for RTLS, when you are busy. So let us take this one abort at a time.

There are only three pre-MECO abort types: TAL, RTLS, and ATO. For TAL aborts, abort processing within the ARD is invoked by the FDO when he punches the appropriate abort PBI on the console. These PBIs provide the ARD with an initial abort proceed time estimate and set flags that tell the ARD to begin dumping OMS pre-MECO, if an OMS dump is involved. Generally, the PBI depression time is accurate enough, but if it gets in late for some reason and you can come up with a more accurate time, the abort proceed time can be updated via K61 MED. TRAJ just tells DYNAMICS, "abort proceed time to such-and-such." Then he monitors the OMS dump in the ARD and verifies that it goes for the right amount of time and/or dumps the right amount of propellant.

ATO aborts are just like TALs in the actions TRAJ must take. The only difference is, the OMS dump can be of variable length, depending on the engine-out Earth-relative velocity. This is the old "ramped-dump" dump, which is designed to limit the underspeed to a certain value and not dump any more OMS than necessary. If a ramped dump is being used, you should have a chart that says how much OMS is to be dumped as a function of velocity and make sure that the ARD dumps correctly.

RTLS has some tricks to it. The OMS dump begins immediately at RTLS selection onboard, then the PBI and abort proceed process are just like a TAL.

The RTLS busyness arises from the fact that RTLS does some active throttling as part of the guidance logic, which attempts to control the vehicle mass at MECO. The purpose of this is to cut off with 2 percent MPS propellant remaining, which provides safe ET separation conditions without a lot of banging around from slosh induced by powered pitchdown. You will get a throttle change to 69 percent at abort select for three-engine RTLS. For an engine out, the throttle will stay put until flyback. At flyback, the throttle will go initially to an I-loaded flyback setting and then will change, as needed by guidance to hit the mass target. Most of the throttling will occur within the first minute or two after pitcharound, and another

tweak should occur at OMS dump completion. Changes of a percent or two may occur at other unpredictable points.

Of course, the reason for all this is for the maintenance of the mass track. Since you have aborted and are committed to an RTLS, a second or two error in throttle times is not very important, but you still want the ARD to accurately monitor the abort progress; hence, the throttles should be kept up as closely as possible. At pitcharound, things occur fast enough that a pencil should be kept handy. Lastly, the throttle times must be manually entered. The TM data is roughly 6 sec stale; so when you see the throttle change and check the MET, subtract 6 sec to model the TM lag. ARD Support will assist in recording these times, and TRAJ will read them up to DYNAMICS for MED input.

After RTLS selection, various parameters associated with pitcharound and flyback, such as pitch time, pitcharound angle, MECO time, and MECO downrange distance and velocity are computed and displayed on the H vs. V_e (RTLS) display, which is why you change the left Eidophor from 447 to 448. Once the ARD is moded to RTLS, the ARD MECO time on the ARD OUTPUT will disappear. Remember, until the OMS dump stops, the ARD and O/B MECO times will differ by a couple of seconds and the margin trend (if any) is not particularly meaningful.

TRAJ does not have to reconfigure the HM for single-engine ops on RTLS aborts, because single-engine ops is defined by other criteria like flight control capabilities to perform powered pitchdown ($H_{dot} = 100$ fps call).

Q: How about subtle things - where can I get tripped up if I am not careful?

A: First, it is good to always keep the HM configured like the AM, only with a good engine down. For instance, the HM is initialized with the left engine out. Let us say the right engine dies, the FDO pushes his PBI, and the ARD reconfigures itself to 104 left and center and 0 in the right, in both AM and HM, just as it should. When you reconfigure the HM for single-engine capability, go to a configuration that keeps the right engine out. This may seem like a small detail, but it is not, because both AM and HM reference the same ISP and MR tables; and since ISP is a function of throttle setting (it varies by about 1.5 sec over the throttle table range) and MR is affected by whatever thrust-limiting case is going on, the HM may not tell you what you want if you do not set its throttles correctly. The reason I make a point of this is that we usually configure left and center to 0 and right to 104 or 109 for single-engine calls, and the "0, 0, 109" call to DYNAMICS gets to be a habit. Make sure, based on the scenario, that you do not want 0, 109, 0 instead.

Then there are PEG error messages. These appear on the ARD display directly above the abort mode to which they apply. There are four or five possible messages and only two appear with any regularity. These are:

- MAX ITER - OLD SOL: This means PEG has cycled 25 times without converging, and the last valid solution is being retained on the display. This message may appear early in the launch for RTLS and is not very

important. It also will appear late in the profile for the TAL channel, if a TAL abort has not occurred, because the TAL MECO targets are different from the nominal and the guidance may not be able to obtain a solution as we get close to “over-flying” the TAL targets. It will go away whenever you get past MECO - 40 sec for the appropriate mode, because guidance releases altitude and plane constraints and can always solve for velocity. Any other occurrence of this message probably means a ground configuration problem; e.g., getting incorrect MECO targets in the machine somewhere.

- MX TURN RATE - NEW SOL: This message means basically the same thing in both 016 and 017 PEG, although the formulations are different and you get there different ways. The bottom line is that the magnitude of the thrust-turning rate vector exceeds the maximum that the guidance formulation will allow and that the solution is being computed with the turn rate limited to an internally computed (016)/I-loaded (017) value. In this case, the ARD will still display the new solution, but treat it with a great deal of skepticism. I would not make a call based on a max-turn-rated margin, unless it was very, very positive, and even then you can get in trouble because the O/B will probably have the same problem with that abort mode and may not properly hit the MECO targets. By the way, we do not have any insight into O/B max turn rate errors.
- VGO MX - TURN THROTTLE ON: In this case, PEG has computed a VGO in excess of 75,000 ft/sec. This is a serious problem. The most likely cause of this is extremely low thrust-to-weight, if you have 0, 0, 65 in the HM at staging, for example, hence the “turn throttle on” portion of the error message. The first thing to do is verify the throttle configuration. If it is okay, you have probably badly mixed up MECO targets and/or IY vectors in the machine, in which case 50 percent of the time you will not figure it out and get it fixed before all the critical calls have to be made.

Note: Do not play games or even accidentally go 0, 0, 0 in a throttle configuration. The logic is supposed to protect for this, but once it is done you cannot get the ARD running again without recycling the TRS.

6.11 ARD BIASES

To be supplied.

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A ACRONYMS & SYMBOLS

#

2HM 2nd Hypothetical Mode

GREEK

Δ delta – defined as the change in a value/parameter
 γ Flight path angle
 μ mean value
 σ One Standard Deviation

A

a.k.a. also known as
A/G Air To Ground
AADDVT ARD/AME/DAE Database Verification Tool
ACLS Augmented Contingency Landing Site
ACME Ascent Core Meeting
ACT Ascent Constraints Table
ADI Attitude Direction Indicator
ADS Ascent Design System
AEFTP Ascent/Entry Flight Techniques Panel
AEROMED Aerospace Medicine
AFSIG Ascent Flight Systems Integration Group
AGT Adaptive Guidance Table
Adaptive Guidance Throttling
ALT alternate
AM Actual Mode
AME Abort Maneuver Evaluator
AOA Abort Once Around
APM Ascent Performance Margin
APU Auxiliary Power Unit
AR Anomaly Report
ARCS Aft Reaction Control System
ARD Abort Region Determinator
ARD Support Officer
ARDTools ARD Tools
ARDWTS ARD Weights
ASAB Ascent/Abort
ASAP As Soon As Possible
ASCII American Standard Code for Information Interchange
ASCT ascent
ASEV Ascent Events Summary

ATL Attitude Timeline
 ATO Abort To Orbit

B

BFS Backup Flight System
 BOOSTER or BSE Booster System Engineer

C

C Center (for SSMEs)
 C/O checkout
 CAPCOM Capsule Communicator
 CFG configuration
 CFP Conceptual Flight Profile
 c.g. or CG center of gravity
 CLIST Command List
 CMD command
 CNST constraint
 COMM communications
 CONF conference
 CONS console
 CONT contingency
 COTM Command Off The MCC
 CPU Central Processing Unit
 CR Change Request
 CSR Customer Support Room

D

D/O deorbit
 D64 or D64 MED list of TRS input commands
 DAE Downrange Abort Evaluator
 DATA Schedule & Data Management products
 DB database
 DBCHEK ARD database checker (a.k.a. AADDVT)
 DCT Deorbit Constraints Table
 DDD Display Decoder Drive
 DDS Descent Design System
 DEAT Deorbit/Entry Atmosphere Table
 DELWT Delta Weight
 DEPD Deorbit Entry Planning Data
 dhm days, hours, and minutes
 DM mail code for the JSC Flight Design & Dynamics Division
 DMP Deorbit Maneuver Processor
 DMT Detailed Maneuver Table

DNAV	Display Navigator
DOD	Department of Defense
DOF	Degree(s) Of Freedom
DOL	Day Of Launch
DOLILU II	Day-of-Launch I-Load Update, Phase II
DPS	Data Processing and Software
	DBCHEK Product Script
DR	Discrepancy Report
DSCT	descent
DV	Delta Velocity
DVIS	Digital Voice Intercommunications Subsystem
DYN	Computer Dynamics personnel (a.k.a. DYNAMICS)

E

E/W	energy/weight
ECAL	East Coast Abort Landing
ECT	Entry Constraints Table
	Engine Characteristics Table
EDS	Entry Dynamics Simulation
	Entry Design System
EDTE	Enhanced Data Terminal Emulation
EDW	Edwards Air Force Base
EECOM	Electrical, Environmental, and Communications
EF	Earth-Fixed
EI	Entry Interface
ELOG	Event Logging
ELS	Emergency Landing Site
EMD	Engineering and Maintenance Division
ENA	enabled
ENG	engineering
EO	Engine Out
EOM	End of Mission
EOR	End of Replenish
EOW	Energy Over Weight (Energy-to-weight ratio)
EP	Event Predictor
EPP	Entry Planning Profile
ER	Earth Rotation
ERB	Engineering Review Board
ET	External Tank
ETD	External Tank Dry weight
ETIP	External Tank Impact Predictor
ETP	External Tank Propellant
EVA	Extra-Vehicular Activity

E

F	force
F/M	Flow Meter
FADS	Flight Analysis and Design System
FAO	Flight Activities Officer
FCOH	Flight Controller Operations Handbook
FCR	Flight Control Room
FCV	Flow Control Valve
FD	flight day
	flight derived
FD or FLIGHT	Flight Director
FDDD	Flight Design and Dynamics Division
fdf	Flight Data File
FDO	Flight Dynamics Officer
FFM	Fuel Flow Meter
FiGMo	FDO/GPO MOnitor
FLT or FLTR	filter
FLT	flight
FLUX	Solar Flux Table
FOP	Flight Operations Plan
FPR	Flight Performance Reserve
FPS	feet per second
FRR	Flight Readiness Review
FSM	Facility Systems Manager

G

G or g	gravity
G&C	Groundrules And Constraints
GA	Group Administrator
GAP	General Attitude And Pointing
GAS	Get Away Special (payload)
GC	Ground Control
GDSD	Ground Data Systems Division
GDSM	Ground Data Systems Manager
GMT	Greenwich Mean Time
GN&C or GNC	Guidance, Navigation, And Control
GOFPR	FPR adjust program
GPC	General Purpose Computer
GPM	General Purpose Maneuver
GPO	Guidance and Procedures Officer
GRND	ground
GUI	Graphical User Interface

H

H	altitude
He	helium
HA	apogee altitude
HAC	Heading Alignment Circle/Cone
Hdot	altitude rate
HM	Hypothetical Mode
HP	perigee altitude
HP9000	Hewlett Packard computer, model 9000
HPOT	High Pressure Oxidizer Turbo Pump
HR	hour
HSEP	High Speed Entry Processor
HSI	Horizontal Situation Indicator
HSIP	High Speed Input Processor
HSTD	High Speed Trajectory Determination

I

ICB	Integration Control Board
ICD	Interface Control Document
ID	identification
ILC	Integrated Load Checkout
I-LOAD	Initialization Loads
IMB	imbalance
IMU	Inertial Measurement Unit
INCO	Integrated Communications Officer
INCT	interconnect
INH	inhibit
INST	instrumentation
IPS	Integrated Planning System
ISP	specific impulse
ISS	International Space Station
IVT	Independent Verification Test
IY	planar targets

J

JIS	Joint Integration Simulation (JSC and others)
JSC	Lyndon B. Johnson Space Center

K

KMAX	maximum throttle level
KSC	John F. Kennedy Space Center

L

L	left SSME
L -	launch minus (time)
L/O	lift-off
LB	pound
LCC	Launch Commit Criteria Launch Control Complex
LDP	Launch Dependent
LH2	Liquid Hydrogen
LLCO	Low Level Cut-Off
LLTD	Launch Landing Trajectory Data
LOX or LO2	Liquid Oxygen
LPFT	Low Pressure Fuel Turbine
LSO	Landing Support Officer
LST	Landing Site Table
LTT	Launch Target Initialization Table
LWLT	Launch Window-Launch Targeting Processor
LWT	Light Weight (External) Tank

M

M	mass
M50	Mean of 1950
MAC	Mission Action Center
MCC	Mission Control Center
MDM	Multiplexer/De-Multiplexer
MDSSC	McDonnell Douglas Space Systems Company
MEC	Main Engine Controller
MECO	Main Engine Cut-Off
MED	Manual Entry Device
MEDCV	Manual Entry Device Control Vector
MEP	Main Engine Propellant
MET	Mission Elapsed Time
MIN	minimum minute
MIT	Miscellaneous Input Table
MM	Major Mode
MMACS	Maintenance, Mechanical, Arm, and Crew Systems
MMT	Mission Management Team
MOC	Mission Operations Computer
MOCR	Mission Operations Control Room
MOD	Mission Operations Directorate
MOD MGR	Mission Operations Directorate Manager
MPROP	Mass of Propellant
MPS	Main Propulsion System

MPSR	Multi-Purpose Support Room
MR	Mixture Ratio
MSC	Mission Systems Contract
MSK	Manual Select Keyboard
MSW	Mainstage Weights

N

N/A	not available not applicable
N-R	Newton - Raphson
NASA	National Aeronautics and Space Administration
NAV	navigation Navigation Support
NLT	Not Later Than
NM	Nautical Mile
NOM	nominal
NOMMETH	Nominal Main Engine Thrust
NOR	Northrup landing strip
NOTAD	Notice to Ascent Designer
NPSP	Net Positive Suction Pressure
NRCS	Null Reaction Control System
NSTS	National Space Transportation System
NTD	NASA Test Director
NZ	normal load factor

O

O/B	onboard
O/S	overspeed
OBMR	Overboard Mixture Ratio
OCF	One-Cycle-to-Flight
OFFP	Operational Flight Profile
OI	Operational Increment
OIO	Operation Integration Officer
OIR	Operation Integration Review
OMS	Orbital Maneuvering System
OPS	operations
OPT	optimum
OTT	Overhead TAEM Targeting
OV	Orbiter Vehicle
OVRD	over-ride

P

PASS	Primary Avionics Software System
------	----------------------------------

PAO	Public Affairs Officer
PB	push-button
PBI	Push-button Indicator
Pc	chamber pressure
PC	Personal Computer
PCH	Pc Shift High
PCL	Pc Shift Low
PCN	Page Change Notice
PEG	Powered Explicit Guidance
PL	Power Level
PLOAD	Propellant LOADING program
PLS	Primary Landing Site
PLSID	Primary Landing Site Identifier
POCC	Payload Operations Control Center
PPA	Powered Pitch-Around
PPD	Powered Pitch-Down
PRI	primary
PROP	propulsion
	Propulsion Engineer
PSIG	Propellant Systems Integration Group
PTA	Press To ATO
PTF	Product Tracking Form
PTM	Press To MECO
PVL	Previously Verified Load

Q

Q or q	Dynamic Pressure
QA	Quality Assurance

R

R	range
	right (SSME)
R-K	Runge - Kutta
R-V	Range-Velocity
RCS	Reaction Control System
REF	reference
REI	Range from Entry Interface
RGO	Range To Go
RID	Rockwell International – Downey
RLSID	Redesignation Landing Site Identifier
RMS	Root Mean Squared
RNDZ	Rendezvous
RPL	Rated Power Level
RSLs	Redundant Set Launch Sequencer

RSO	Range Safety Officer
RSOC	Rockwell Space Operations Company
RSS	Root Sum Squared
RTHD	Roll to Heads Down
RTHU	Roll to Heads Up
RTLS	Return To Launch Site

S

S/V	Space Vehicle
SAIL	Shuttle Avionics Integration Laboratory
SCA	Simulation Control Area
SDM	Schedule and Data Management
SDRS	Shuttle Display Reconfiguration System
SE	Singe Engine
SECD	Secure Dependent Trajectory Parameter Table
SEP	separation
SEQ	sequential
SERC	Single Engine Roll Control
SERS	Shuttle Equipment Record System
SH	shallow
SIM	simulation
SIMO	simultaneous
SLF	Shuttle Landing Facility
SLWT	Super Light Weight (External) Tank
SMS	Shuttle Mission Simulator
SOP	Standard Operating Procedure
SP	System Parameters
SPAD	Shuttle Performance Assessment Databook
SPAN	Spacecraft Analysis
SPEC	specification
SPF	Software Production Facility
SPOC	Shuttle Portable Onboard Computer
SR	Support Request
SR&QA	Safety, Reliability and Quality Assurance
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SS	Selected Source
SSC	John C. Stennis Space Center
SSME	Space Shuttle Main Engine
SSP	Second Stage Predictor
	Space Shuttle Program
SSV	Space Shuttle Vehicle
ST	steep
STAMPS	Spacecraft Trajectory and Mission Planning System
STS	Space Transportation System

SUM summary
 SV State Vector
 SVDS Space Vehicle Dynamic Simulator
 SVO Space Vehicle Operations

I

T time
 T/L Thrust Limiting
 TAEM Terminal Area Energy Management
 TAL Transoceanic Abort Landing
 TBD To Be Determined
 TBS To Be Supplied
 TDDP Trajectory Design Data Package
 Tdel, T_del, or TDEL difference in time to velocity reference (actual - predicted)
 TDRSS Tracking And Data Relay Satellite System
 TF Thrust Factor
 Trade Factor
 TGO Time to GO
 TGT target
 THRT, THRTL, THROTT Throttle Level
 TIG Time of Ignition
 TLA Thrust Limiting Application
 TLDFA Thrust Limiting Delta File Application
 TLM telemetry
 TM telemetry
 TMECO Time of Main Engine Cutoff
 TMEOUT Time of Main Engine Out
 TOAST Trajectory Operations Applications Software Team
 TOCSS Trajectory Operations Computer System Support
 TOM Trajectory Operations Manager
 TRAJ Trajectory Officer
 Trajectory
 TRS Trajectory Server
 TSA Trajectory Subsystem Application
 TST Test Configuration
 TSUP Trajectory System Upgrade Project
 TTIT Telemetry/Trajectory Interface Table
 TUP Trajectory Update

U

U/S underspeed
 US United States
 USA United Space Alliance

V

V	velocity
VAT	Vector Administration Table
Ve	earth-relative velocity
Vi	inertial velocity
Vrel	relative velocity
VGO	Velocity To Be Gained
VIP	Very Important Person (viewing room)
VMEOUT	Velocity Of Main Engine Out

W

WFCR	White Flight Control Room
WRT	with respect to
WSS	WorkStation Support
WT	weight
WX	weather

X

XR	crossrange
----	------------

Y

Z

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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 (usually you'll share with Entry Support) 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. Give the original to GC, place a copy in the Trajectory Operations Computer Systems Support (TOCSS) AR Box on top of the Navigation (NAV) console and place a copy in your log. 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). The TOCSS personnel pick up ARs from their in box daily. They will track and help resolve (if required) the problem. 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. To submit an AR:
 - a) If you do not have a blank AR form, obtain one from GC.
 - b) Fill in Blocks 1, 2, and 4 with obvious information.
 - i) Block 1: Date of failure (Local time)
 - ii) Block 2: Problem Impact (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.
 - iii) Block 4: Software/Hardware/Admin.
 - c) Fill in Blocks 5-8, 10-12 and 17: they are critical for proper response and tracking. The possible entries are kept up-to-date on the console, or can be obtained by contacting WSS or the GA.

- i) Block 5: System (If it is one of our applications → User Apps)
 - ii) Block 6: Application/Subsystem (If it is one of our applications → Owner of software. (FDO,GPO,NAV,etc...))
 - iii) Block 7: Sub-System (If it is one of our applications → Application Name)
 - iv) Block 8: Building/Room (30S/2334 MPSR, 30S/WFCR, or 30S/SVO)
 - v) Block 10: System Version/Training Load (Ask GC or Use Activity Select and click Info for you activity. The version is on the PSS line. (e.g. or07))
 - vi) Block 11: Host (Your workstation ID)
 - vii) Block 12: Flight ID (Your Activities flight ID)
 - viii) Block 17: Activity (SIM, MISSION, TEST)
- d) Complete the TITLE and DESCRIPTION section.
- e) If you have attachments, do NOT include them with the AR. Keep a copy of the AR and attachments for future reference. Place a note at the bottom of the DESCRIPTION section "Contact AR originator for attachments." Place the AR number on the attachments if contacted.

C KNOWN "GOTCHAS"

This appendix is informal, listing and describing things that are easy to mis-model in the ARD, or that can be confusing and lead to errors. The main text touches on each of these topics, but they appear here for easy reference and as a reminder. The list shown below is an incomplete one.

- Any TMEOUT update after RTLS throttle-chasing will cause all throttle steps that occurred after TMEOUT to be eliminated in the throttle tables, and these will have to be re-done manually. (See 4.2.4)
- ARD Support must note the time of throttle-up (using ARD Output) if a restringable stuck-in-bucket command path SSME is restrung. This throttle-up time will not be captured on any ARD displays, and if the ARD Support does not catch it, we must rely on BSE. (See 4.2.2)
- Using the EOW vs. RGO plot for the RTLS "On the R-V" call is valid only for the flight path angle (gamma) that the display was designed for. (See 4.2.4)
- Check IYs as soon as an ATO is selected onboard. This is an easy check to forget, since we do not perform it for any other aborts. (See 4.2.6)
- Do not judge the ARD's health during OMS assists or dumps based on TMECO differences, unless the ARD's model of the dump has the dump ending very near the predicted MECO time. This is because the onboard computers erroneously assume all OMS assists and dumps will extend to MECO, while the ARD knows that the dump will stop earlier than MECO. Thus, PASS/BFS will assume the vehicle has more delta-V than it really has.
- Watch for second EO K60 AM contingency abort enable cases. (See 4.2.1.2)
- Watch for automatic throttle-downs for any 3-engine RTLS, or 3-engine TAL, or late TAL. (See 4.2.4 & 4.2.5)
- The ARD output may show a single throttle setting (0, 0, 104) in the HM when actually trying to process 0, 0, 0, which is accompanied by many error messages. When the ARD tries to digest the zero throttles, ARD Output complains and kicks out of further processing before getting to the display update task. So basically you are confronted with a display that is lying to you. This situation can happen when FDO turns off the last HM engine via the PBI before turning on another one; e.g., going from 0, 0, 104 to 0, 104, 0 by attempting 0, 0, 0 first. Also recall that the PBI setting of HM throttles toggles between 0 and the current value in the AM. Therefore, to select an engine on in the HM via PBI, that engine needs to be running in the AM.
- Do not become lax and let any single engine call be made with an engine that has a performance case on it.

- LPFT cases can enter "fixed-density mode", and the off-nominal values go away. We need the time it returns to normal for the ARD. Be prepared. We rarely see this in sims. (See 4.2.3.1)
- In the case when an SSME fails, then later a drifter develops on one of the remaining engines, if the ARD is modeled by locking the drifting engine at the BSE-called lockup time, the ARD will be hosed. It is believed that this case causes a line-mismatch in the ARD throttle table on either the locked-up engine, or the engine that has failed, causing havoc in the ARD. The proposed way to avoid this is to lock the engine at the other engine's EO time, not the BSE-called lockup time. (VERIFY)
- Remember that the thrust update computation is not valid in many instances: if an SSME has failed, if an abort has been selected, if an SSME is stuck in the bucket, if a different number of OMS engines is burning onboard as compared to the ARD, and if MET is after 6:00. (See 4.1.4.8)
- Remember to remove any thrust updates if BSE calls a performance case after a thrust update has been put into the ARD, and if the trend was measured during a time when the performance case was in effect. But do not remove a trend after an SSME failure (see 4.1.4.8 and 6.2).
- If an SSME fails in 1st stage behind a data path, and you also perform throttle-table updates, make sure that the MED that updates VMEO to the staging velocity does not wipe out the throttle changes (the VMEO MED engages the ARD's EO Safing Subtask); it has done so in at least one sim. (See 4.2.1.1)
- Note that the ARD will interpret a 104% throttle level in the throttle table as 104.5. This creates a problem with performance cases where 104.0 is the actual desired throttle level. To work around this problem, a value of 103.99 may appear in the throttle table automatically when TRAJ ships the case, and no further action is required. However, if 104.0 appears in the ARD throttle table, a manual update to the tables to 103.99 may be required. We've been seeing this in FFM L/H LVL 1 & 1.5, B/U HYD L/U LVL 1 AND 3 (PWR LVL 104), for all three engines --- WARNING: Don't assume these are the only possible instances. (See 4.2.3.1)
- Note that the ASEV and DPS scripts will not automatically pick up special product deliveries, and thus may not provide the latest data. (See 5.2.3 & 5.2.4)
- Note that the ARD will ignore attempts to model an Item 9 if the K64 MED is shipped prior to the start of OMS Assist (if manifested) (this would only be attempted to get ahead of things), or if the Item 9 modeled quantity is the same as the K64 CUR quantity. (See 4.2.7.6).
- Remove Item 9s if not implemented on-board, if you don't it can really screw things up!

D CHECKLISTS, FORMS, AND DOCUMENTS

This appendix contains the following items in this order.

1. ILC Checklists
 - Orbit ILC-2 Weeks Checklist
 - Post Orbit ILC Checklist
 - Ascent ILC-1 Week Checklist
 - Ascent ILC-2 Days Checklist
 - Ascent ILC Checklist
 - Post Ascent ILC Checklist
2. Launch Checklists
 - L-1 Week Checklist
 - L-1 Day Checklist
 - Launch Day Checklist
 - T-9 Minute Hold Checklist
 - Realtime Checklists
 - Nominal First Stage Checklist
 - Nominal Second Stage Checklist
 - SSME Out Checklist
 - SSME Off-Nominal Checklist
 - Abort Checklist
 - OMS Off-Nominal (Leaks) Checklist
 - OMS Off-Nominal (Fails) Checklist
 - OMS Off-Nominal (Misc.) Checklist
 - Non-Standard Procedures Checklist
 - Post-MECO (DOL) Checklist
 - Post-DOL Checklist
3. FDO Electronic Datapack
4. Thrust Limiting Delta File Verification Form
5. Number of Parameters that Change for DOL

6. Thrust Update Chart
7. ARD Thrust Update History spreadsheet
8. Example of non-standard parameter change

D.1 ORBIT ILC-2 WEEKS CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

1. For the orbit ILC, ARD Support will generate an orbit init PAD and generate files with the data that is used to configure the TSA entry processors. These files are generated using applications in the MCC (as discussed below), and copied from the ARD Support's working directory to the final destination by the GA. MCC applications will access the data from this final application
2. \$PC_ARD refers to the directory S:\Divisions\DM\Private\DM46\ARDSTUFF\ on the PC platform
3. \$IPS_ARD refers to the directory /ips/home/fddm2/ARD_SUPPORT on the IPS FADS platform
4. \$ARD_DB refers to the directory /users/fdo/Data/SSP(XXX)/cycleY/Ard1.0 on the dec alpha (Compaqs in the MCC) platform, where XXX is the flight number and Y is the MCC cycle of the activity you are logged into.

PROCEDURE

1. Determine which flight design cycle (e.g. OCF, OCFR1, etc) and MCC rev (e.g. A, B, C, etc.) to use. Typically, the last flight design cycle will be used; however, this is not always the case. Ask the Lead FDO to make certain. Use this flight design cycle/MCC cycle for all data in the orbit init PAD. In some cases, the ILC may be scheduled before certain products are available. If this is the case, contact the Lead FDO for the parameters not in delivered products.
2. Check the TDDP for the following. Vehicle number and inclination can also be found in prop02.fopchart.asc. Discovery is OV-103, Atlantis is OV-104, and Endeavour is OV-105.
 - o OV#: _____
 - o OV Name: _____
 - o Inclination: _____
3. See onor37 (confirm in onor9.landopts, K83 in data22b.ltt) for L/O times --- verify desired time (open vs. in-plane) with FDO.
 - o D65 L/O Time: _____
 - o K83 L/O Time: _____
4. Get the official OMS Engine assignments at the top link below. Click on each engine to obtain the OME S/N (serial number) at the top right of the page that comes up. (If the top link does not contain data for your OV, PROP sometimes maintains the middle link. You should verify with PROP the table has been updated if this link is used to obtain OMS engine data). Once you know which two engines are on your vehicle and their S/Ns, get thrusts and flowrates from the SODB (bottom link below) Vol I table 4.3.3-8 (add the Oxid and Fuel Flowrates together).

<http://p51.ksc.nasa.gov/dept/oms/oms.htm> (click "Location in Pod/Module" link)

<http://mod.jsc.nasa.gov/df/df63/prop.htm> (click OMS Engine Assignments and Perf link)

<https://opo.jsc.nasa.gov/sodw/>

- Left OMS: Thrust:_____ lbf Flowrate: _____ lbs/sec
 - Right OMS: Thrust:_____ lbf Flowrate: _____ lbs/sec
5. Gather the following, and contact your lead FDO early to gain concurrence on the data:
- M51 Ephemeris 3 (rndz target). See the description section of onor29a.XXX.YYY.01.pdf or XXXYYY_onor29a.ftf for the target's weight, area, KCON, and integrator option. Sometimes these files are in the FTF directory under the flight and cycle in ARDSTUFF\PROD:
 - Init Weight: _____ Area: _____
 - KCON: _____ Integrator Option: _____
 - Set M1 and M2 the same as the previous mission's LDP (or whichever LDP rev was used) cycle:
 - ECT M1: Thrust:_____ Flowrate:_____ Pitch:____ Yaw:____ Comment:_____
 - ECT M2: Thrust:_____ Flowrate:_____ Pitch:____ Yaw:____ Comment:_____
 - F10.7 _____ and Kp_____ These values can also be found in the description section of onor29a.XXX.YYY.01.pdf . If they are not there or that product is not delivered at the point you're doing this step, then use the default values that are in data22b.jvt.asc. Ensure you're using the same values as Nav
 - Any vectors your Lead FDO would like included in the baseline VAT.
 - If any of the above data can not be obtained, simply ask your Orbit FDO for the data. We used to ask the Lead Orbit FDO for all of this data, but having sources for it can speed up the process. You'll find that as long as it's reasonable the accuracy of this data doesn't matter too much to most Orbit FDOs at this stage, so the values will usually be sufficient if you gather the data as described above. If you are consistently seeing that the above products are not available to support the Orbit ILC preparation, blame it on Roger Rojas as these were his suggestions, and talk to the Orbit FDOs about possibly changing our procedure.
6. Build standard CRP Group MED. Unlike the process used to generate GMEDs for the ascent/entry ILC, here the AGM tool is not used because the GMED is very short.
- Login to the IPS and go to the \$IPS_ARD/AGM directory. Obtain a copy of the CRP GMED from the last flight/cycle, and delete all but the following MEDS. Update these MEDS with the values for your mission (except for P41 and G50 since they are fixed):
 - Standard P41 data
 - D65
 - Standard G50 data
 - M51 Ephemeris 3 data
 - M10 left and righ OMS thrust and flowrate
 - The path to the CRP GMED will be listed in your orbit Init Pad, which is sent to the NAV Mission Engineer.
 - Note: Syntax in the CRP GMED file and the order of the MEDS are both very important, so maintain the exact structure, and only modify the necessary values.

- o The following is an example of all that is required in the Orbit CRP GMED file (note, much more will be included in this file for ascent).

P41,D,,1:::\$

D65,121:05:05:05\$

P41,A,C,::\$

P41,A,O,1:30:\$

G50,::,CURI,ON\$

M51,3,200000,DM,1000,2,X9,Prime Target\$

M10,OL,6000,20\$

M10,OR,6001,21\$

7. Build Init Pads

- o Note: The data collected in the steps above are things that must be set, in addition to all TSA settings (see ARD CH Section 2.2.4).
- o Init pads are due to the both the lead and backup (lead for the next flight) Mission Engineers 7 business days prior to the ILC.
- o Refer to ARD CH Sections 2.2.3 and 2.2.4 for instructions on building the init pad. It's the ARD's and FDO's option to set as much ascent-related data that is available at this time. The init pad should list the path to the CRP group MED built in the last step.

8. Get FDO approval of init pad.

9. Submit Init Pad to GA (contact list is top link) and NAV Mission Engineer (middle link), and place a copy of the pad in the directory at the bottom link. Do not submit until after both you and FDO have signed.

<http://mod.jsc.nasa.gov/dm/TOCSS/GA/GA%20Contact%20Info.htm>

<http://usa1.unitedspacealliance.com/usahou/orgs/48-50/Flights/index.htm>

S:\Divisions\DM\Shared\FDDNav\Open

10. Once the changes are made/files are moved, ARD Support must verify that the requested changes were made correctly. After verification, sign the form to signify the database change was verified. Re-send to ME/GA and cc: the lead, ascent and entry FDOs, and move the electronic Pad to the appropriate flight specific (XXX) directories (copies in both TSA and TRS subdirectories):

S:\Divisions\DM\Shared\FDDNav\XXX\TSA\

S:\Divisions\DM\Shared\FDDNav\XXX\TRS\

11. Begin putting the ARD Support console data book together (see Ascent ILC-1 Week Checklist). Create necessary sections, and add the orbit init pad to the book.

12. Note: The ARD Support Officer does not attend the Orbit ILC.

D.2 POST ORBIT ILC CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

None

PROCEDURE

1. THIS STEP MUST BE COMPLETED BEFORE THE NEXT ORBIT ILC.
 - Update the following checklists with any changes, things you have learned, clarifications, etc., that you think need to be made or would help any future ARD Support, especially a new one on their first launch. This is one of the most important steps! Work with the handbook manager (S. Graybeal) to have a CR opened, and to obtain a copy of this appendix to edit. Before editing, make sure that all previous changes have been accepted. During edits, make sure "Track Changes" (under the Tools menu) is ON. When done with changes, send an e-mail to all ARD Supports to screen the changes you made. Don't assume you're done with this step until all ARDs have agreed to your changes. Once all ARDs have agreed, the handbook manager will release a PCN before the next Orbit ILC.
 - D.1 Orbit ILC-2 Weeks Checklist
 - D.2 Post Orbit ILC Checklist

D.3 ASCENT ILC-1 WEEK CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

1. \$PC_ARD refers to the directory S:\Divisions\DM\Private\DM46\ARDSTUFF\ on the PC platform
2. \$IPS_ARD refers to the directory /ips/home/fddm2/ARD_SUPPORT on the IPS FADS platform
3. \$ARD_DB refers to the directory /users/fdo/Data/SSP(XXX)/cycleY/Ard1.0 on the dec alpha (Compaqs in the MCC) platform, where XXX is the flight number and Y is the MCC cycle of the activity you are logged into.

PROCEDURE

1. Ensure all products have been delivered for your flight per the FDO electronic datapack (ARD CH App D) to the directory below. The Auto Group MED (AGM) application (discussed later) will require several of these files to run properly.

\$PC_ARD/PROD/(flt)/(cyc)

- o Use Appendix D.15 of the ARD Handbook (later in this appendix) for the Data Pack checklist. Check off those files that have successfully made it to the above directory.
- o For any that haven't made it to \$PC_ARD, check on the FADS system ("mastdyn" see link below) to see if it was delivered by Flight Design but simply hasn't made it to \$PC_ARD yet. For any files falling into this situation, make a copy in the above directory, but see the first note at the end of the datapack checklist for special instructions for .mif files. Note that any L-1 week datapack items will not be in the \$PC_ARD and mastdyn locations at this time.

/fads/fd10b/dms8/mds/mastdyn/fltcyc

- o Any remaining unchecked items are products that haven't been delivered for some reason. You must determine for each remaining product if it is because the ILC is happening too early in the product delivery schedule (see link below), or if there is another problem with the product. If a product is behind schedule, discuss with your FDO.

\\USAHOUU4\DATA\Shared\SDMSCHEd

2. Determine if any non-standard database changes are required for sims. Your Ascent FDO should know about these. These will typically come from the Ascent/Entry Flight Design group for non-standard updates to the ARD, AME, or DAE. Just tag up with your Abort Support to be double sure. The list of "standard" parameters can be found in the FDO Console Handbook, Section 4.3. These should be built into a separate group MED file from your standard SIM group MEDs so they can be easily removed should there be any issues with them.
3. See onor37 (confirm in onor9.landopts, K83 in data22b.ltt) for L/O times --- verify desired time (open vs. in-plane) with FDO. K83 is in-plane.
 - o D65 L/O Time: _____
 - o K83 L/O Time: _____
4. Check the TDDP for the following. Vehicle number and inclination can also be found in prop02.fopchart.asc. Discovery is OV-103, Atlantis is OV-104, and Endeavour is OV-105.

- OV#: _____
- OV Name: _____
- Inclination: _____

5. Get the official OMS Engine assignments at the top link below. Click on each engine to obtain the OME S/N (serial number) at the top right of the page that comes up. (If the top link does not contain data for your OV, PROP sometimes maintains the middle link. You should verify with PROP the table has been updated if this link is used to obtain OMS engine data). Once you know which two engines are on your vehicle and their S/Ns, get thrusts and flowrates from the SODB (bottom link below) Vol I table 4.3.3-8 (add the Oxid and Fuel Flowrates together).

<http://p51.ksc.nasa.gov/dept/oms/oms.htm> (click "Location in Pod/Module" link)

<http://mod.jsc.nasa.gov/df/df63/prop.htm> (click OMS Engine Assignments and Perf link)

<https://opo.jsc.nasa.gov/sodw/>

- Left OMS: Thrust: _____ lbf Flowrate: _____ lbs/sec
- Right OMS: Thrust: _____ lbf Flowrate: _____ lbs/sec

6. Check which launch pad to use in prop02.fopchart.asc. Include a line that says to load the Launch Pad x Standard Init Pad, dated 11-28-94. The official values can be found in several places, including the following file, where "X" is the launch pad (i.e., "A" or "B").

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\PADS\MASTERS\LPAD39\LC39X.doc

Launch Pad: _____

7. Contact your ascent FDO early to obtain:

- PLSID _____ and RLSID _____

8. Contact your lead FDO early to obtain:

- M51 Ephemeris 3 (rndz target) (verify weight with Orbiter Pre-OMS2 Burn weight from the abbrevrep file in PROP34):
 - Weight: _____ Area: _____
 - KCON: _____ Integrator Option: _____
- ECT M1: Thrust: _____ Flowrate: _____ Pitch: _____ Yaw: _____ Comment: _____
- ECT M2: Thrust: _____ Flowrate: _____ Pitch: _____ Yaw: _____ Comment: _____
- F10.7 _____ and Kp _____ (default values are in data22b.jvt.asc, ensure you're using the same values as Nav)
- Any vectors they'd like included in the baseline VAT.

9. Build standard Group MEDs

- Check the latest navo16b landing site table to see if there have been any changes to the data for site NZC or PMR. These are in the template file, and must be updated prior to running AGM if there have been any changes.

- o Log on to an IPS FADS workstation and cd to:

```
/ips/home/fddm2/ARD_SUPPORT/AGM
```
- o Execute start_agm.ksh. This shell script will set required environment variables and start the AGM interface.
- o Select your flight, cycle, inclination, and launch pad from the pulldowns and radio buttons.
- o Type your data into the fields (launch times, OMS data, Eph 3 info).
- o Click the "Extract Times" button. The 8 time slots should now contain the times for the first 8 lines from the data22b.mit.asc throttle tables.
- o Click the "Build GMED's" button.
- o A popup should appear telling you that the MED files have been built. They will be located in the directory linked below under your flight and cycle, and will be called: SXXXZZZ. 'S' indicates these are sim group MEDs, 'XXX' will be the flight number and 'ZZZ' will be either CRP or THR. CRP = miscellaneous data, THR = throttle table data.

\$IPS_ARD/AGM/V1.0/OUTPUT/(flt)(cyc)

- o Compare your group MEDs with a previous flight for any new/unexpected/omitted changes.
- o If any manual changes to the files are required, ensure the resultant files reside on the IPS FADS platform in the OUTPUT directory above. These are the MEDs that will be moved to the MCC Ops platform.

10. Build Init Pads

- o Note: The data collected in the steps above are things that must be set, in addition to all TSA settings (see ARD CH Section 2.2.4).
- o Init pads are due to both the lead and backup (lead for the next flight) Mission Engineers 3 business days prior to the ILC.
- o Refer to ARD CH Sections 2.2.3 and 2.2.4 for instructions on building the init pad.
- o Include the IPS FADS path and filenames for the group MEDs built during the previous step.

11. Get FDO approval of init pad

12. Submit Init Pad to GA (contact list is top link) and NAV Mission Engineer (middle link), and place a copy of the pad in the directory at the bottom link. Do not send submit until after both you and FDO have signed.

<http://mod.jsc.nasa.gov/dm/TOCSS/GA/GA%20Contact%20Info.htm>

<http://usa1.unitedspacealliance.com/usahou/orgs/48-50/Flights/index.htm>

S:\Divisions\DM\Shared\FDDNav\Open

13. Once the changes are made/files are moved, ARD Support must verify that the requested changes were made correctly. After verification, sign the form to signify the database change was verified. Re-send to ME/GA and cc: the lead, ascent and entry FDOs, and move the electronic Pad to the appropriate flight specific (XXX) directories (copies in both TSA and TRS subdirectories):

S:\Divisions\DM\Shared\FDDNav\XXX\TSA\

S:\Divisions\DM\Shared\FDDNav\XXX\TRS\

14. Configure the stuck actuator tool.

- In \$ARD_DB, create a directory called "Stuck_Actuator". The GAs may need to create this directory along with all the others (e.g. Tools, OMS_Data, etc) for each MCC cycle. Copy over the six files from another flight/cycle (center2.csh, center3.csh, center5.csh, side2.csh, side3.csh, and side5.csh).
- Update the Isp in each file (433.4665 in the example line below):
 - \$DH/Exec/DH_sendmed -hBOTH -mK69,\$1,433.4665,,L,100.1,,A\$
 - $Isp_NEW = (TH_NEW/104.5)*Isp_INITIAL$
 - TH_NEW from Table 4-2 "ARD Update Throttle Setting" in Section 4.2.3.4 (different for each case).
 - Isp_INITIAL is the Isp for each engine at 104.5% throttle (from throttle tables) - note an average of the left and right SSME is sufficient for side.
 - For an MS Excel tool that will do the calculation for you, see the following file. If you use this method, do at least one hand calculation to double check.

S:\Divisions\DM\Private\DM46\ARDSTUFF\STUCK ACTUATOR TABLE\Stuck Actuator Table.xls.

- Note: if the generic booster data remains the same, there should be no change to Isp from one generic setup to the next, but you should still double check this.

15. Create ASEV file (ARD CH 2.2.1)

16. Check on Trajectory Matrix Update (ARD CH 2.1.4)

17. Create OMS Dump Plot (optional --- check with FDO) (ARD CH 2.2.2)

18. Fill in On-Console Data Page for sims (next page)

19. Fill in DBCHEK Updates Checklists throughout the remainder of this checklist with Init Pad data as appropriate.

D.4 ARD SUPPORT ON-CONSOLE DATA PAGE

STS-___ Cycle: ___ ARD: _____ Date: _____

Parameter	Sims	Flight
Bucket Throttle Level ¹	%	%
Bucket Lockup Model Times ¹	ss	ss
Bucket Stop Time ¹	mm:ss	mm:ss
Bucket Length (Stop - Start)	sec	sec
OA Start/Stop Times ²	mm:ss	mm:ss
OA Duration ³	sec	sec
SE OA Weight ⁴	lb/side	lb/side
OME Full Tank ⁵	lb	lb
Useable OMS ⁶	lb	lb
Max Dump Quantity ⁷	lb	lb
RTLS/TAL/ATO INCT ⁸		
Pre-MECO TAL DMP QNTY ⁹		
if ENA	lb	lb
if INH	lb	lb
VLIN ¹⁰	fps	fps
VZERO ¹⁰	fps	fps
V_MISS_CNT (VMEOATO) ¹⁰	fps	fps
TMECO Prediction ¹¹	mm:ss	mm:ss
Pre-L/O Throttle-Up Qnty ¹²	lb	lb
Launch Pad ¹³		

Parameter	Sims	Flight
<ol style="list-style-type: none"> 1. from data22b.mit (asct47 if L-1 week); left-hand number used if stuck in 1st step of a 2-step bucket; right-hand number used if stuck in cold or nominal bucket 2. Start time: Staging time from asct17a + OMSADL from asct08.iloads, no update for DOL 3. K87 Item 6 from data22b.mit (asct47 if L-1 Week; watch discussions on dial-down) OR DTOMSA from asct08.iloads 4. (OA Duration)*19.56 lb/sec 5. (0.5*(K73 Usuable OMS + OA – MR Losses)) (data22b.ame K73 Item 2; asab32b.medcv if DOL) OR (0.5*(K67 ARD OMS WT - MCWTOX) – MR Losses) (data22b.mit K67 Item 7; asab32b.medcv if DOL) MR Losses found on the Prop Loadings page with the OMS leak levels MCWTOX = 798.0 (trapped OMS tank + lines) 6. K73 Item 2 from data22b.ame (asab32b.medcv if DOL) 7. (K87 I2 from data22b.mit)* 39.12 lb/sec (ARD CH 2.2.2) (asct47 if DOL) 8. K66 from data22b.mit: Items 5, 4, 3 respectively for RTLS/TAL/ATO (asct47 if DOL) 9. from Abort Support 10. K88 from data22b.ltt; asct08.iloads (asct47 if DOL) 11. asct17a if sim (Abort Support if DOL) 12. 0.5* time in 1st line of throttle tables *100*3*10.4 if sim TDDP AOA Propellant Inventory “loss for thrust buildup & SRB ignition delay” OR ASCT-47 wtsfpr, ARD Loading Summary, under the “SSME Ignition Time” line if flight 13. prop02.fopchart if sim; TDDP if DOL 		

D.5 ASCENT ILC-2 DAYS CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

1. \$PC_ARD refers to the directory S:\Divisions\DM\Private\DM46\ARDSTUFF\ on the PC platform
2. \$IPS_ARD refers to the directory /ips/home/fddm2/ARD_SUPPORT on the IPS FADS platform
3. \$ARD_DB refers to the directory /users/fdo/Data/SSP(XXX)/cycleY/Ard1.0 on the dec alpha (Compaqs in the MCC) platform, where XXX is the flight number and Y is the MCC cycle of the activity you are logged into.

PROCEDURE

1. Put ARD support console data book together, in this order:
 - o Checkpoint log
 - o ARD Support On-Console Data Page
 - o Init pad(s)
 - o Group MEDs
 - o Formatted AGT (from asct22a.agt.asc)
 - o ASEV
 - o PROP Data
 - o OMS Dump plot (if generated)
 - o DPS output, Full *.print_nc
 - o Datapack checklist
 - o ARDTools inputs (ATDATA on IPS)
 - o All of Appendix D of the ARD Console Handbook
 - o Generic performance case data
2. Go to MCC and login under activity containing same flight number.
3. Check MCC directories created with proper permissions:

Object	Type	Permissions
/users/fdo/Data/SSPXXX/Ard1.0/ (\$ARD_DB)	Populated Directory	Read/Write
\$ARD_DB/AADDVT/	Populated Directory	Read/Write

Object	Type	Permissions
\$ARD_DB/AADDVT/BASE_REFERENCES/	Populated Directory	Read ONLY
\$ARD_DB/AADDVT/BASE_REFERENCES/ baseline	Link	Read ONLY
\$ARD_DB/AADDVT/BASE_REFERENCES/ baseline_2.2	File (current DBCHEK version)	Read ONLY
\$ARD_DB/AADDVT/LOCAL_REFERENCES/	Unpopulated Directory	Read/Write
\$ARD_DB/AADDVT/PLACE_HOLDERS/	Unpopulated Directory	Read/Write
\$ARD_DB/AADDVT/PRODUCT_REFERENCES/	Unpopulated Directory	Read/Write
\$ARD_DB/Delta/	Populated Directory	Read/Write
\$ARD_DB/Delta/ CLUSTER_REF_MR_ISP_VALUES	Link	Read/Write
\$ARD_DB/Delta/ CLUSTER_REF_MR_ISP_VALUES.sim	File (sim version)	Read/Write
\$ARD_DB/Delta/ SIM_DELTA_DATA_C	File (sim version)	Read/Write
\$ARD_DB/Delta/ SIM_DELTA_DATA_L	File (sim version)	Read/Write
\$ARD_DB/Delta/ SIM_DELTA_DATA_R	File (sim version)	Read/Write
\$ARD_DB/FPR/	Populated Directory	Read/Write
\$ARD_DB/FPR/ NOM_EE_BASELINE_VALUES	Link	Read/Write
\$ARD_DB/FPR/ NOM_EE_BASELINE_VALUES.sim	File (sim version)	Read/Write
\$ARD_DB/OMS_Data/	Populated Directory	Read/Write
\$ARD_DB/OMS_Data/ OMS	Link	Read/Write

Object	Type	Permissions
\$ARD_DB/OMS_Data/ OMS.sim	File (sim version)	Read/Write
\$ARD_DB/Reference/	Populated Directory	Read ONLY
\$ARD_DB/Reference/ BLOCK_1_REF_DELTAS	Link	Read ONLY
\$ARD_DB/Reference/ BLOCK_1_REF_DELTAS.sim	File (sim version)	Read ONLY
\$ARD_DB/Reference/ BLOCK_2_REF_DELTAS	Link	Read ONLY
\$ARD_DB/Reference/ BLOCK_2_REF_DELTAS.sim	File (sim version)	Read ONLY
\$ARD_DB/Reference/ PHASE_2_REF_DELTAS	Link	Read ONLY
\$ARD_DB/Reference/ PHASE_2_REF_DELTAS.sim	File (sim version)	Read ONLY
\$ARD_DB/Save	Unpopulated Directory	Read/Write
\$ARD_DB/Scripts/	Populated Directory	Read/Write
\$ARD_DB/Scripts/ Create_TL_Delta_File.inp	File (latest flight version)	Read/Write
\$ARD_DB/Tools/	Populated Directory	Read/Write
\$ARD_DB/Tools/ loadings.asc	Link	Read/Write
\$ARD_DB/Tools/ loadings.asc.sim	File (sim version)	Read/Write
\$ARD_DB/Tools/ misc_data.asc	Link	Read/Write
\$ARD_DB/Tools/ misc_data.asc.sim	File (sim version)	Read/Write

Object	Type	Permissions
\$ARD_DB/Tools/ tldata.asc	Link	Read/Write
\$ARD_DB/Tools/ tldata.asc.sim	File (sim version)	Read/Write

4. Copy DPS files from IPS to MCC (ARD CH 5.2.5.2)

- o Copy the file in the top link below to the directory in the bottom link. Naming convention is <flt><cyc>_<inc><pad>.

\$IPS_ARD/DPS/V2.0/AUTORUN/OUTPUT/(flt)(cyc)/*.dbchek

\$ARD_DB/AADDVT/PRODUCT_REFERENCES

- o Copy the file in the top link below to the directory in the bottom link.

\$IPS_ARD/DPS/V2.0/AUTORUN/OUTPUT/(flt)(cyc)/*.place_holders

\$ARD_DB/AADDVT/PLACE_HOLDERS

- o Do not copy the files *.print_nc to the MCC. These are the print files and trying to open them in the Xess environment will bomb DBCHEK. Print the files (while in IPS) with the following command if desired: `enscript -G -2 -fCourier8 -Pyour_printer filename`

- o Ensure that the baseline file in this directory is the correct file that goes with the DPS data (it should be version 2.2):

\$ARD_DB/AADDVT/BASE_REFERENCES

- o Open these files from DBCHEK to ensure they are readable

5. Check engine selection data. This data should be correct since it's generic for sims. To view the data, go to the DNAV → Applications → Edit ARD Files → SSME Tags.

- o Filename is CLUSTER_REF_MR_ISP_VALUES in:

\$ARD_DB/Delta

- o Move this file to CLUSTER_REF_MR_ISP_VALUES.SIM
- o Create link using this command "ln -s CLUSTER_REF_MR_ISP_VALUES.SIM CLUSTER_REF_MR_ISP_VALUES"

6. Check FPR data. This data should be correct since it's generic for sims. To view the data, go to the DNAV → Applications → Edit ARD Files → FPR Inputs.

- o Filename is NOM_EE_BASELINE_VALUES in:

\$ARD_DB/FPR

- o Move this file to NOM_EE_BASELINE_VALUES.SIM

- Create link using this command "ln -s NOM_EE_BASELINE_VALUES.SIM NOM_EE_BASELINE_VALUES"
7. Check your OMS data file in the link below and update as appropriate with data from the FDO Leak Level sheet from PROP.

\$ARD_DB/OMS_Data

- Filename is OMS in this above directory.
 - Move this file to OMS.SIM
 - Create link using this command "ln -s OMS.SIM OMS"
8. Obtain Trade Factor (see ARD CH 3.3.4 and ASCT-22A), FPR and MR (found in the sim standard engines data Init Pad) for use in the Mass Calibration portion of the ILC.
- FPR: _____
 - Trade Factor: _____
 - MR: _____

D.6 ASCENT ILC CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

None.

PROCEDURE

1. DBCHEK (ARD CH 3.3.2 and 5.1.4.2)
 - Bring up DBCHEK: DNAV → PreLaunch → ARD/AME/DAE DB Check.
 - Get the appropriate flight cycle data by choosing the appropriate file from the “Product-Refs” pull down menu.
 - Select the correct place holder file from the “Set_Placeholder” pull-down menu.
 - Ensure Dynamics hasn’t loaded any group MEDs and then get TRS data: DBCHECK → Data → Get Current.
 - NOTE(2/2/04): There is a system parameter database error that needs to be patched currently. This patch (in the form of a group MED) should be loaded before your initial comparison. Revised (6/21/06): This note may be out of date (e.g. this fix may be rolled into the server initialization)
 - NOTE: There is a P80 MED that is loaded when the server is brought up. The P80 should not change any parameters in the DBCHEK database.
 - Check the placeholder (yellow) rows to ensure only appropriate rows are ignored and update the placeholders file if necessary to add or remove ignored rows. During initial comparisons with the DPS Product file, it is important to scan the entire database and not just search for the mismatches. If DPS doesn’t find a particular piece of data in data22a/b, a “NO VALUE” comment will be entered in the field, and the line will be placeholdered out. Consequently, the line won’t show up in comparisons. If the NO VALUE comment is erroneous, the line number needs to be removed from the placeholder file. There are some cases where the NO VALUE and placeholder are correct. For example, AME target sets and MECO underspeed curves that aren’t required. For these, no data will show up in either the reference or current column. Give extra Scrutiny to rows where data shows up in the current (server) column, but NO VALUE shows up in the reference column. This alone does not tell you if a row should be placeholdered out (e.g. rows 702-713 and 755-766 are DAE coefficients used for low inclination flights, and several “FLT” and “1” rows likes 3358 and 3360), but scrutinize each of these. When in doubt, ask your FDO.
 - Check the DPS product data against the current data and understand all differences. DBCHEK Updates Checklist #1 (below) is used to verify all expected mismatches. All of these should be mismatches, and there shouldn’t be any others. Explain any discrepancies in the space provided.
 - The number of mismatches should be around 70.

Table D-1. DBCHEK Updates Checklist #1

Row	Description	Comment	Notes
-----	-------------	---------	-------

Row	Description	Comment	Notes
23	Slot # of target sequence used for auto-queue execution	Null character in TRS	
72	Slot 4: TAL area ID	DPS data set per init pad	
73	Slot 5: TAL area ID	DPS data set per init pad	
74	Slot 6: TAL area ID	DPS data set per init pad	
80	Primary RTLS runway ID	DPS data contains site ID	
96	Secondary RTLS runway ID	DPS data contains site ID	
240	Primary TAL runway ID	DPS data contains site ID	
253	Secondary TAL runway ID	DPS data contains site ID	
266	Wx Alt 1 TAL runway ID	DPS data contains site ID	
278-316	Wx Alt 2 through 4 Data	DPS data set per init pad	
2944	Site used by comps needing runway coordinates	DPS data set per init pad	
2958	OMS left pitch trim gimbal angle - null angle	See PMP	
2959	OMS right pitch trim gimbal angle – null angle	See PMP	
2960	OMS left cg yaw trim gimbal angle – null angle	See PMP	
2961	OMS right cg yaw trim gimbal angle – null angle	See PMP	
2962	OMS left parallel yaw trim gimbal angle – null	DPS data set per init pad	
2963	OMS right parallel yaw trim gimbal angle – null	DPS data set per init pad	
2967	OMS left steady state thrust level	See flight specific init pad	
2968	OMS right steady state thrust level	See flight specific init pad	
2969	OMS left steady state weight loss rate	See flight specific init pad	
2970	OMS right steady state weight loss rate	See flight specific init pad	
2980	RCS thrust level (-Z high)	DPS data set per init pad	
2991	RCS weight loss rate (-Z high)	DPS data set per init pad	
2998	OMS left pitch trim gimbal angle	See PMP	
2999	OMS right pitch trim gimbal angle	See PMP	
3000	OMS left parallel yaw trim gimbal angle	See PMP	
3001	OMS left cg yaw trim gimbal angle	See PMP	
3002	OMS right parallel yaw trim gimbal angle	See PMP	

Row	Description	Comment	Notes
3003	OMS right cg yaw trim gimbal angle	See PMP	
3215	Rendezvous option	See flight specific init pad	
4122	TGT 18: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
4160	TGT 20: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	

ARD SUPPORT NOTES:

- When satisfied with the data, go to Data → Save Cur as Ref using file name format: XXX_YYY where XXX is the three digit mission number and YYY is the appropriate flight cycle (ocf, eng, or flt) (e.g. 111_OCF). Note that DBCHEK will save the file under Local_REFs.
- If necessary, edit the PLACE_HOLDERS file (can be done after the ILC).
 - From “Edit_PlaceHolders” pull-down menu.
 - Identifiable by rows flagged as placeholders (yellow) but has data in them, or has no data but are not flagged.
 - Add or remove appropriate row numbers (in numerical order!) that should be place holders.
 - Save the file when done.
- Once cold TRS data checkout is complete, tell FDO that you are "go" to load the Group MEDs and system parameters. Ask Dynamics to list the group MEDs they are loading. The following is a list of the standard group MEDs:
 - K69 PREP
 - Throttle table and CRP group MEDs you built earlier, SXXXCRP and SXXXTHR (where XXX is flight number)
 - Standard Block II/Ila group MED (Block_II_Ila.asc.parm)
 - Launch Pad group MED
 - NAV group MED (not built by ARD Support)
- NOTE: Occassionally, we have non-standard group MEDs. Most recently, we used to have to load DAE coefficients and ET photo maneuver adjustment group MEDs. Sometimes we have to do this until such changes are incorporated in the regular products. You should be aware of any such changes at this point.
- Once all group MEDs are loaded, ARD Support must use DBCHEK (get current data again) and verify that the only changes made were due to the init pads submitted using DBCHEK Updates

Checklist #2 (below). Explain any discrepancies in the space provided . IMPORTANT: This comparison must be done against the product data, not the XXX_YYY checkpoint just saved. You may have to reload the appropriate product data from the “Product-Refs” pull down menu, and reselect the place_holder file. At a minimum, the place holder file must be reselected if modified above.

- The number of mismatches should be 32 + any engine configuration differences (total ~330). (If all rows below are mismatched, then there are 479 mismatches (32 + 447 due to engines)).
- NOTE: You may also have IY differences in rows 3218-3223 (and more?). If so, this is could be due to different L/O times between products and Init Pads. Change K83 L/O time to the product L/O time so that the IYs are rotated, see if these IY differences go away (they should), then reset the L/O time to that desired according to the Init Pad.

Table D-2. DBCHEK Updates Checklist #2

Row	Description	Comment	Notes
23	Slot # of target sequence used for auto-queue execution	Null character in TRS	
27	Total vehicle weight from MPT or K73 MED	See flight specific init pad	
47	Nominal Mixture Ratio (K89 MED)	Ensure SIM configuration	
49	Nominal Fuel Bias (K88 MED)	Ensure SIM configuration	
80	Primary RTLS runway ID	DPS data contains site ID	
96	Secondary RTLS runway ID	DPS data contains site ID	
240	Primary TAL runway ID	DPS data contains site ID	
253	Secondary TAL runway ID	DPS data contains site ID	
266	Wx Alt 1 TAL runway ID	DPS data contains site ID	
279	Wx Alt 2 TAL runway ID	DPS data contains site ID	
292	Wx Alt 3 TAL runway ID	DPS data contains site ID	
305	Wx Alt 4 TAL runway ID	DPS data contains site ID	
2944	Site used by comps needing runway coordinates	No null char in TRS data	
2951	ARD flight performance reserve (FPR)	Ensure SIM configuration	
2952	Usable ET propellant at MECO (PROPLVL)	Ensure SIM configuration	
2958	OMS left pitch trim gimbal angle - null angle	See PMP	
2959	OMS right pitch trim gimbal angle – null angle	See PMP	
2960	OMS left cg yaw trim gimbal angle – null angle	See PMP	
2961	OMS right cg yaw trim gimbal angle – null angle	See PMP	

Row	Description	Comment	Notes
2967	OMS left steady state thrust level	See flight specific init pad	
2968	OMS right steady state thrust level	See flight specific init pad	
2969	OMS left steady state weight loss rate	See flight specific init pad	
2970	OMS right steady state weight loss rate	See flight specific init pad	
2998	OMS left pitch trim gimbal angle	See PMP	
2999	OMS right pitch trim gimbal angle	See PMP	
3000	OMS left parallel yaw trim gimbal angle	See PMP	
3001	OMS left cg yaw trim gimbal angle	See PMP	
3002	OMS right parallel yaw trim gimbal angle	See PMP	
3003	OMS right cg yaw trim gimbal angle	See PMP	
3215	Rendezvous option	See flight specific init pad	
4141	TGT 19: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
4179	TGT 21: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
5022-5051	Center SSME Actual Throttle Level	Ensure SIM configuration	
5056-5059	Center SSME Actual Throttle Level MET Pts 5-8	Ensure SIM configuration	
5082-5111	Center SSME Hypothetical Throttle Level	Ensure SIM configuration	
5142-5171	Center SSME Specific Impulse	Ensure SIM configuration	
5176-5179	Center SSME Specific Impulse MET Pts 5-8	Ensure SIM configuration	
5202-5231	Center SSME Mixture Ratio	Ensure SIM configuration	
5236-5239	Center SSME Mixture Ratio MET Pts 5-8	Ensure SIM configuration	
5262-5291	Left SSME Actual Throttle Level	Ensure SIM configuration	
5296-5299	Left SSME Actual Throttle Level MET Pts 5-8	Ensure SIM configuration	

Row	Description	Comment	Notes
5322-5351	Left SSME Hypothetical Throttle Level	Ensure SIM configuration	
5382-5411	Left SSME Specific Impulse	Ensure SIM configuration	
5416-5419	Left SSME Specific Impulse MET Pts 5-8	Ensure SIM configuration	
5442-5471	Left SSME Mixture Ratio	Ensure SIM configuration	
5476-5479	Left SSME Mixture Ratio MET Pts 5-8	Ensure SIM configuration	
5502-5531	Right SSME Actual Throttle Level	Ensure SIM configuration	
5536-5539	Right SSME Actual Throttle Level MET Pts 5-8	Ensure SIM configuration	
5562-5591	Right SSME Hypothetical Throttle Level	Ensure SIM configuration	
5622-5651	Right SSME Specific Impulse	Ensure SIM configuration	
5656-5659	Right SSME Specific Impulse MET Pts 5-8	Ensure SIM configuration	
5682-5711	Right SSME Mixture Ratio	Ensure SIM configuration	
5716-5719	Right SSME Mixture Ratio MET Pts 5-8	Ensure SIM configuration	
5742-5756	Center SSME Influence Coefficients	Ensure SIM configuration	
5757-5771	Left SSME Influence Coefficients	Ensure SIM configuration	
5772-5786	Right SSME Influence Coefficients	Ensure SIM configuration	
5790-5792	Center/Left/Right SSME Tag Liquid O2 Flowrates	Ensure SIM configuration	
5793-5795	Center/Left/Right SSME Tag Liquid H2 Flowrates	Ensure SIM configuration	
5796-5798	Center/Left/Right SSME Tag Gas O2 Flowrates	Ensure SIM configuration	

Row	Description	Comment	Notes
5799-5801	Center/Left/Right SSME Tag Gas H2 Flowrates	Ensure SIM configuration	
5802-5804	Center/Left/Right SSME Tag Thrusts	Ensure SIM configuration	

ARD SUPPORT NOTES:

- When all differences are explained, go to Data → Save Cur as Ref using file name format: XXX_ILC where XXX is the three digit mission number (e.g. 111_ILC). Note that DBCHEK will save the file under Local_REFs.
- 2. Mass Calibration Procedure (ARD CH 3.3.4) - This procedure will configure the SMS to have similar performance properties to the ARD so that the ARD boundaries will be accurate for sims.
 - Begin by reading the following notes:
 - Do not use the Thrust Update method in any of the runs!
 - In all runs, do not compare TMECOs until after the OMS Assist is complete! During the OMS assist, TMECOs may differ between the Onboard and ARD by a couple seconds even if there is no mass error. This is because the onboard assumes that it will have this additional thrust all the way to MECO, causing a TMECO error. The ARD knows the duration of the OMS Assist and calculates its TMECO more accurately. After the OMS Assist is complete, any difference in TMECOs is likely due to a mass error.
 - Avoid different OMS Loads between the SMS and the ARD.
 - Avoid different lift-off times between the SMS and the ARD.
 - Avoid in general, using different SMS and ARD databases. Check for any possible input errors.
 - The FIGMo should use consistent SRBs on runs 1 and 2. They have stated that they see fluctuations in the TDEL even when the SRB model is unchanged. This should not be a problem if the deltas are small. However, we prefer we sim with a base load that has nominal SRBs, and the training folks can change them per sim run to hot or cold if they desire.
 - You will use the ARDTools ILC function to calculate the SMS updates, however, the equations are provided here for reference. You will need ARDTools in auto mode (see ARD CH 5.1.1 for procedures).
 - Run #1 - Nominal Ascent. Objective is to determine how much weight error exists between the SMS and ARD.
 - Begin by reading the following notes:

- If Run #1 has a mass error, determine the magnitude of the error using ARDTools as described below. This run can be stopped after 5-6 minutes, once the quantity of any mass error has been determined. Then compute the SMS correction as described below and have it put into the SMS by FIGMo. Then you can proceed with Run #2.
- Avoid making a mental note of the Run #1 weight adjustment for use later and going ahead with the underspeed evaluation all in Run #1. This method will cause an incorrect underspeed delta and subsequent mass adjustments.
- There should not be an engine out in Run #1, but if there is, avoid using a post-EO TMECO delta for the Run #1 mass computation.
- Prior to the run, ask FIGMo for the initial SMS ETD, L02, and LH2 values:
 - SMS ETD = _____
 - SMS L02 = _____
 - SMS LH2 = _____
- Now you are ready for Run #1. After L/O, record TDEL
 - TDEL = _____
- In ARDTools, after completion of the OMS Assist, click the Δ WT1, 2, and 3 buttons in 20 second intervals (e.g. 4:45, 5:50, and 5:25 MET). It's a good idea to also write down the TGO/MET at each click. Then click the average button. ARDTools will compute the Δ ETD or Δ ETP required for the second run.
- Confirm nominal mixture ratio and then call ARDTools weight adjustments to FIGMO.
 - If ARD heavy: provide FIGMo the delta ETD.
 - If ARD light: provide FIGMo the delta LOX and delta LH2.
- Ask FIGMo for the new SMS ETD, L02, and LH2 values:
 - SMS ETD = _____
 - SMS L02 = _____
 - SMS LH2 = _____
- All remaining steps are the associated manual procedure, and are provided for information. Plus it's a good idea to run through the calculations to understand what's going on.
- Estimate average ARD weight error, 1st run (Δ WT1). Δ TMECO = PASS - ARD.
 - Δ TMECO = _____ @ TGO = _____ → ARD Weight error _____ lb
 - Δ TMECO = _____ @ TGO = _____ → ARD Weight error _____ lb
 - Δ TMECO = _____ @ TGO = _____ → ARD Weight error _____ lb
 - Average ARD weight error = Δ WT1 = _____
- Condition: ARD heavy light (circle one)

- Assign $\Delta W T 1$:
 - If "ARD heavy" ↓ If "ARD light" ↓
 - SMS $\Delta E T D 1 = +$ _____ ($\Delta W T 1$) SMS $\Delta E T D 1 = 0$
 - SMS $\Delta E T P 1 = 0$ SMS $\Delta E T P 1 = -$ _____ ($\Delta W T 1$)
- IF "ARD light", compute SMS $\Delta E T P$ Breakdown:
 - $\Delta L H 2 = - (\Delta E T P 1) / (\text{Nom MR} + 1.0)$ = _____
 - $\Delta L O X = - (\Delta E T P 1) - L H 2$ = _____
- Run #2 - EO between PTA and PTM → no ATO dump effects. Objective: To make sure the calibration from the first run was good (TMECOs match) and determine dry weight error and delta ETP breakdown.
 - Begin by reading the following notes:
 - The Run #1 SMS correction can be confirmed on this second run, before taking a crack at the underspeed evaluation. If done correctly, we should not see any other significant trends on Run #2, and your MECO times should be very close.
 - Avoid aborting ATO after the engine out. You don't want any dump (besides OMS Assist) or planar steering effects in your data.
 - Avoid forgetting to obtain the proper Predicted Underspeed by not subtracting your FPR ΔV from the AM Nom MPROP.
 - $\Delta V F P R$ is the velocity equivalent of FPR. Adding the $\Delta V F P R$ to the AM NOM MPROP is basically adjusting the underspeed prediction for a nominal day. AM NOM MPROP is predicting the underspeed for a 2-sigma bad day (adding in underspeed for the FPR held back). We know we will have a nominal day for ILC runs, so we need to take the FPR underspeed back out.
 - Note: PERFORM WEIGHT ADJUSTMENT USING $\Delta E T P$. DO NOT PERFORM A WEIGHT ADJUSTMENT AFTER THE ENGINE OUT!
 - Talk with FDO and FIGMo before the run to converge on an SSME failure time. The time must be after PTA and before PTM.
 - Now you are ready for Run #2. After L/O, record TDEL
 - TDEL = _____
 - Click the Run2 $\Delta W T$ button after OMS assist completes. If the Run 2 delta weight is not near zero:
 - Inform FDO to see what he/she wants to do. You can either do the Run 1 procedure again for this run (i.e., Run 2 becomes the new Run 1, Run 3 becomes Run 2, etc.), or you can try putting a delta ETP in before the engine failure, and still fail the engine on Run 2 --- but this is tricky because you'll have to calibrate ETD and delta LH2 and LOX all in the same run, so make sure FDO is comfortable with this.
 - Have FIGMo fail the SSME.
 - Record AM NOM MPROP immediately after EO is modeled in ARD

- AM NOM MPROP = _____
- Record ACTUAL MECO U/S = _____ fps (SMS) (from FDO Launch Digitals)
(nominal MECO Vi - actual MECO Vi)
- Call ARDTools weight adjustments to FGMO. Make sure the SMS adds/subtracts ET propellant in the proper mixture ratio as before. The ARD and SMS should now be ready to support sims with this load.
- Ask FIGMo for the new SMS ETD, L02, and LH2 values:
 - SMS ETD = _____
 - SMS L02 = _____
 - SMS LH2 = _____
- All remaining steps are the associated manual procedure.
- Estimate average ARD weight error, 2nd run ($\Delta W T 2$)
 - $\Delta T M E C O =$ _____ @ TGO = _____ → ARD Weight error _____ lb
 - $\Delta T M E C O =$ _____ @ TGO = _____ → ARD Weight error _____ lb
 - $\Delta T M E C O =$ _____ @ TGO = _____ → ARD Weight error _____ lb
 - Average ARD weight error = $\Delta W T 2 =$ _____
- Condition: ARD heavy light (circle one)
- Assign $\Delta W T 2$ sign. If ARD is heavy, $\Delta W T 2$ is positive; if ARD is light, $\Delta W T 2$ is negative.
 - Average ARD weight error = $\Delta W T 2 =$ _____
- Compute $\Delta V F P R$ below and add that to the AM NOM MPROP after the engine out is modeled in the ARD. This will be your predicted underspeed. Obtain your actual underspeed from FDO Launch Digitals, then click calculate for run 2.
 - Compute $\Delta V F P R = F P R / T r a d e \ F a c t o r =$ _____ / _____ = + _____ fps
- Record AM NOM MPROP after EO config = _____
- Compute PREDICTED MECO U/S = $\Delta V F P R +$ AM NOM MPROP margin = _____ fps
- Record ACTUAL MECO U/S = _____ fps (SMS) (from FDO Launch Digitals)
(nominal MECO Vi - actual MECO Vi)
- Compute delta PERFORMANCE = (abs(ACTUAL U/S)-abs(PREDICT U/S))*Trade Factor
 - $\Delta P E R F O R M A N C E = (a b s (_ _ _ _) - a b s (_ _ _ _)) * _ _ _ _ =$ _____
 - WARNING! The quantity (abs(ACTUAL)-abs(PREDICTED)) can be either + or -; be sure to keep the correct sign for the next step!
- Compute SMS run 2 deltas:
 - $\Delta E T P 2 = (0.95 * A v g . \ A R D \ w e i g h t \ e r r o r \ f r o m \ 2 n d \ r u n) + (\pm \Delta P E R F O R M A N C E)$

- SMS $\Delta ETP_2 = (0.95 * \text{_____}) + (\text{_____}) = \text{_____}$ lbs (round to 100 lbs)
- SMS $\Delta ETD_2 = (\Delta WT_2) - (\Delta ETP_2) = \text{_____}$ lbs (round to 100 lbs)
- Compute final SMS deltas:
 - FINAL $\Delta ETP = \Delta ETP_1 + \Delta ETP_2$ FINAL $\Delta ETD = \Delta ETD_1 + \Delta ETD_2$
 - SMS FINAL $\Delta ETP = \text{_____}$ ($\Delta ETP_{\text{final}}$) SMS FINAL $\Delta ETD = \text{_____}$
- Compute final SMS ΔETP breakdown:
 - SMS $\Delta ETP_{\text{final}}$ Breakdown:
 - (a) $\Delta LH_2 = (\Delta ETP_{\text{final}}) / (\text{Nom MR} + 1.0) = \text{_____}$
 - (b) $\Delta LOX = (\Delta ETP_{\text{final}}) - \Delta LH_2 = \text{_____}$
- Run #3 - Verification Run - Make a third run to ensure the ETD, LOX, and LH2 quantities are correct. This is done by repeating the procedure from Run 2. This time, however, the predicted MECO U/S should be within 20 fps of the actual MECO U/S. If not, you may need to recalculate and rerun.
 - Compute PREDICTED MECO U/S = $\Delta VFPR + \text{AM NOM MPROP margin} = \text{_____}$ fps
 - Record ACTUAL MECO U/S = _____ fps (SMS) (from FDO Launch Digitals) (nominal MECO V_i - actual MECO V_i)
 - Compute
 - $\text{ABS}(\text{PREDICTED MECO U/S} - \text{ACTUAL MECO U/S}) = \text{_____}$ fps
- Once happy, FDO will usually run through a series of performance case (thrust limiting) and OMS cases to make sure everything else is working.

D.7 POST ASCENT ILC CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

None

PROCEDURE

1. THIS STEP MUST BE COMPLETED BEFORE THE FIRST SIM ON THIS LOAD.
 - After the ILC, after all the data and placeholders been confirmed, have the GAs move both the files (e.g. 111_OCF AND 111_ILC) from LOCAL_REFERENCES to BASE_REFERENCES. DO NOT FORGET THIS STEP! If you forget this, it is very easy to accidentally delete the DBCHEK ILC files you created at the ILC. If they are deleted, you'll have to re-do the DBCHEK portion of the ILC!
2. THIS STEP MUST BE COMPLETED BEFORE THE NEXT ASCENT ILC.
 - Update the following checklists with any changes, things you have learned, clarifications, etc., that you think need to be made or would help any future ARD Support, especially a new one on their first launch. This is one of the most important steps! Work with the handbook manager (S. Graybeal) to have a CR opened, and to obtain a copy of this appendix to edit. Before editing, make sure that all previous changes have been accepted. During edits, make sure "Track Changes" (under the Tools menu) is ON. When done with changes, send an e-mail to all ARD Supports to screen the changes you made. Don't assume you're done with this step until all ARDs have agreed to your changes. Once all ARDs have agreed, the handbook manager will release a PCN before the next Ascent ILC.
 - D.3 Ascent ILC-1 Week Checklist
 - D.5 Ascent ILC-2 Days Checklist
 - D.6 Ascent ILC Checklist
 - D.7 Post Ascent ILC Checklist

D.8 L-1 WEEK CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

1. \$PC_ARD refers to the directory S:\Divisions\DM\Private\DM46\ARDSTUFF\ on the PC platform
2. \$IPS_ARD refers to the directory /ips/home/fddm2/ARD_SUPPORT on the IPS FADS platform
3. \$ARD_DB refers to the directory /users/fdo/Data/SSP(XXX)/cycleY/Ard1.0 on the dec alpha (Compaqs in the MCC) platform, where XXX is the flight number and Y is the MCC cycle of the activity you are logged into.

PROCEDURE

1. Determine if any non-standard database changes will occur for flight. This may be known well before L-1 week. Your Ascent FDO should know about these. These will typically come from the Ascent/Entry Flight Design group for non-standard updates to the ARD, AME, or DAE. Just tag up with your Abort Support to be double sure. The list of "standard" parameters can be found in the FDO Console Handbook, Section 4.3 (also see Section 4.1.1.1 of this handbook). These should be built into a separate group MED file from your standard flight group MEDs so they can be easily removed should there be any issues with them. Ask Abort Support about M_TEOSTG, which was treated as a non-standard parameter for STS-114. If any non-standard updates are needed:
 - o Make sure the new values are tested in the MCC during the last sim. We are required to sim with these changes during an integrated sim, TRS Checkout run, or a dedicated standalone session.
 - o Use extra caution in verifying the units for any non-standard SYSTEM parameter changes.
 - o Coordinate with Flight Design and fill out the paperwork. An example of the form required can be found at the link below. Signatures are required by: FDO, TRAJ, ARD Support, ARD Designer, ARD Supervisor, and Ascent/Entry Flight Dynamics Group Lead.

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\PADS\MASTERS\Nonstd_Chg_Example.doc

2. Pick a run from the last sim (or any other flight specific sim) to be used in the TRS Checkout run at L-1 day. A nominal run is preferred but not required. Try to save hardcopies and your checklist from the run you choose for reference later. You need to record the following data for input into the trend predictor spreadsheet later:
 - o Sim Date: _____ Run Number: _____ TDEL _____
 - o ARD Trend: _____ ARD Thrust: _____ @ Time _____

Get a hardcopy of the IY display. After the checkpoint prior to the confidence run, this will be used to check the sim lift-off time and IYs loaded for the confidence run.

NOTE: With FDO and TRAJ agreement, it was decided the ASCT-47 throttle tables should be loaded for the confidence run. Reason: If Flight Cycle SSME types differ from DOL SSMEs, updated influence coefficients are also delivered in ASCT-47. Therefore, in order to maintain consistent SSME data for the confidence run, ASCT-47 throttle tables should always be used.

3. Although products are now normally automatically transferred to the PC from FADS, check all products to ensure you have the most recent version from FADS. (For example, DSCT-05 tends to get updated a lot.) Check all directories (especially FRR and LDP). Also, look for ASCTS, DSCTS,

ASABS, & ONORS (Special Request) products. If you find any, tell the FDOs what is new and different from the flight cycle data with which you have been simming. Entry FDO products - DSCT-13, DSCT-28. Inform Entry FDO only if there are any updates. Also, check DSCT-05 and DSCT-30. File location would be the top link below where XXX is mission number. If the mastdyn file server is down, there should be an alternate mastdyn located at the bottom link. (This location is preliminary, and may need to be updated when it is finalized.)

/fads/msn/mds/mastdyn/fltcyc/XXXldp/

/fads/fd10b/dms8/mds/mastdyn/fltcyc

If a hardcopy of a product is needed from FADS, you need to run the MEDIA tool. It is easy to use but can be slow. If you need a FADS ID, call the help desk at 282-2841. To run MEDIA, see the User's Guide in the ARD office or call Patricia Hallbick (282-4648), the developer.

Product Directory Transfer - Copy the flight directory (top link below) from JSC-MOD-FS3 (S:) to JSCMODM (V:). This is done to safeguard product access in case of network connection failure between the MCC fileserver and the B30S fileserver where the products originally reside, or in case of S: failure (happened L-1 Day and DOL of STS-112). Product transfer is accomplished by logging into the JSCMODM fileserver on an MCC PC and dragging the flight product folder from the top directory below to the bottom directory below on JSCMODM. For last week products (Step 5 below), it's your call on giving FDO/TRAJ hardcopies or remembering to transfer them to the JSCMODM V: drive as they arrive. If the B30S fileserver is upgraded to flight critical at some point in the future, which means 24-hour maintenance of the fileserver, then this procedure will become obsolete

\\ARDSTUFF\PROD\

V:\FDO\ARDSTUFF\PROD

4. Get DOL (L-7) TDDP through the Internet. You can go directly to the TDDP document site using the web site below (now password protected; contact Robert Bardwell, 281-226-5782, Robert.Bardwell@boeing.com for access).

<https://rp.boeing.com/ReverseProxy/Authentication.html>

or you can go to ARDSTUFF/PROD directory and click on "TDDPs". Although it contains some of the same Buildup/Mass data that you'll get from other products, it also has the engine tags and MPS budgets.

5. Get last week (mass properties dependent) products from FADS. You need:
 - o PROP-31 (includes the ARD Loading worksheet) _____
 - o ASCT-47 _____
 - o ASAB-32B _____
 - o ASAB-25 _____
 - o ASCT-99 _____
 - o Main Engine Performance Cases Data (non-FADS) _____
 - o OMS Prop & Helium Leak Levels, ΔV Summary, & ATO Dump Table (non-FADS) _____
 - o Give copies to: FDO _____ TRAJ _____ (if electronic copies do not exist in the ARDSTUFF/PROD)

Note that ASCT-47 and ASAB-32B are due at L-3 days. You can find product delivery schedules at the link below. The Flight Designers can fax you preliminary copies ahead of time, before the entire QA cycle is complete. For ASCT-47 call Abort Support and for ASAB-32B call Targeting. If you expect to be preparing for launch over a weekend, consider asking for the automated product search script to run over the weekend.

\\USAHOOU4\DATA\Shared\SDMSCHEd

6. Compare the TDDP mass props and the PROP-31/ARDDATA mass props to be sure they agree. All values must be verified except for the ballast values (last three values in PROP-31). Discrepancies surfaced on STS-82 and STS-91. They are the only ones to occur since the electronic versions came along. In STS-82, the left OMS oxidizer quantity had been updated since publication of the TDDP. In STS-91 the left and right OMS oxidizer quantity had been updated since publication of the TDDP. In both cases, PROP-31 had the latest values. If you find a discrepancy, call whoever signed off on the PROP-31 product, and the FDM if necessary, to find out the story. Also verify these values vs. the mainstage weights table in asct47.wtsfpr.
7. Give the landing weights for RTLS, TAL, and Nominal EOM (called "Orbiter Landing", NOT "Orbiter Landing Nominal") from PROP-34 (Abbrev. Report) to the LSOs to use in the ALP. Do not provide AOA; the FDOs provide this one.
8. Compute NOMMETH and NOMISP. Although nominal main engine thrust is no longer used as NOMMETH in the ARD database, it is used as an input to the trend predictor used for the confidence run. For NOMMETH, average the TDDP data @ 100%. For NOMISP, use the average of the 104.5% values. NOMISP and NOMMETH go into the checkout run trend predictor spreadsheet and NOMISP also goes into ARDTools mass error computation input.
 - o NOMMETH = _____
 - o NOMISP = _____
9. Build the Thrust Limiting Delta Files.
 - o Obtain Main Engine Tables from BOOSTER. All engines should be type Block II. Check the data and make sure that a change to the shuttle program or Booster engine model has not affected the data in ways you may be unaware of (see Delta file update step below).

BOOSTER MET DATA	Center	Left	Right
Engine Type:			
ISP @ 104.5%			
Overboard Mixture Ratio at 104.5%			

Crosscheck data against the TDDP. The TDDP does not contain the Overboard Mixture Ratio (OBMR), but it can be computed using the controller data for liquid and gaseous O2 and H2 on the TDDP SSME Tag Data page.

TDDP DATA	Center	Left	Right
Engine Type:			
ISP @ 104.5%			

TDDP DATA	Center	Left	Right
Overboard Mixture Ratio at 104.5%			

$$\text{OBMR} = (\text{LO2 FLOWRATE} - \text{GO2 FLOWRATE}) / (\text{LH2 FLOWRATE} - \text{GH2 FLOWRATE})$$

- Flowrates from the 104(.5)% column
- Example (using the STS-91 DOL TDDP):
 - Center OBMR = $(937.61 - 1.90) / (155.32 - 0.70) = 6.052$, which agreed with the Main Engine Tables.
- Thrust Limiting Delta File Application (TL DFA)
 - Build delta-files.
 - Login to the MCC LAN (normal ARD Support login).
 - Copy booster flight specific Main Engine Tables (MET) from booster location to a working directory. BSE will provide file location, typically as given below. The file needed is the absolutes (usually: met-rr.FXXX) not the delta files. The normal BSE POC is Jeff Musler at x30720.

/users/booster/FOR_FDO_XXX_FLT/ met-flt.FXXX.no_delta

- Copy this file into the working directory:
 - ~fdo/data/ARD1.0/Scripts/Create_TL_Delta_File.inp
- Modify the above input file using the flight specific MET data.
 - (a) Modify the SSME tags at the top of the file. (Note: NOM_MR = OBMR)
 - (b) Enter the correct B/U HYD L/U LVL 1 and 2 MR and ISPs.
 - (c) Note that HYD L/U Low/Mid/High power levels should not need changing; they are arbitrary within these limits: Low <80, Mid 80 - 94, and High >94.
 - (d) Update the line numbers for all remaining cases; use the "vi" editor to view the MET data with line numbers. (Vi Commands: display line number is ":set number"; quit is ":q!")
- Set script environment with the following command (where XXX is the last flight flown – this picks up the most recent changes):

setenv SCRIPTS /users/trj/Config/cert_apps/SSPXXX/Scripts

- Execute this command:
 - \$SCRIPTS/Create_TL_Delta_File.csh Create_TL_Delta_File.inp
- The delta files will be called: left_delta_file, center_delta_file, and right_delta_file.
- The QA files will be called: left_output, center_output, and right_output.

- Ensure the proper data was extracted using the QA files.
- NOTE: NEW FOR STS-98 & SUBS - WATCH OUT FOR 104% THROTTLE LEVELS IN THE MET FILES WHICH REALLY ARE INTENDED TO BE 104.5. MAY NEED TO MANUALLY CHANGE THEM TO 103.99% IF ACTUALLY INTENDED TO BE 104.0. WE'VE BEEN SEEING THIS IN FFM L/H LVL 1 & 1.5, B/U HYD L/U LVL 1 AND 3 (PWR LVL 104), FOR ALL THREE ENGINES --- WARNING: DON'T ASSUME THESE ARE THE ONLY POSSIBLE INSTANCES OF 104.0. USE "grep "104.0" file" COMMAND TO SEARCH FOR INSTANCES OF 104.0. SEE E-MAIL BELOW FOR MORE INFO, AND AUTHORITY TO DO THIS MANUAL CHANGE. SEE AN EXPERIENCED ARD SUPPORT FOR MORE INFORMATION. IF THESE CASES EXIST:
 - (a) For cases where TRAJ does not have to enter the throttle level in the Thrust Limiting Application (e.g., FFM cases): manually edit the delta files to change 104 to 103.99. Then no further action is required in realtime (since the application will ship 103.99 to the throttle table), and the thrust limiting worksheets will show 103.99. MAKE SURE YOU DISCUSS WITH FDO AND TRAJ PRIOR TO LAUNCH DAY.
 - (b) For cases where TRAJ must enter throttle levels in the Thrust Limiting Application (e.g., B/U L/U or HYD L/U cases): DO NOT manually edit the delta file to change 104 to 103.99. Unfortunately, the Thrust Limiting Application will enter a zero throttle level in realtime if TRAJ enters 103.99. We don't know why, it just does. For this case in realtime, TRAJ will enter 104, 104 will go into the throttle table, and ARD Support must now call TRAJ to call DYN to manually change to 103.99 in realtime. MAKE SURE YOU DISCUSS WITH FDO AND TRAJ PRIOR TO LAUNCH DAY.

E-mail from DF/M. Patel to DM46/R. Mrozinski, July 10, 2001, "RE: STS-104 MET Data":

Richard,

In all these cases you have mentioned, the reference to 104.0 is intended to be 104.0 (not 104.5). I have no issue with ya'll changing it to 103.99 or 104.01 to work around the problem of ARD converting the 104.0 to 104.5. The MET will specify 104.5 when needed. Can you guys keep this e-mail on file instead of verifying it every flight. I am worried that some future Booster/Main Engine operator might not know the answer to your question and instruct you to change it to 104.5.

Thanks,
Munish Patel

-----Original Message-----

From: MROZINSKI, RICHARD B. (JSC-DM) (NASA)
Sent: Tuesday, July 10, 2001 9:15 AM
To: MACHULA, MICHAEL F. (JSC-DF) (NASA)
Cc: PATEL, MUNISH P. (JSC-DF) (NASA)
Subject: RE: STS-104 MET Data

Mike, Munish:

Thanks for the data --- I've processed it for the ARD and all looks good.

However, I did find "104.0" power levels for the following cases, for all three engines:

FFM L act H, Lvl 1
FFM L act H, Lvl 1.5
B/U Elect L/U, Lvl 1

The ARD will take the "104.0" string given by the MET tables and convert it internally to the full value of "104.5", unless we change the string "104.0" to "103.99" (or to "104.01" as another example) in the MET's you delivered. I'd like to verify with you that my manually changing the MET tables for these cases would be appropriate. (This was verified for previous flights, but our procedure for now is to verify every time).

Also, a "104.0" power level line is given for B/U Elect L/U, Lvl 3. If this case is called out in realtime, we would manually enter in realtime a value of 103.99, with the MR and ISP shown in the table. Please verify that this manual realtime change from 104.0 to 103.99 would be appropriate as well.

Thanks,
Rich

Richard B. Mrozinski

NASA Johnson Space Center
Flight Design and Dynamics Division
Ascent/Descent Dynamics, Mail Code DM4
2101 NASA Road 1
Houston, TX 77058
281-483-1062
281-483-6204 (fax)
richard.b.mrozinski1@jsc.nasa.gov

- Once satisfied with the quality of the delta files, solicit the help of a GA to get the delta files loaded into the proper MCC directories. The \$ARD_DB/Deltas directory contains the files that the thrust limiting application refers to in realtime, and the files that the Engine Selection application uses when you are testing the thrust limiting data pre-lift-off. Necessarily, the \$ARD_DB/Reference/ directory is a write-protected directory, and it can be accessed in only by the GA. In this step, the Select Baseline Value option within the Engine Selection application is used to configure the four necessary files in the \$ARD_DB/Deltas directory for flight.

To understand the remaining steps of this procedure, one must understand what occurs when the “OK” button is selected in the Select Baseline Value option within the Engine Selection application. First, the file \$ARD_DB/Deltas/CLUSTER_REF_MR_ISP_VALUES is updated with the nominal throttle levels, ISPs, and MRs for each engine as entered in the Select Baseline Value screen according to the assigned engine types (explained below). When the deltas are applied in realtime, they are applied relative to these values. Next, the files in the left-hand column of the table below are copied from \$ARD_DB/Reference/ to \$ARD_DB/Delta and renamed to the file names in the right-hand column of this same table.

\$ARD_DB/Reference (write protected) ↓	\$ARD_DB/Delta (not write-protected) ↓
BLOCK_1_REF_DELTAS	SIM_DELTA_DATA_L
BLOCK_2_REF_DELTAS	SIM_DELTA_DATA_C
PHASE_2_REF_DELTAS	SIM_DELTA_DATA_R

Which file from the left-hand column above is copied to which file in the right-hand column above is left up to you and it is arbitrary as long as you are consistent. The reason for all the confusion is that the Engine Selection Application’s naming convention is constrained assuming one engine of each of three types: Block I, Block II, and Phase II. In other words, when the “OK” button is selected in the Select Baseline Value option within the Engine Selection application, it assumes that the \$ARD_DB/Reference directory is populated with three files with the exact filenames in the left-hand column in the above table. Thankfully, the Engine Selection application does not care which engine’s data is in which file, and so we can get around this limitation by simply copying the proper data into each type. For example, if a flight contains all three Block II engines, one Block II delta file can be copied to the Block I type, another Block II to the Block II type, and the third Block II to the Phase II type. Each must be copied to a different type. Note which copying configuration you plan to use here; again it is arbitrary, as long as each of the three types (Block I, Block II, and Phase II) are populated and you are consistent in using this mapping.

Engine	Actual (e.g. Block II)	Copied To (e.g. Phase II)
Left		
Center		
Right		

This mapping is set in the Select Baseline Value screen within the Engine Selection application, see below.

Now, the files shown in the left-hand column of the top table above are actually links to other files. At the time of the L-1 week activities, the links should be pointing to files BLOCK_1_REF_DELTAS.sim, BLOCK_2_REF_DELTAS.sim and PHASE_2_REF_DELTAS.sim. So, if you depress the “OK” button now, sim-based files will be copied into the /Deltas directory. So, you need to have the GA switch these links from sim mode to flight (usually done after the last ascent sim prior to flight), meaning that the files linked to will have .flt extensions. To do this and configure all the data for flight, follow these steps:

- Have a GA accompany you to the MPSR.
- Login as FDO.

- Select an activity that deals with the flight.
- Have the GA copy the delta files created in your working directory in the previous step (left_delta_file, center_delta_file, and right_delta_file) to populate these three files /Reference/BLOCK_1_REF_DELTAS.ftt, /Reference/BLOCK_2_REF_DELTAS.ftt, and /Reference/PHASE_2_REF_DELTAS.ftt. NOTE THE “.ftt” EXTENSIONS!. For example, if \$wd represents your working directory, have the GA perform the following commands:

```
cp $wd/left_delta_file $ARD_DB/Reference/BLOCK_1_REF_DELTAS.ftt
```

```
cp $wd/center_delta_file $ARD_DB/Reference/BLOCK_2_REF_DELTAS.ftt
```

```
cp $wd/right_delta_file $ARD_DB/Reference/PHASE_2_REF_DELTAS.ftt
```

- Have the GA change the /Reference links should be pointing to the “.ftt” files in the previous step.
- Open the ARD Thrust Limiting Application using the positional DNAV → Pre-Launch → Engine Selection.
- At the top of the input menu, press “Select Baseline Value.”
- Update the input fields with the MET file data. Be careful to match left, center and right data from the MET to the correct input fields. Set the toggle switches to the correct engine type according to the naming convention selected above. When finished, press “OK”. Continuing with the example above, you would match the left SSME to the BLOCK 1 engine, center to BLOCK 2, and right to PHASE 2. When you select “OK”, then the BLOCK 1 data, which was populated by the left engine delta file, would be copied to /Delta/SIM_DELTA_DATA_L. Similarly for the center and right SSMEs.

Note that if for some reason the delta files are updated the engines MUST be reassigned using the Select Baseline Value option of the Engine Selection Application. The /Delta directory files will not update simply because the /Reference files are updated.

What you have done is update the files: \$ARD_DB/Delta/CLUSTER_REF_MR_ISP_VALUES, and SIM_DELTA_DATA_C. (and _L, _R). The first file contains the MR and ISP tags. The last three files contain copies of the appropriate delta file, depending on engine type, copied from the reference files.

- Perform some checks of the data using the following tables. The purpose of doing this is to record the verification of the flight specific delta files used by the ARD Thrust Limiting Application (TLA). The data recorded includes differences in mixture ratio (MR), specific impulse (ISP) and power level (PL) between the TLA output and the main engine table (MET) data provided by Booster (i.e. diff = TLA value - MET value). All differences must be zero! These tables must be filled out and stored in the ARD Support flight specific folder as proof of verification.

Chamber Pressure (Pc) Shift Low Actual High											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
2.0				1.5				1.0			
4.5				2.5				4.0			
6.0				5.5				6.5			
8.0				8.0				8.0			

Chamber Pressure (Pc) Shift High Actual Low											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
2.0				1.5				1.0			
4.5				2.5				4.0			
6.0				5.5				6.5			
8.0				8.0				8.0			

Backup Electrical Lockup											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0				0				0			
1				1				1			
2				2				2			
109				103				101			
100				92				95			
86				78				90			
68				70				83			
60				62				66			

High Pressure Oxidizer Turbopump (HPOT) Efficiency Loss											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0				0				0			
3				2				1			
5				4				3			
7				6				6			
9				8				8			

Fuel Flowmeter (FFM) Shift High Actual Low											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
1.0				3.0				1.5			
2.0				3.5				2.5			
4.0				4.0				4.0			

Fuel Flowmeter (FFM) Shift Low Actual High											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
3.0				1.5				1.0			
3.5				2.5				2.0			
4.0				4.0				4.0			

Low Pressure Fuel Turbine (LPFT) Discharge Temperature Shift Low											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
1.0				2.0				3.0			
3.0				4.0				5.0			

Nozzle Leak											
Left				Center				Right			
Level	MR	ISP	PL	Level	MR	ISP	PL	Level	MR	ISP	PL
0.0				0.0				0.0			
2.0				1.0				2.0			
4.0				3.0				3.0			
7.0				5.0				6.0			
21.0				22.0				23.0			
24.0				25.0				26.0			

Hydraulic Lockup - Center									
Level	Low			Mid			High		
	MR	ISP	PL	MR	ISP	PL	MR	ISP	PL
12									
9									
4									
0									
-3									
-7									
-12									

Hydraulic Lockup - Left									
Level	Low			Mid			High		
	MR	ISP	PL	MR	ISP	PL	MR	ISP	PL
12									
7									
3									
1									
0									
-10									
-11									

Hydraulic Lockup - Right									
Level	Low			Mid			High		
	MR	ISP	PL	MR	ISP	PL	MR	ISP	PL
11									
8									
2									
0									
-5									
-9									
-12									

- Thrust Limiting Worksheet Application (TLWSA).
 - Having thoroughly verified the delta files, transfer them to the PC:
 - On a DECTerm or Xterm window, navigate to the location of your files.
 - Then ftp to FADS: ftp 130.196.75.1 Enter your FADS ID & password when prompted.
 - Navigate (cd) to your PCDrop Box directory shown below [This account will automatically mail each file to your e-mail address. (Reported max time for transfer is 5 minutes.)]


```
/fads/msn/gds/gen_common/topo/pcdrop/your-id
```
 - Then use the following command to transfer each delta file: put filename

- To exit the ftp process, enter: quit.
- Log on to your PC email account and save files to the link below. Modify file names so they have ".txt" extensions.

S:\Divisions\DM\Private\DM46\ARDSTUFF\TLWSA_v2\flt#

- To run TLWSA, simply double click on TLWSA_v2.xls. You may get an error message resulting from incorrect drive location depending on whether you run this from the office or the MPSR. If so, run the debugger and make sure Drive = V (MPSR) or Drive = S (office). If you need further help, refer to the TLWSA User's Guide (see link below). Modify the second line in the upper-left corner to indicate to which engine in "ENGINE SELECTION" each engine is mapped (see mapping table earlier in this step), and further note that the script will incorrectly label a Block IIA as Block II --- modify if necessary. As an example: "BLOCK II (PHASE II IN ENGINE SELECTION)". Hardcopy each of the three sheets (IMPORTANT: open one at a time, print, and close) and spot check the hardcopy data. Insert a copy of the worksheets in the ARD DOL notebook.

ARDSTUFF\DOCS\Cert TLWSA\Users_Guide.doc

Note: Opening, printing, and closing each sheet one at a time is important because on STS-92 it was observed that the printed copies were incorrect due to opening multiple sheets at once.

Copies to: FDO_____ TRAJ_____

10. Get FDO Leak Levels & OMS Loadings from PROP. Targeting needs the loading benchmarks and mixture ratio losses to complete ASAB-32B. Targeting needs the leak level information in order to complete their console products. Copies (probably electronic) to:

FDO_____ TRAJ_____ TARGETING_____ (ASAP - FAX if required, or ask PROP to do it)

Configure the workstation OMS leak level file with this information. Just a note for the DOL OMS Full tank computation, OMS Full tank is = $\frac{1}{2} * (K73 \text{ OMS Wt} + \text{N.O.A. Wt} - \text{Mixture Ratio Losses})$. Mixture ratio losses can be found on the Prop Loadings page with the OMS leak levels.

11. Hype EO configuration (delivered in ASCT-47) is based on ISP. Two engine calls assume the best engine out; single engine calls assume the two best engines out. ISP is still used as the main driver even though OI-26 ARD computes thrust for each engine based on the influence coefficients compared to a single NOMMETH pre OI-26. Historically, ISP differences between the engines have had a larger impact to boundary calls than differences in thrust.

	TDDP ISP @ 104.5%	2 ENG (1 EO) Calls	1 ENG (2 EO) Calls
Center			
Left			
Right			

Crosscheck your configuration against that delivered in ASCT-47. If they don't match call Abort Support and find out why.

FDO/TRAJ can always use the PBIs in launch phase to set the Hype if they are misconfigured or desire different settings. Discuss the SE config with FDO/TRAJ.

12. Ensure the new K61 SSME ignition time exists in the ASCT-47 icddata file (Ex: K61, -0:04.592\$). Check it against the first line in the new throttle tables. They should match. If they don't, find out why. You will do this again with the new DOLARD throttle tables you receive on DOL, so now it is not too important; but it could give you a heads up if something is wrong.

13. Run the ARDTools Data (ATDATA) application on the IPS FADS.

- o Login to IPS and cd to this directory:

/ips/home/fddm2/ARD_SUPPORT/ATDATA

You will need to make sure the single input file is up to date. cd to input, and check the data in spad_data.asc. An example of this file is shown here (the numbers on the left are for reference and are not in the actual file):

```

Flight Derived Dispersion Data with PLOAD
-----!-----!
Non 6:1 dispersions      !      1 Sigma      !
-----!-----!
4a LO2 LOAD ERROR        !      1374          !
3a LH2 LOAD ERROR        !      260           !
5 OBMR ERROR             !      0.016390     !
7 GO2 PRESSURANT ERROR   !      43.7          !
6 GH2 PRESSURANT ERROR   !      20.0         !
-----!-----!

Auxiliary Data
-----!-----!
8 GAMMA                  !      1.008         !
11 SIGMA LEVEL           !      2.0          !
1 NOMINAL OBMR           !      6.0565       !
  WP1                    !      975000       !
-----!-----!

NSTS 08209 Vol I Table 8.4 - Change No. 62 Dated 06/12/2006
* NOMINAL OBMR obtained from Table 4.149 STS-GEN R0302S MPS PROPELLANT INV ???

SMS SSME Data - Rev 9802
-----!-----!
NOMMETH                  !      469965       !
NOM Isp                  !      452.62      !
23 Fuel Bias             !      679         !
24 FPR                   !      2322        !
-----!-----!

```

Ensure the first eight values in spad_data.asc match the data in the actual SPAD, NSTS 08209 Volume 1, Table 8.4, PTA column ("with" PLOAD). The actual SPAD can be found using the following links. See the following SPAD example, but ALWAYS check that an update to the official dispersions has not occurred between the time this checklist was updated and now. In the example SPAD, the values labeled 4a, 3a, 5, 7, 6, 8, 11, and 1, must match the example spad_data.asc above. The Change No. and the date of the SPAD Table current data should be updated in the file if necessary. Record a copy of the SPAD "without" PLOAD values in case PLOAD is NOT available DOL.

SPAD Web Address: <http://sspweb.jsc.nasa.gov/webdata/pdcweb/08209v1.htm>

(or find NSTS08209 Volume 1 at <http://sspweb.jsc.nasa.gov/webdata/pdcweb/subdocs.htm>)

Ensure also that the "NOMINAL OBMR" value (1) is the same as in the TDDP, an example of which follows the SPAD example, and also includes reference labels. This value should also match the AOA OBMR from the STS-GEN R0302S MPS Propellant Inventory Load Sheet (AOL/TAL) Table G.4.149. NOTE: These values may not match if the Table 8.4 is based on one MPR Propellante Inventory (e.g. R0104S) and Table 4.149 is based on another (e.g. R0302S).

Continue the verification of the spad_data.asc file, by noting that WP1 is based on Flight Cycle engine tags and data, but FPR is not very sensitive to WP1. Therefore, you could use the default

value of 975,000 lbs. The values of NOMMETH and NOM lsp should be edited to match those calculated in Step 8. Fuel bias (23) must match that in the TDDP example below (23). FPR (24) must match the value labeled (24) in the example following the TDDP, which is the "ARD AOA FPR TABLE" taken from asct47.wtsfpr.

TABLE 8.4
 CLASS 2 (NON 6:1) DISPERSIONS AND AUXILIARY DATA
 FOR FPR COMPUTATION

	NOR	PTA	RTLS
LO ₂ Load at T _c , 1s (lb _m) ⁴ (LWVT, w PLOAD/w/o PLOAD)	1,374/1,740	1,374/1,740	1,374/1,740
(SLWVT, w PLOAD/w/o PLOAD)	1,374/1,740	1,374/1,740	1,374/1,740
LH ₂ Load at T _g , 1s (lb _m) ¹ (LWVT, w PLOAD/w/o PLOAD)	260/291	260/291	260/291
(SLWVT, w PLOAD/w/o PLOAD)	260/291	260/291	260/291
OBMR 1s (MRU)	0.014529	0.016390	0.016390
GO ₂ Pressurant 1s (lb _m)	43.7	43.7	43.7
GH ₂ Pressurant 1s (lb _m)	20.0	20.0	20.0
Nom. MPS Usable at OBMR (lb _m) ⁵	1,592,280	1,591,945	1,590,208
Nom. OBMR (MRU) ⁵	6.0550	6.0565	6.0559
Gamma	0.921	1.008	0.972
FPR s Level	3	2	3

⁴Includes start transient uncertainty
⁵Revision 0104S Propellant Inventories

PAGE 12 6B. MPS PROPELLANT INVENTORY DATA - AQA/TAL
 TDDP: DOLAFL10(006)

RELEASED
 LOAD SHEET AQA/TAL SHEET 2 OF 2

MPS PROPELLANT INVENTORY STS GEN REV 0104S

 FUEL BIAS = 894 THROTTLE NOM/AQA = 104.5/104.5 SYS MR = 6.0414
 TOTAL FPR = 2269.4 ULL O2 = 1.52 SIGMA = 2.000 OBMR = 6.0565
 CNTRL MR = 6.02200 ULL H2 = 1.82 LH2 LO2 TOTAL

LOADED	231385	1389104	1620489
ORE LINES	249	3904	3563
SSME X 3	58	1325	1383
ET(HKT=1044.6HUP=.27LXT=412.58LUP=0.78)	231078	1384475	1619553
LOSS PRIOR TO ENG START CMD DET 4.M:55.3	104	5959	6063
BOILOFF, DRAINEACK, ETC.	104	5959	6063
*** MANY LINES DELETED ***			
USABLE RESERVES	1216	1947	3163
ORE LINES (FPR)	0	1863	1863
SSME X 3	0	0	0
ET (FPR)	322	85	406
BIAS	894	0	894
USABLE IMPULSE	226110	1365835	1591945
USED AT OBMR	225129	1362498	1588627
SHUTDOWN CONSUMPTION	922	2165	3088
1 SSME FROM NOM PCT THROTTLE SETTING	332	802	1134
2 SSME FROM 91 PCT THROTTLE SETTING	590	1363	1954
VENTED AFTER SSME X 3 VALVE CLOSURE	58	172	230

STS 110 LDP

ARD AOA FPR TABLE

FPR ITEM	PRE-MISSION 2.0 SIGMA FPR VALUE	TO GET ARD 2.0 SIGMA, MULTIPLY BY	ARD 2.0 SIGMA MPS FPR	CONTRIBUTION TO ARD FPR
ET LOAD & MR	55.+ 1013.	1.000	55.+ 1013	55.+ 616.
SSME ISP (1.42 SEC/SSME)	0.+ 889.	1.000	0.+ 889.	0.+ 474.
SSME THRUST (1563.67 LB/SSME)	0.+ 429.	1.000	0.+ 429.	0.+ 110.
INERT WEIGHT	0.+ 880.	1.000	0.+ 880.	0.+ 464.
SSME THRUST SHAPE	0.+ 61.	1.000	0.+ 61.	0.+ 2.
RESULTS			55.+ 1667.	55.+ 1667.

TOTAL = 1721.

- After verifying `spad_data.asc`, determine the proper directories for the file builds. You will need the “sim” cycle name and the “close to launch” cycle name. Typically, these will be OCF and LDP, respectively. Your sim cycle, however, may have been a rev, in which case, it will be OCFR1, R2, etc. This is important because ATDATA will build your confidence run spreadsheet inputs using this cycle, so make sure you have the same cycle that was used for the confidence run you saved off during the last sim.
- Execute the following command: `start_atdata (flight) (ldp_cycle) (ocf_cycle)` from within the latest version’s directory. Note that if the script complains about write permissions to the output directory (see below), you need to be added to the `ard_spt` group --- see R. Rojas. This start script sets some environment variables and starts the `atdata.perl` script which will extract all the data needed and build the input files for ARDTools, the confidence run spreadsheet, and `AUTO_FPR`.
- The output files will be written to the location below. They should consist of `misc_data.asc`, `ssme.asc`, `fpr.asc`, `loadings.asc`, `confrun.asc`, and `tldata.asc`. MANUALLY QA EACH NUMBER IN EACH of these files, as this script is not yet certified. If you find any errors, edit the files directly.

`/ips/home/fddm2/ARD_SUPPORT/ATDATA/output/(flt)(ldp_cycle)`

- QA `ssme.asc`
 - Data should match data you collected in the two tables of Step 9.
- QA `fpr.asc`
 - Check the output against the following table that gives example data, descriptions, and their sources. The leading numbers in the last column refer to the sample SPAD and TDDP shown above.

FPR DATA SOURCES		
6.0565	Nominal Overboard Mixture Ratio	1 SPAD Table 8.4 (NSTS 08209 Vol I)
1588627	Total Loaded Weight of Prop	2 TDDP AOA/TAL Load Sheet TOTAL "Used at OBMR"
309	1 sigma LH2 Loading	3a SPAD Table 8.4
1376	1 sigma LO2 Loading	4a SPAD Table 8.4
0.008819	1 sigma MR uncertainty	5 SPAD Table 8.4
21.4	1 sigma LH2 vapor uncertainty	6 SPAD Table 8.4
49.4	1 sigma LO2 vapor uncertainty	7 SPAD Table 8.4
1.006	Gamma	8 SPAD Table 8.4
1389104	LOX Load	9 TDDP AOA/TAL Load Sheet LO2 "Loaded"
231385	LH2 Load	10 TDDP AOA/TAL Load Sheet LH2 "Loaded"
2.0	Sigma Level	11 SPAD Table 8.4
0.	Mean SSME Isp dispersion	12 asct47.wtsfpr ARD AOA FPR Table
891.	2 sigma SSME Isp dispersion	13 asct47.wtsfpr ARD AOA FPR Table
0.	Mean SSME Thrust dispersion	14 asct47.wtsfpr ARD AOA FPR Table
428.	2 sigma SSME Thrust dispersion	15 asct47.wtsfpr ARD AOA FPR Table
0.	Mean inert weight dispersion	16 asct47.wtsfpr ARD AOA FPR Table
879.	2 sigma inert weight dispersion	17 asct47.wtsfpr ARD AOA FPR Table
0.	Mean SSME Thrust shape disp	18 asct47.wtsfpr ARD AOA FPR Table
61.	2 sigma SSME Thrust shape disp	19 asct47.wtsfpr ARD AOA FPR Table
0	Mean 2nd stage collector	Zero - not currently used
0	2 sigma 2nd stage collector	Zero - not currently used
975000	WP1	Constant
894.	ARD Fuel Bias	23 TDDP MPS Propellant Inv. AOA/TAL - INPUT SHEET
1723.	ARD Mean + 2 sigma FPR	24 asct47.wtsfpr ARD AOA FPR Table

□ QA loadings.asc

- Check the output against the following table that gives the data sources. The parenthetical numbers in the last column refer to the same numbers in the sample asct47.wtsfpr MAINSTAGE WEIGHTS in the figure following the table.

LOADING DATA SOURCES		
183037.	Inert Orbiter	asct47.wtsfpr MAINSTAGE WEIGHTS(1)
7060.	NPC	asct47.wtsfpr MSW(2)
38423.	Cargo Module	asct47.wtsfpr MSW(3)
104.	ET MPS Pressurant	asct47.wtsfpr MSW(4)
59684.	ET Inert	asct47.wtsfpr MSW(5)
175.	ET Bouyancy	asct47.wtsfpr MSW(6)
447.	ET Ice 1st Stg	asct47.wtsfpr MSW(7a)
10.	ET Ice 2nd Stg	asct47.wtsfpr MSW(7b)
374880.	SRB Inert	asct47.wtsfpr MSW(8)
1620489.	MPS Prop Load	asct47.wtsfpr MSW(10)
1690.	Orb Line Trapped	asct47.wtsfpr MSW(11)
1383.	3SSME Trapped	asct47.wtsfpr MSW(12)
175.	ET Wet Walls	asct47.wtsfpr MSW(13)
3930.	ET Flt Pressurant	asct47.wtsfpr MSW(14)
810.	ET Line Trapped	asct47.wtsfpr MSW(15)
6063.	Boiloff,bleed...	asct47.wtsfpr MSW(16)
230.	Transfer MPS	asct47.wtsfpr MSW(17)
894.	Fuel Bias	asct47.wtsfpr MSW(18)
1863.	Inert Orbiter	asct47.wtsfpr MSW(19)

STS 110 LDP MAINSTAGE WEIGHTS		006
LAUNCH VEHICLE SUBSYSTEM	SUBSYSTEM WT	
	(LBS)	
(1) ORBITER WITHOUT CONSUMABLES (+ OMS MR LOSSES)		184160.
(2) NON-PROPULSIVE CONSUMABLES		7060.
(3) CARGO MODULE		35879.
(4) ET MPS PRESSURANT		104.
(5) ET INERT		59703.
(6) BOUYANCY		175.
(7A) ET ICE 1ST STAGE		447.
(7B) ET ICE 2ND STAGE		10.
(8) L SRB INERT (INFLIGHT LOSS=2223441.		374391.
(9) R SRB INERT LBS KEPT SEPARATELY)		
(10) MPS PROPELLANT LOAD		1620489.
(11) ORBITER LINES UNUSEABLE MPS		1690.
(12) SSME X 3 UNUSEABLE MPS		1383.
(13) ET WET WALLS, BELLOWS MPS		175.
(14) ET FLIGHT PRESSURANT MPS		3930.
(15) ET LINES MPS		810.
(16) BOILOFF, BLEED, SEAL LEAK, POGO FLUSH		6063.
(17) IGNITION TRANSFER		230.
(18) FUEL BIAS		894.
(19) FPR ORBITER LINES		1863.
TOTAL		

- QA confrun.asc: Will be used in Step 16.
- QA misc_data.asc:
 - An example misc_data.asc output follows. It contains the data, a description, and the source. The third column contains some reference numbers (1, 3b, 4b) to the SPAD Table 8.4 example shown earlier. The Nominal Throttle Setting should be clear, and is always 104.5 at this time. The Throttle time for early TL cases refers to the 1:07 time used in Section 4.2.3 for early performance cases; if that procedure has changed, this value must change to reflect the new value. The Average SSME Isp should match the value in Step 9. MECO weight is not to be changed. Verify drainback rate using the "LO2 Drainback (lbm)" from SPAD Table 4.152, and dividing by 4.76667 min. The Trade Factor is found in asct47.wtsfpr in the "ARD AOA FPR TABLE", "ISP RESERVE" subtable, and example of which is found after the example misc_data.asc file, where the trade factor is shown in extra large font. Nominal thrust and Isp were found in Step 8.

MISC_DATA	SOURCE FILE	
104.5	Nominal Throttle Setting	TDDP, NSTS 0770 Vol 3, take your pick
67	Throttle time for early TL cases	Standard Operating Procedure, See Section 4.2.3
10.4	lb of MPS / % throttle / sec	MPS Flow Rate
96.522	Acceleration limit: 3 g's	Constant
1	FTFACT	Constant
452.67	Avg SSME Isp	Average of Step 9 Values
332000	MECO weight	Typical, unlikely to ever update
1275.1	drainback rate (lb/min)	(LO2 drainback in SPAD Table 4.152)/4.6667 min
6.05	Nominal OB mixture ratio	1 SPAD Table 8.4 (NSTS 08209 Vol 1) & TDDP
21.7	Trade factor	asct22a.wtsfpr, asct47.wtsfpr
0.95	Gamma	Constant
469965	Nominal thrust (100%)	See Step 8
452.67	Avg SSME Isp	See Step 8
6.05	Nominal OB Mixture ratio	1 SPAD Table 8.4 (NSTS 08209 Vol 1) & TDDP
1689234	Staging weight	Typical, unlikely to ever update
309	No-PLOAD 1 sigma LH2 Loading	4b SPAD Table 8.4 NSTS 08209 Vol 1)
1746	No-PLOAD 1 sigma LO2 Loading	3b SPAD Table 8.4 NSTS 08209 Vol 1)
wfcr10	WFCR FDO Printer name	Used by ARDTools print function

ARD AOA FPR TABLE
 ISP RESERVE

AVG THRUST = 493208.9 LBS
 AVG ISP = 452.745 SEC
 MEAN ISP per SSME (ISPM) = SYSTEM ISP MEAN
 MEAN ISP per SSME (ISPM) = 0.0000
 3 SIGMA ISP (3SISPS) = (SYSTEM ISP 3 SIGMA * SQRT(3))
 3 SIGMA ISP (3SISPS) = (0.82 * SQRT(3)) = 1.41854954

DWD3ISPM = ((THRUST)/(SPECIFIC IMPULSE - MEAN ISP per SSME)) - (THRUST)/SPECIFIC IMPULSE
 DWD3ISPM = 0.000000 = ((493208.9)/(452.745 - 0.000000)) - (493208.9)/452.745

FOR 2 SSMES OPERATING, ISP DISPERSION:
 D-ISP-2SSME = 1.42/SQRT(2) = 1.003 SEC/SSME
 EXHAUST VELOCITY ERROR = G * D-ISP-2SSME
 EXHAUST VELOCITY ERROR = 32.174049 * 1.003 = 32.273

FOR 3 SSMES OPERATING, ISP DISPERSION:
 D-ISP-3SSME = 1.42/SQRT(3) = 0.819 SEC/SSME
 D-WDOT-3SSME (DWD3ISPS) = (493208.9)/(452.745 - 0.819) - (493208.9)/452.745
 D-WDOT-3SSME (DWD3ISPS) = 1.97 LBS/SEC/SSME
 ARD MECO WT = ZERO MARGIN + GUESS AT AOA FPR
 ARD MECO WT = 314363.812 + 1800.00
 EXHAUST VELOCITY = G * TAG ISP
 EXHAUST VELOCITY = 32.174049 * 452.745 = 14566.64 FPS
 TRADE FACTOR = ARD MECO WT * (1.0 - EXP(-1.0/EXHAUST VELOCITY))
 TRADE FACTOR = 316163.81 * (1.0 - EXP(-1.0 / 14566.64)) = **21.71 LBS/FPS**

SSME ISP MEAN = - TRADE FACTOR * [EXHAUST VELOCITY * ALOG((VEHICLE WEIGHT AT ABORT TIME + (PTA TIME * 3 * DWD3ISPM)) / VEHICLE WEIGHT AT ABORT TIME) + G * ISPM * ALOG(VEHICLE WEIGHT AT ABORT TIME / (ZERO MARGIN WEIGHT + GUESS AT AOA FPR))]]
 SSME ISP MEAN = - 21.70925 * [14566.64 * ALOG((1022112.38 + (279.00 * 3.0 * 0.0000000)) / 1022112.38) + 0.000 * ALOG(1022112.38 / (314363.81 + 1800.00))]]
 = 0.000 LBS

SSME ISP 2 SIGMA = - TF FACTOR * [EXHAUST VEL. * ALOG((VEHICLE WEIGHT AT ABORT TIME + (PTA TIME * 3 * DWD3ISPS)) / VEHICLE WEIGHT AT ABORT TIME) + EXHAUST VEL. ERROR * ALOG(VEHICLE WEIGHT AT ABORT TIME / (ZERO MARGIN WEIGHT + GUESS AT AOA FPR))] * 2 SIGMA/3 SIGMA
 SSME ISP 2 SIGMA = - 21.70925 * [14566.64 * ALOG((1022112.38 + (279.00 * 3.0 * 1.9742432)) / 1022112.38) + 32.273 * ALOG(1022112.38 / (314363.81 + 1800.00))] * 2.0/3.0
 = -888.526 LBS

□ QA tldata.asc:

- An example of tldata.asc is shown below. This file is created by extracting data from asct47?, and adding biases to this thrust limiting data. The biases are fixed (for each mission) and are added to each lsp extracted from the file to generate the data in tldata.asc. The tldata.asc output file is used by the hydraulic lockup drifter portion of the ARD Tools code.

```

-15,5.0056,454.11,454.51,454.96
-14,5.0756,454.14,454.54,454.99
-13,5.1456,454.15,454.54,455.00
-12,5.2156,454.12,454.52,454.97
-11,5.2856,454.06,454.46,454.91
-10,5.3556,453.97,454.37,454.82
-9,5.4256,453.85,454.25,454.70
-8,5.4956,453.70,454.10,454.55
-7,5.5656,453.52,453.92,454.37
-6,5.6356,453.31,453.71,454.16
-5,5.7056,453.07,453.46,453.92
-4,5.7756,452.79,453.19,453.64
-3,5.8456,452.49,452.89,453.34
-2,5.9156,452.16,452.56,453.01
-1,5.9856,451.79,452.19,452.64
0,6.0556,451.40,451.80,452.25
1,6.1256,450.97,451.37,451.82
2,6.1956,450.52,450.92,451.37
3,6.2656,450.03,450.43,450.88
4,6.3356,449.52,449.91,450.37
5,6.4056,448.97,449.37,449.82
6,6.4756,448.39,448.79,449.24
7,6.5456,447.78,448.18,448.63
8,6.6156,447.15,447.54,447.99
9,6.6856,446.48,446.87,447.33
10,6.7556,445.78,446.17,446.63
11,6.8256,445.05,445.44,445.90
12,6.8956,444.29,444.68,445.13
13,6.9656,443.50,443.89,444.34
14,7.0356,442.67,443.07,443.52
15,7.1056,441.82,442.22,442.67
  
```

- Use the PC drop box to send the confrun.asc file to your PC account. On the PC, copy the file to this directory and name as:

\$ARDSTUFF/CONFRUN/(flt)confrun.asc

- FTP the misc_data.asc, fpr.asc, loadings.asc, and tldata.asc files to the MCC, in a fashion similar to transferring the MET files.
- Move the misc_data.asc, loadings.asc, and tldata.asc files to the directory below. Move the links to point to the new files you just moved over.

\$ARD_DB/Tools

- Move the fpr.asc file to the directory below, rename it to fpr_dol.asc, and link NOM_EE_FPR_BASELINE to the new file. Both ARDTools and AUTO_FPR will use this file.

\$ARD_DB/FPR

- Start ARDTools and load all files. Go through each view to ensure the new data was loaded. The thrust limiting data file is not directly viewable via ARDTools, so just enter a drifter case and ensure no errors occur.

14. Create the DOL GAME INIT PAD per steps of Section 2.2.3. Init pads are due to the both the lead and backup (lead for the next flight) Mission Engineers 3 business days prior to the launch.

- Contact your ascent FDO early to obtain:

- PLSID _____ and RLSID _____
- o Contact your lead FDO early to obtain:
 - M51 Ephemeris 3 (rndz target) (verify weight with Orbiter Pre-OMS2 Burn weight from the abbrvrep file in PROP34):

Weight: _____ Area: _____

KCON: _____ Integrator Option: _____
 - ECT M1: Thrust:_____ Flowrate:_____ Pitch:____ Yaw:____ Comment:_____
 - ECT M2: Thrust:_____ Flowrate:_____ Pitch:____ Yaw:____ Comment:_____
 - F10.7 _____ and Kp _____ (default values are in data22b.jvt.asc, ensure you're using the same values as Nav)
 - Any vectors they'd like included in the baseline VAT.
- o Check the old Flight cycle pads very carefully. Any applicable changes done with group MEDs for sims should be duplicated. Include Group MEDs, F02s, etc. If you used an old INIT PAD as an example, make sure you didn't leave any old data on the one you submit to Nav.
- o Ensure "MIS" is selected in the ME Miscellaneous Inputs "Apply To:" checkbox.
- o See onor37b for L/O time estimates --- verify desired time with FDO.
 - D65 L/O Time: _____
 - K83 L/O Time: _____
- o Get the official OMS Engine assignments at the top link below. Click on each engine to obtain the OME S/N (serial number) at the top right of the page that comes up. (If the top link does not contain data for your OV, PROP sometimes maintains the middle link. You should verify with PROP the table has been updated if this link is used to obtain OMS engine data). Once you know which two engines are on your vehicle and their S/Ns, get thrusts and flowrates from the SODB (bottom link below) Vol I table 4.3.3-8 (add the Oxid and Fuel Flowrates together). If KSC switched pods on your Orbiter from the time you wrote the ILC INIT PADS, then the values will be different. (This happened on STS-59 and STS-80, but the ARD Support avoided the caning required by Singsofmore law.) Definitely check this. The STS-82 ARD Support got an update a few days before launch, and the one before that was not very old. Abort Support and Targeting will not use these engine specific numbers in their calculations.

<http://p51.ksc.nasa.gov/dept/oms/oms.htm> (click "Location in Pod/Module" link)

<http://mod.jsc.nasa.gov/df/df63/prop.htm> (click OMS Engine Assignments and Perf link)

<https://opo.jsc.nasa.gov/sodw/>

- Orbiter: : OV-_____
- Left OMS: Thrust:_____ lbf Flowrate: _____ lbs/sec
- Right OMS: Thrust:_____ lbf Flowrate: _____ lbs/sec
- o Check that the atmospheres to use in the DCT have not changed due to the actual launch date slipping compared to the sim launch date. The high-inc switchpoints are April/May and Sept./Oct.

(Could make a difference on high inclination flights.) For low-inc, the spring switchpoint is Feb/Mar. If so, make sure the N-cycles are set correctly.

- Make sure all non-standard System Parameter units are correct! Use the "ARD/AME Database Procedures" document for assistance. Its location is given below.

S:\Divisions\DM\Private\DM46\HNDBOOKS\Ascent FDO\AFDOCHB.doc (Section 4.3)

- Note: Reference to STF No. 660-320-94-087 from Ron Herdrich dated 5/20/94: the following parameters were standardized, even though they technically vary from flight to flight (*These parameters were not found during STS-114 and were assumed to have been deleted with the MOC):
 - MCWTOX = 798 lbs. mass (regardless of OV-102 or not) (in DBCHEK)
 - MCWTRX = 378 lbs. mass (in DBCHEK)
 - *MCRCS1 = 4592 lbs. mass = 142.70 slugs/lbm
 - *MCVDM3 = 50000 fps = 8.60185 ER/HR
 - *MCDEOM = 575 fps = .09892 ER/HR
 - MCMEPT = 1470 lbs. Force (in DBCHEK)
- Ensure that the asct47 and asab32b files are called out in the init pad.
- Be careful! The change file may not list a change for main engine thrust and flow rate tag values and influence coefficients from OCF Cycle (data22b.tmtt) to DOL (asct47) and make it easy for us to forget. (see file linked below for parameter names to check). Just remember to check the ASCT-47 thrust and flow rate values and influence coefficients (SPAD Table 10.9.1) and NOMMXRT against what was delivered in OCF cycle (data22b.mit) to determine if a change has occurred. This must get into the database! Failure to do so will introduce a thrust error in the ARD 3 times the size of the thrust deltas!

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\PADS\MASTERS\StdEngineData9802 TRS.doc

- Make sure you have the correct launch pad loaded in. Include a line that says to load the Launch Pad x Standard Init Pad, dated 11-28-94. It is rare, but there may have been a change since the time the OCF cycle was built and the actual launch date. You usually know about this way ahead of time and probably simmed with the change. (Sometimes you won't sim with the change because it is too hard to get the SMS updated). The official values can be found in several places. Include the following file in the init pad, where "X" is the launch pad (i.e., "A" or "B").

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\PADS\MASTERS\LPAD39\LC39X.doc

- Launch Pad: _____
- Make sure the TAL reduced XR targets are in. The FDO console handbook has the details and standard init pads exist. Basically, just ask DYN to redo what they did for Flight cycle. Check that the XR value is correct - it may be updated. The actual numerical "slots" they use in the landing site table should not change - there should not be any need to confirm the values with GPO.
- Configure the TSA entry processors and add file locations to the init pad. See the ARD Console Handbook, Section 2.2.4, "Procedures to Configure TSA Entry Processors".
- Generate Group MEDs using the Auto Group MED (AGM) Application.

- Check the latest navo16b landing site table to see if there have been any changes to the data for site NZC or PMR. These are in the template file, and must be updated prior to running AGM if there have been any changes.
- Log on to an IPS FADS workstation and cd to:

```
/ips/home/fddm2/ARD_SUPPORT/AGM
```
- Execute start_agm.ksh. This shell script will set required environment variables and start the AGM interface.
- Select your flight, cycle, inclination, and launch pad from the pulldowns and radio buttons.
- Type your data into the fields (launch times, OMS data, Eph 3 info).
- The “Extract Times” button should be grayed out since you won’t modify the throttle table delivered in asct47.
- Click the “Build GMED’s” button.
- A popup should appear telling you that the MED files have been built. They will be located in the directory below under your flight and cycle, and will be called: FXXXZZZ. ‘F’ indicates these are flight group MEDs, ‘XXX’ will be the flight number and ‘ZZZ’ will be either CRP, THR, SYSP, or US. CRP = miscellaneous data, THR = throttle table data, US = MECO U/S Table data, and SYSP = system parameter changes.

```
$IPS_ARD/AGM/V1.0/OUTPUT/(flt)(cyc)
```

- Compare your group MEDs with a previous flight for any new/unexpected/omitted changes.
- If any manual changes to the files are required, ensure the resultant files reside on the IPS FADS platform in the OUTPUT directory above. These are the MEDs that will be moved to the MCC Ops platform.
- You and your Ascent FDO will electronically sign and date once the pad is complete and approved by your Ascent FDO. Place a copy in the bottom link below, and e-mail a copy to the TOCSS GAs (contact list is top link) and NAV Mission Engineers (middle link) and cc: your Ascent FDO, Entry FDO, and Lead FDO, as appropriate. Do not send submit until after both you and FDO have signed. The GA and ME sign the form once the MEDs are screened/file moves are complete, and you’ll be notified via email.

http://mod.jsc.nasa.gov/dm/tocss/GA/ga_info.htm

<http://usa1.unitedspacealliance.com/usahou/orgs/48-50/Flights/index.htm>

S:\Divisions\DM\Shared\FDDNav\Open

15. Init Pad Close-Out:

- Ensure you receive notification from the ME that the Group MEDs cleared the screening process. Your ME will schedule a comp run in the CDE at L-2 days to screen the group MEDs. They should let you know when this is happening so you can be available for any issues. Resolve any problems before L-1 Day! If there is a problem, you don’t want to find out at the confidence run!
- QA the TSA file moves once the GA reports that this has been done. ARD Support must verify that the requested init pad changes were made correctly.

- o After verification of the above two, sign the init pad to signify the database change was verified. Re-send to the GA and ME and cc: the lead, ascent and entry FDOs, and move the electronic Pad to the appropriate flight specific (XXX) directories (copies in both TSA and TRS subdirectories):

S:\Divisions\DM\Shared\FDDNav\XXX\TSA\

S:\Divisions\DM\Shared\FDDNav\XXX\TRS\

16. Determine the expected nominal margin trend for the ARD Confidence run on L-1 day. This is a function of the differences in mass properties and engine models between SMS/SIM and launch data. Use the spreadsheet (link below). If you click the load data button, it will open up a filepicker in the directory where you hopefully saved your confrun.asc file from ATData Step 13. Select your file and click open, and all the data should be filled in for you, other than the data at the top right, which you get from Step 2 of this L-1 Week Checklist.

S:\Divisions\DM\Private\DM46\ARDSTUFF\CONFRUN\Ardconpr.xls or

v:\fdo\ARDSTUFF\...

Take a copy with you to the L-1 day festivities. You may want to give FDO a heads-up on the magnitude of the mass change, especially if it is large enough to affect boundaries.

Copies to: FDO_____ TRAJ_____

17. (Optional - check with your FDO/TRAJ) Generate a new ATO OMS Dump Plot (2.2.2), if one was generated due to FDO request for the ILC, and if VLIN and/or VZERO have changed in asct47.

Copies to: FDO_____ TRAJ_____

18. Update the ARD Support On-Console Data Page.

19. (Optional pending certification of DPS 3.0). Login to IPS FADS and cd to the top directory below. Run the dol_dps.perl script. Command line for this is: dol_dps.perl FLT CYC INC PAD. The CYC in this case is the latest sim cycle. If any LDP updates have been delivered (asct47, asab32b), they will be automatically picked up. FTP the latest DPS LDP data file from the FADS system to the MCC environment (see Section 5.2.5.2 of the ARD Console Handbook). Transfer to the bottom directory below. Open in DBCHEK and sanity check the file for formatting, etc., errors. See an experienced ARD Support if any problems, or if DPS hasn't been run during launch week yet. NOTE: DPS V3.0 MUST BE USED FOR THIS STEP, HOWEVER IT IS NOT CERTIFIED!. The L-1 Day checklist assumes that you do not have this output, so it is okay that this is not certified. It is simply meant to give you additional confidence at the L-1 day activities.

/fads/fd10a/ARD_SUPPORT/DPS/V3.0

\$ARD_DB/AADDVT/Product_References

20. FDO/TRAJ datapacks: Include any late products. DOUBLE-CHECK FOR ANY RE-DELIVERED LDP PRODUCTS (ex: asab32b is sometimes redelivered). Distribute what they don't have by L-1 day. Now that it's all available electronically, just send them an e-mail note telling them it's ready & location

21. Summary check-off:

- o Products:
 - PROP-31 (includes the ARD Loading worksheet) _____

- ASCT-47 _____
- ASAB-32B _____
- ASAB-25 _____
- ASCT-99 _____
- Main Engine Performance Cases Data (non-FADS) _____
- OMS Prop & Helium Leak Levels, ΔV Summary, & ATO Dump Table (non-FADS) _____
- o Created by ARD Support:
 - Non-standard database change paperwork (if applicable) _____
 - Thrust Limiting Tables _____
 - ATO OMS Dump Plot (if FDO requests) _____
 - Ascent Events Summary (if updated and ready at this point - it may be - usually is too early. (On STS-90, we blew it off) Note: Don't make blow-off decision on your own, ask FDO or TRAJ. _____
 - DOL Notes page if deemed applicable. A "nominal" flight with an experienced team probably doesn't need this, but it can answer some typical questions before they are asked, and is a good place to capture any late changes, special procedures, or reminders. Reference: _____

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\DOLNotes\DOLNOTES.doc

22. Ensure you have copied of all critical electronic files (products, init pads, etc.) on the MCC PC, again in case the connection to the S: goes down on L-1 or launch day. Consider also burning all data to a CD.

23. Update these items in the ARD support console data book:

- o ARD Support On-Console Data Page.
- o Init pad(s)
- o Group MEDs
- o ASEV (if done at this point)
- o PROP Data
- o OMS Dump plot (if generated)
- o DPS output, Full *.print_nc
- o Datapack checklist
- o ARDTools inputs (ATDATA on IPS)

- Generic performance case data (updated to flight data)

Note: The sim binder data is preserved. All the screen prints, etc., go into the mission folder. You can build your own DOL binder, similar to the sim binder, but after the fact, all goes into mission folder. Don't redline sim binder for easy checkout use, unless you make your own copy first.

D.9 L-1 DAY CHECKLIST

STS-___ Cycle: ___ ARD: _____ Date: _____

NOTES

1. Recommend ARD Support getting there before the scheduled “TRS-up-and-ready” time for L-1 day database checkout support. Any jump you can get on the process is an advantage. You don’t want to hold up checkpoints and checkout runs, BUT - the idea on L-1 is to get it RIGHT, not get it QUICK. DO NOT be unduly pressured to continue if you are not satisfied with the data. Use your judgment. If it’s not a big deal and doesn’t affect the checkout run, proceed and fix it up/check it later. There is still plenty of time.

PROCEDURE

1. L-1 Database Updates
 - o Run DBCHEK against the IVT checkpoint (e.g. XXX_OCF) prior to loading Group MEDs. DBCHEK Updates Checklist #3 (below) is used to verify all expected mismatches. All of these should be mismatches, and there shouldn’t be any others. Explain any discrepancies in the space provided.
 - o Mismatches should equal 73 because of reference cells without initial values.

Table D-3. DBCHEK Updates Checklist #3

Row	Description	Comment	Notes
23	Slot # of target sequence used for auto-queue execution	Null character in TRS	
72	Slot 4: TAL area ID	DPS data set per init pad	
73	Slot 5: TAL area ID	DPS data set per init pad	
74	Slot 6: TAL area ID	DPS data set per init pad	
80	Primary RTLS runway ID	DPS data contains site ID	
96	Secondary RTLS runway ID	DPS data contains site ID	
240	Primary TAL runway ID	DPS data contains site ID	
253	Secondary TAL runway ID	DPS data contains site ID	
266	Wx Alt 1 TAL runway ID	DPS data contains site ID	
278-316	Wx Alt 2 through 4 Data	DPS data set per init pad	
2944	Site used by comps needing runway coordinates	DPS data set per init pad	
2958	OMS left pitch trim gimbal angle - null angle	See PMP	
2959	OMS right pitch trim gimbal angle – null angle	See PMP	
2960	OMS left cg yaw trim gimbal angle – null angle	See PMP	

Row	Description	Comment	Notes
2961	OMS right cg yaw trim gimbal angle – null angle	See PMP	
2962	OMS left parallel yaw trim gimbal angle – null	DPS data set per init pad	
2963	OMS right parallel yaw trim gimbal angle – null	DPS data set per init pad	
2967	OMS left steady state thrust level	See flight specific init pad	
2968	OMS right steady state thrust level	See flight specific init pad	
2969	OMS left steady state weight loss rate	See flight specific init pad	
2970	OMS right steady state weight loss rate	See flight specific init pad	
2980	RCS thrust level (-Z high)	DPS data set per init pad	
2991	RCS weight loss rate (-Z high)	DPS data set per init pad	
2998	OMS left pitch trim gimbal angle	See PMP	
2999	OMS right pitch trim gimbal angle	See PMP	
3000	OMS left parallel yaw trim gimbal angle	See PMP	
3001	OMS left cg yaw trim gimbal angle	See PMP	
3002	OMS right parallel yaw trim gimbal angle	See PMP	
3003	OMS right cg yaw trim gimbal angle	See PMP	
3215	Rendezvous option	See flight specific init pad	
3799	TGT 1: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
3818	TGT 2: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
4122	TGT 18: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
4160	TGT 20: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	

ARD SUPPORT NOTES:

- o You are GO for loading your inputs, even if FDO is not there yet, assuming this has been agreed to by prior coordination with FDO. Make sure everything gets in correctly. DO NOT LOAD/RELOAD SIM ENGINE DATA FOR ANY REASON. Note: Never update the TRS without FDO or TRAJ approval! When loading the nominal Group MEDs:

- First have DYN load: (Note: Do not load the FxxGND Group MED, this is GPO's responsibility)
 - FXXXCRP (general Group MED)
 - FXXXUS (MECO Underspeeds Table and/or Curves)
 - System parameters (System Parameter Group MED)
 - Launch pad group Med (if needed)
- Perform a K69 prep prior to loading the throttle tables to ensure throttle time conflicts will not cause errors. Note: On STS-99 throttle line 5 caused errors and did not get loaded. Greatly affected trend prediction.
- Load throttle table Group MED, FXXXTHR (SSME throttle tables) where XXX= flight number. Ensure K61 was included in the FXXXCRP or is the first line in FXXXTHR to avoid K61 problems on the second line of the throttle tables. DO NOT load the generic (sim) engine data group MED or you will overwrite flight specific engine data!
- For any System Parameter that will change and that is NOT displayed on an MCC display or DBCHEK, have Dynamics call up the parameter, then make a hardcopy for you. Have the change made and make another hardcopy. Do this procedure carefully! Verify units! Use the System Parameter Report if necessary.
- Double-check that all non-standard database changes are in! They are most likely not in DBCHEK, and will require you to have DYN call up the parameter and make a hardcopy for you (see previous item).
- The following is a subset of parameters to keep an eye on during the L-1 database checkout. Most are listed in the DBCHEK Checklist below. Those flagged with an "*" are not.
 - MCRSET = 0.0 (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3040)
 - MCMPSP = 0.0 (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3045)
 - MCWTDR (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3048)
 - MCWTET (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3046)
 - MCWTSD (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3047)
 - MCK2MN (MCK2MN on ARD/AME SYS PARM or ASC SYS Parms 2, and EPS K2 on ARD CONTROL DATA/DBCHEK Row 5824)
 - MCTMST (ARD/AME SYS PARM or ASC SYS Parms 2/DBCHEK Row 3082)
 - MCORBR = 4.33476 (TRAJ PARMS (F02)/DBCHEK Row 3158)
 - MCWTOX = 798.0 (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3049)
 - MCWTRX = 378.0 (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 3050)
 - MCMEPT = 1470 lbf (ARD/AME SYS PARM or ASC SYS Parms 1/DBCHEK Row 2996)
 - *ATOMBO = (see product) (AME Primary/DBCHEK Row 44)

- Check launch pad again, mainly if there has been a change (MISC PARAMETERS/DBCHEK rows 4933 to 4945; compare against MASTER INIT PAD for your Launch Pad).
 - Launch Pad: _____
- Run DBCHEK again. Verify miscompares against DBCHEK Updates Checklist #4 (CURRENT). Make absolutely sure you understand every change, especially unexpected ones.
- Number of Miscompares is ~166 + K94's (e.g. 421) (Number also may vary based on inclination and even more depending on the engine config from IVT to launch because of the influence coeffs.)

Table D-4. DBCHEK Updates Checklist #4 (CURRENT)

Row	Description	Comment	Notes
9	Initial OMS		
10	Aft RCS weight		
11	MEP weight		
12	Dry weight		
13	SRB Jettison weight		
14	Weight loss from ET jettison		
16	Time of SSME ignition		
26	Vehicle weight		
27	Usable OMS wt for AME planning		
28	Usable RCS wt for AME planning		
44	Fwd RCS weight		
45	Nom mixture ratio		
47	Fuel Bias		
61	Slot 1: TAL Area ID	= low cr site, e.g. LZA (see 348)	
62	Slot 2: TAL Area ID	= low cr site, e.g. LBY (see 349)	
63	Slot 3: TAL Area ID	= low cr site, e.g. LMN (see 350)	
267	Alt 2 TAL: Runway Area		
268	Alt 2 TAL: Runway ID		
269	Alt 2 TAL: Runway A1		

Row	Description	Comment	Notes
270	Alt 2 TAL: Runway A2		
271	Alt 2 TAL: Runway A3		
272	Alt 2 TAL: Runway A4		
273	Alt 2 TAL: MECO Gamma		
274	Alt 2 TAL: MECO radius		
275	Alt 2 TAL: Max CR		
276	Alt 2 TAL: Max valid velocity		
277	Alt 2 TAL: Min valid velocity		
278	Alt 2 TAL: 2E throt down vel		
279	Alt 2 TAL: 3E throt down vel		
280	Alt 3 TAL: Runway Area		
281	Alt 3 TAL: Runway ID		
282	Alt 3 TAL: Runway A1		
283	Alt 3 TAL: Runway A2		
284	Alt 3 TAL: Runway A3		
285	Alt 3 TAL: Runway A4		
286	Alt 3 TAL: MECO Gamma		
287	Alt 3 TAL: MECO radius		
288	Alt 3 TAL: Max CR		
289	Alt 3 TAL: Max valid velocity		
290	Alt 3 TAL: Min valid velocity		
291	Alt 3 TAL: 2E throt down vel		
292	Alt 3 TAL: 3E throt down vel		
293	Alt 4 TAL: Runway Area		
294	Alt 4 TAL: Runway ID		
295	Alt 4 TAL: Runway A1		
296	Alt 4 TAL: Runway A2		
297	Alt 4 TAL: Runway A3		

Row	Description	Comment	Notes
298	Alt 4 TAL: Runway A4		
299	Alt 4 TAL: MECO Gamma		
300	Alt 4 TAL: MECO radius		
301	Alt 4 TAL: Max CR		
302	Alt 4 TAL: Max valid velocity		
303	Alt 4 TAL: Min valid velocity		
304	Alt 4 TAL: 2E throt down vel		
305	Alt 4 TAL: 3E throt down vel		
862	Delta time from MECO to start OMS dump (B72)	See flight specific init pad	
863 – 982 (misc of these)	MECO U/S Curves Updates	See FXXXUS D64	
2933	Site used by comp needing rnwy coord	= KSC	
2939	Fuel Performance Reserve (FPR)		
2940	Usable ET prop at MECO		
2945	OMS left par. yaw, trim gimbal - null	= -5.7	
2946	OMS rt par. yaw, trim gimbal - null	= 5.7	
2950	OMS left steady state thrust lvl		
2951	OMS right steady state thrust lvl		
2952	OMS left ss weight loss rate		
2953	OMS right ss weight loss rate		
2963	RCS thrust level (-Z high)	= 1470	
2974	RCS weight loss rate (-Z high)	= 0.1	
2979	MCMEPT	= 1470	
3027	Weight of External Tank (MCWTET)		
3028	Weight of SRB's (MCWTSD)		
3029	Orbiter Dry Weight (MCWTDR)		
3030	MCWTOX	= 798	
3031	MCWTRX	= 378	

Row	Description	Comment	Notes
3038	MCC1DL	??? NOT IN ASCT44 or PAD	
3039	MCC2DL	??? NOT IN ASCT44 or PAD	
3055	Max throttle for EO		
3057	MCTMST (careful! Listed as MCKRT2, see next item)	??? NOT IN ASCT44 or PAD	
3062	SRB Staging Time (MCTMST?)		
3097	MCXWTO		
3098	MDMBOD01	??? NOT IN ASCT44 or PAD	
3099	MDMBOD02	??? NOT IN ASCT44 or PAD	
3149	Rendezvous option	AR opened on this variable	
3150	Lift-off calendar day		
3151	Lift-off time		
3733		Should be blank vs. blank	
3752		Should be blank vs. blank	
4056		Should be blank vs. blank	
4094		Should be blank vs. blank	
4856	MCDBD1		
4857	MCDBD2		
4858	MCDBD3		
4862	MCDVN2		
4863	MCDVN3		
4867	MDLSDD01	??? NOT IN ASCT44 or PAD	
4869	MDLSDD03	??? NOT IN ASCT44 or PAD	
4872	MDLSDD06	??? NOT IN ASCT44 or PAD	

Row	Description	Comment	Notes
4892	VLIN		
4893	VZERO		
4894	VMEOATO		
4959-4985	Pt 4-30: C SSME - Actual Throttle		
4986	Pt 1: C SSME - Act Throt MET		
4988-4993	Pt 3-8: C SSME - Act Throt MET		
5016-5045	Pt 1-30: C SSME - Hyp Throttle		
5046	Pt 1: C SSME - Hyp Throt MET		
5076-5105	Pt 1-30: C SSME - Specific Impulse		
5106	Pt 1: C SSME - ISP MET		
5108-5113	Pt 3-8: C SSME - ISP MET		
5136-5165	Pt 1-30: C SSME - Mixture Ratio		
5166	Pt 1: C SSME - MR MET		
5168-5173	Pt 3-8: C SSME - MR MET		
5199-5225	Pt 4-30: L SSME - Actual Throttle		
5226	Pt 1: L SSME - Act Throt MET		
5228-5233	Pt 3-8: L SSME - Act Throt MET		
5256-5285	Pt 1-30: L SSME - Hyp Throttle		
5286	Pt 1: L SSME - Hyp Throt MET		
5316-5345	Pt 1-30: L SSME - Specific Impulse		
5346	Pt 1: L SSME - ISP MET		
5348-5353	Pt 3-8: L SSME - ISP MET		
5376-5405	Pt 1-30: L SSME - Mixture Ratio		
5406	Pt 1: L SSME - MR MET		
5408-5413	Pt 3-8: L SSME - MR MET		
5439-5465	Pt 4-30: R SSME - Actual Throttle		
5466	Pt 1: R SSME - Act Throt MET		
5468-5473	Pt 3-8: R SSME - Act Throt MET		

Row	Description	Comment	Notes
5496-5525	Pt 1-30: R SSME - Hyp Throttle		
5526	Pt 1: R SSME - Hyp Throt MET		
5556-5585	Pt 1-30: R SSME - Specific Impulse		
5586	Pt 1: R SSME - ISP MET		
5588-5593	Pt 3-8: R SSME - ISP MET		
5616-5645	Pt 1-30: R SSME - Mixture Ratio		
5646	Pt 1: R SSME - MR MET		
5648-5653	Pt 3-8: R SSME - MR MET		
5676	C SSME Thrust Infl Coeff 1		
5677	C SSME Liquid O2 Infl Coeff 1		
5678	C SSME Liquid H2 Infl Coeff 1		
5679	C SSME Gaseous O2 Infl Coeff 1		
5680	C SSME Gaseous H2 Infl Coeff 1		
5681	C SSME Thrust Infl Coeff 2		
5682	C SSME Liquid O2 Infl Coeff 2		
5683	C SSME Liquid H2 Infl Coeff 2		
5684	C SSME Gaseous O2 Infl Coeff 2		
5685	C SSME Gaseous H2 Infl Coeff 2		
5686	C SSME Thrust Infl Coeff 3		
5687	C SSME Liquid O2 Infl Coeff 3		
5688	C SSME Liquid H2 Infl Coeff 3		
5689	C SSME Gaseous O2 Infl Coeff 3		
5690	C SSME Gaseous H2 Infl Coeff 3		
5691	L SSME Thrust Infl Coeff 1		
5692	L SSME Liquid O2 Infl Coeff 1		
5693	L SSME Liquid H2 Infl Coeff 1		
5694	L SSME Gaseous O2 Infl Coeff 1		
5695	L SSME Gaseous H2 Infl Coeff 1		

Row	Description	Comment	Notes
5696	L SSME Thrust Infl Coeff 2		
5697	L SSME Liquid O2 Infl Coeff 2		
5698	L SSME Liquid H2 Infl Coeff 2		
5699	L SSME Gaseous O2 Infl Coeff 2		
5700	L SSME Gaseous H2 Infl Coeff 2		
5701	L SSME Thrust Infl Coeff 3		
5702	L SSME Liquid O2 Infl Coeff 3		
5703	L SSME Liquid H2 Infl Coeff 3		
5704	L SSME Gaseous O2 Infl Coeff 3		
5705	L SSME Gaseous H2 Infl Coeff 3		
5706	R SSME Thrust Infl Coeff 1		
5707	R SSME Liquid O2 Infl Coeff 1		
5708	R SSME Liquid H2 Infl Coeff 1		
5709	R SSME Gaseous O2 Infl Coeff 1		
5710	R SSME Gaseous H2 Infl Coeff 1		
5711	R SSME Thrust Infl Coeff 2		
5712	R SSME Liquid O2 Infl Coeff 2		
5713	R SSME Liquid H2 Infl Coeff 2		
5714	R SSME Gaseous O2 Infl Coeff 2		
5715	R SSME Gaseous H2 Infl Coeff 2		
5716	R SSME Thrust Infl Coeff 3		
5717	R SSME Liquid O2 Infl Coeff 3		
5718	R SSME Liquid H2 Infl Coeff 3		
5719	R SSME Gaseous O2 Infl Coeff 3		
5720	R SSME Gaseous H2 Infl Coeff 3		
5721	C SSME Block 2 flag (OI-28)		
5722	L SSME Block 2 flag (OI-28)		
5723	R SSME Block 2 flag (OI-28)		

Row	Description	Comment	Notes
5724	C SSME tag liquid O2 flowrate		
5725	L SSME tag liquid O2 flowrate		
5726	R SSME tag liquid O2 flowrate		
5727	C SSME tag liquid H2 flowrate		
5728	L SSME tag liquid H2 flowrate		
5729	R SSME tag liquid H2 flowrate		
5730	C SSME tag gas O2 flowrate		
5731	L SSME tag gas O2 flowrate		
5732	R SSME tag gas O2 flowrate		
5733	C SSME tag gas H2 flowrate		
5734	L SSME tag gas H2 flowrate		
5735	R SSME tag gas H2 flowrate		
5736	C SSME tag thrust value		
5737	L SSME tag thrust value		
5738	R SSME tag thrust value		
5750	RTLS Abort Dump Timer		
5751	ATO Abort Dump Timer (K87, I2)		
5752	TAL Abort Dump Timer		
5753	Contingency Abort Dump Timer		
5755	OMS assist (nominal) timer (K87, I6)		
5756	Minimum K2 value allowed (K2MIN)		
5771	MKWTEF	= 450	
5772	MCDTMS	= 2.0	

- NOTE: THIS STEP AND ASSOCIATED CHECKLIST (#4 - FUTURE) PROVIDED FYI ONLY PENDING CERTIFICATON OF DPS 3.0. Ensure you have the latest DPS LDP data file from the FADS. If there was a late product, or if a product was re-delivered, the file you ftp'ed earlier may no longer be the current file. If needed, FTP the latest DPS LDP data file from the FADS system to the MCC environment (see Section 5.2.5.2 of the ARD Console Handbook). Transfer to the directory below. When you have the most recent file, run DBCHEK now against this file. Verify

miscompares against DBCHEK Updates Checklist #4 (FUTURE) (below). Make absolutely sure you understand every change, especially unexpected ones.

\$ARD_DB/AADDVT/Product_References

- Number of Miscompares is 39.

Table D-4. DBCHEK Updates Checklist #4 (FUTURE)

Row	Description	Comment	Notes
23	Slot # of target sequence used for auto-queue execution	Null character in TRS	
27	Vehicle weight	See flight specific init pad	
69	Slot 1: TAL Area ID		
70	Slot 2: TAL Area ID		
71	Slot 3: TAL Area ID		
266	Wx Alt 1 TAL: Runway ID	= low cr site, e.g. LZA	
279	Wx Alt 2 TAL: Runway ID	= low cr site, e.g. LBY	
292	Wx Alt 3 TAL: Runway ID		
2944	Site used by comp needing rnwy coord	= KSC	
2945-2947	X, Y, Z ly components		
2958-3027	Mass Properties	See PMP and flight specific pad	
3215	Rendezvous option	AR opened on this variable	
3218-3238	M50 and EF IYs		
4141	TGT 19: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	
4179	TGT 21: OMS-2 Mnvr TGT D/O DV	TRS value should be blank	

ARD SUPPORT NOTES:

- Note: Automatic verification of MSK2310 not included at FDO request, but visual inspection still required.

- When all differences are explained, go to Data → Save Cur as Ref using file name format: XXX_CONF where XXX is the three digit mission number (e.g. 111_CONF). Note that DBCHEK will save the file under Local_REFs.
- 2. Server Checkout Run
 - IMPORTANT! After the checkpoint, ensure REF DAY (P80 MED) on Checkout Monitor MSK 2300 and the IYs correspond to the SIM day. Use the MSK 2442 hardcopy you took after Ascent Sim #4. Or if you forgot, use the IYs from the DBCHEK checkpoint you took for Ascent Sim #4. Make sure Dynamics puts in the lift-off time first, then the IYs. Also, make sure the K83 is still set to "R" for rendezvous flights. If REF DAY does not correspond to the SIM day, for example if the actual launch day is used, REF data such as the RNP matrix may not be accessible and RTLS data will not be computed since the RNP matrix is used to convert relative runway site data to inertial (Mean of 50). TAL data may also run the same risk, except default IYs are available for TAL that might still work. (Note: This procedure is brought to you courtesy of STS-88.)
 - Sim lift-off time: _____
 - Real lift-off time: _____
 - Read these notes:
 - With FDO and TRAJ agreement, it was decided the ASCT-47 throttle tables should be loaded for the confidence run. Reason: If Flight Cycle SSMEs differ from DOL SSMEs, updated influence coefficients are also delivered in ASCT-47. Therefore, in order to maintain consistent SSME data for the confidence run, ASCT-47 throttle tables should always be used.
 - Things to match for the run:
 - Lift-off time.
 - IYs. These are especially important if you did LWLT during the sim that the tape is taken from.
 - Performance case. If applicable. (There should not have been, but it is still do-able.)
 - Stay on TLM.
 - Start ARD Tools during the checkout and verify that it runs.
 - During the STS-106 Confidence Run, the OMS Assist timer was updated from 102 seconds to 15 seconds. While the ARD was not dumping but "on-board" was, then trend was flat (0 or 1). Once the on-board dump stopped then the thrust values matched the predicted fairly well. It was just about 2 minutes late. This could happen to you. Eventually the predictor spreadsheet will need to take this into account.
 - Coordinate with TRAJ before the run to see if he/she wants to test Thrust Limiting and/or PROP cases. This can be done after the trends are confirmed to look good, before MECO. Check FPR when each case is modeled. Be sure to remove all cases entered before MECO, as TRAJ will likely do some AME testing as well.
 - Have your trend spreadsheet from the L-1 Week preparations ready. Follow along on the checkout run. DO NOT DO A THRUST UPDATE, even if you did one on the tape. If you match fairly well and the ARD behaves, you are a happy camper. If something does not work right, start figuring out what went wrong and fix it! Notes: We don't have any criteria for tolerances on this. Since the predictor is an "instantaneous" type of calculation, and the ARD trend on MSK 600 is an

“averaged” comp, you are looking for the general magnitude and direction to be correct, and that everything is behaving sensibly and sanely. Don’t panic if you see the MECO imbalance tasks changing instead of their normal “static state” when there is no thrust limiting case. This is happening because the new NOMMXRT you loaded does not match the sim throttle tables. You can check the current imbalance however. It should at least start out at the value of fuel bias you loaded.

- o Record the comparisons here:

MET	PREDICTED	ACTUAL

3. DOLILU Transfer Test

- o Read these notes:
 - This test will be performed sometime after the confidence run.
 - K87 Items: 1 CONT, 2 ATO, 3 TAL, 4 RTLS, 5 OA FLAG, 6 OA; K66 Items: 3 ATO, 4 TAL, 5 RTLS.
 - This data will stay in the TRS until the DOLILU II L-4:30 data comes in. The I-load generated from the 6:15 Jimsphere balloon is not sent to the TRS unless there is a failure of the L-4:30 Jimsphere.
 - All changes in DOLCOM that we care about are also in DOLARD; plus, the DOLCOM changes don’t go into the TRS, they only go onboard. Therefore we don’t need to check DOLCOM changes.
- o Obtain the MEDCV table, which contains the throttle table, FO2s, etc. from Ascent Support. File location is given below (confirm with Abort Support), where XXX is the flight number. To obtain a hardcopy, type: lpr -Olandscape DOLARD.mcc.MEDCV

/amd/rwserv2/ascdol/Database/SSPXXX/MIS/Iloads/DOLARD.mcc.MEDCV

Copy to: TRAJ_____

- o Verify the “DSNAME” with Abort Support and DYN before proceeding.
- o As with any Group MED throttle table procedure, make sure you run the “K69 Prep” first to setup the throttle tables, before loading the new data. Ensure that all throttle table entries are wiped clean, including the hype mode. Note that the hype mode gets wiped AFTER the actual mode, so the K69 Prep may still be going once it appears to have stopped with the actual mode.
- o Once FDO concurs, have DYN load the DOLARD group MED.
- o Verify all updates either on the displays and/or DBCHEK. It may be easiest to use the throttle table displays to verify all throttle table entries, and then use DBCHEK to verify the remaining 11 changes. Verify miscompares against DBCHEK Updates Checklist #5 (below) using “flt_CONF”

as the reference. Make absolutely sure you understand every change; there should NOT be any unexpected ones.

- Number of Miscompares is 11 + Any engine configuration differences (total ~307).

Table D-5. DBCHEK Updates Checklist #5

Row	Description	Comment	Notes
3163	AGT reference time (SECD02)		
3166	AGT Throt-to-wt factor - hot SRB (SECD05)		
3167	AGT Throt-to-wt factor - cold SRB (SECD06)		
3168	AGT time-to-wt factor - hot SRB (SECD07)	Most likely to remain zero	
3169	AGT time-to-wt factor - cold SRB (SECD08)	Most likely to remain zero	
3170	AGT array 1 - throttle velocity (SECD09)	Most likely to remain 60	
3171	AGT array 2 - throttle velocity (SECD10)	Most likely to remain 384	
3172	AGT array 3 - throttle velocity (SECD11)		
3173	AGT array 4 - throttle velocity (SECD12)		
4122	TGT 19: OMS-2 Mnvr TGT D/O DV	Should be blank vs. blank	
4160	TGT 21: OMS-2 Mnvr TGT D/O DV	Should be blank vs. blank	
5052	Pt 1: C SSME - Act Throt MET		
5054-5059	Pt 3-8: C SSME - Act Throt MET		
5142-5171	Pt 1-30: C SSME - Specific Impulse		
5172	Pt 1: C SSME - ISP MET		
5174-5179	Pt 3-8: C SSME - ISP MET		
5202-5231	Pt 1-30: C SSME - MR		
5232	Pt 1: C SSME - MR MET		
5234-5239	Pt 3-8: C SSME - MR MET		
5292	Pt 1: L SSME - Act Throt MET		
5294-5299	Pt 3-8: L SSME - Act Throt MET		
5382-5411	Pt 1-30: L SSME - Specific Impulse		
5412	Pt 1: L SSME - ISP MET		
5414-5419	Pt 3-8: L SSME - ISP MET		

community should know by now that the new version will be out between L-18 and L-6 hours. It is usually later than earlier. PAO uses it on console and in the pressroom. Flight, HQ, the cape, EECOM, BSE, etc. use this, so make sure it is right! Keep a few extra copies with you.

Copies to: FDO_____ TRAJ_____ Abort Support _____

If FDO wants you to do this: FAX or e-mail copies to:

- o PAO (Kyle Herring – x38653, kyle.j.herring1@jsc.nasa.gov; Steve Nesbitt - x35758, stephen.a.nesbitt1@jsc.nasa.gov; or Rob Navias – x38651, rob.navias1@jsc.nasa.gov), Fax: x32000, Mail Code: AP1
- o FCOs at Patrick AFB. Office Fax: 321-494-6535; Mail Code: 45SPW/SEO.
- o Astronaut Station (Crew Quarters) 321-867-2348 There is no actual POC, and if they're confused, ask them to notify us if they no longer want it sent.

7. Compute/check ARD mass adjustment quantities in case of erroneous MEDs:

- o Pre-SRB ignition SSME throttle-up propellant usage = TDDP AOA Propellant Inventory "loss for thrust buildup & SRB ignition delay" total quantity (e.g. $\Delta ETP \approx -11261$ lbs.). You can also find it in ASCT-47, ARD Loading Summary, under the "SSME Ignition Time" line. The STS-60/STS-111 scenarios are not supposed to be able to happen again, but this number is a good value for ARD Support to know.

$\Delta ETP =$ _____ lbs.

- o Accidental wiped bucket quantity (bucket METs from ARD throttle tables - does not account for DOLILU bucket times, but the delta is negligible). 1 engine wiped bucket $\Delta ETP = + 1/2[(\text{end throttle up} - \text{start throttle down}) + (\text{end bucket bottom} - \text{start bucket bottom})] * (104.5 - \text{nom bucket \%}) * 10.4 \text{ lbs./sec/SSME/\%}\Delta$ (e.g. ΔETP for 3 engines $\approx +15000$ lbs.).

Accidental wiped single bucket $\Delta ETP =$ _____ lbs.

8. Update the ARD Support On-Console Data Page. Obtain concurrence from TRAJ on all numbers. After concurrence, distribute copies:

Copies to: FDO_____ TRAJ_____

9. Update your ARD Support Console Databook(s) with LAUNCH data. Don't forget:

- o New correct-config engine data and performance case data
- o New Ascent Events Summary
- o New Prop data
- o New Biases (may come on DOL)

Note: New AGT and Launch Hold tables come on DOL with DOLILU and PLOAD, respectively.

10. You should try a printer test from the PC in the MPSR. This is a good practice if you don't print often and also assures the printer is working. You don't want to be caught during launch support without a good printer. Also, have a spare ream of paper handy, or fill up both paper trays now.

11. Stick around after the DOLILU Transfer Test while FDO & TRAJ are doing LWLT and MECO U/S curve changes to make sure you've captured any and all changes made to the DB. When they are

done making changes, run DBCHEK again to verify any updates & save again if necessary ("flt_CONF_wD2"). Then you can leave.

12. Sometime before arriving on console for launch day, review the latest PLOAD, Revert, and Launch Hold procedures. You need to be refreshed on what to do when a launch hold or a Revert occurs. Consult the ARD Console Handbook, Section 4.1.3.3, and Flight rules A-2.1.1-7 & A-4.1.2-2.
13. Sometime before arriving on console for launch day, review the ARD Bucket Exam. This is the single most complex hand-calculation that you might be performing in realtime; so review it to get it right!

D.10 LAUNCH DAY CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

ATTEMPT NUMBER: ____

NOTES

1. Be sure to bring all the equipment you'll need, e.g. highlighter, pencil, eraser, red pen, calculator, stopwatch (if not using PC version), post-it reminders, etc.

PROCEDURE

1. Make double sure that FDO, TRAJ, and you have the latest official ARD biases, products, etc. Check with Abort Support and Targeting to make sure any late changes have been passed on to all team members
2. If this attempt is for a launch date different than what was planned for with the init pad submittal, ensure that the atmosphere tables are still correct. That is, if the launch date has crossed over a switch point, update atmosphere tables. The high-inc switchpoints are April/May and Sept./Oct. (Could make a difference on high inclination flights.) For low-inc, the spring switchpoint is Feb/Mar. If so, make sure the N-cycles are set correctly.
3. L-5:30 hours or earlier: Perform the first database check. Run DBCHEK, use "flt_CONF_wD2" as reference. Double-check ATOMBO (which is NOT in DBCHEK).
4. L-4:45 hours: Spot-check the "Thrust Limiting" application as you did on L-1 day using Engine Selection --- don't use the Thrust Limiting application itself!. Although nothing should have changed, it's a good idea to make sure nobody ELSE hosed something up on you over the last 24 hours.
5. L-4:15 hours: Double-check workstation configuration and ARDTools for:
 - o Workstation: OMS inputs
 - o Workstation: SSME Tags
 - o Workstation/ARDTools: FPR Inputs
 - o ARDTools: loadings.asc
 - o ARDTools: misc_data.asc
 - o ARDTools: tldata.asc
6. L-4:00 hours: Double-check ECT and DCT data from Init Pads.
7. L-3:45 hours: Double-check that ARDTools Loadings has the correct/latest and greatest numbers (compare with ASCT-47 and ASAB-32B).
8. L-3:00 hours: Review PLOAD scenarios.
 - o There are four possible outcomes to the PLOAD assessment.
 - o The propellant measurement is assessed and Ascent Support gives you the PLOAD EOR numbers. You select "With PLOAD" in ARDTools' dropdown menu, then enter the EOR loadings. ARDTools computes quantities of significant difference to require changes; the

PLOAD update is required and applied per the procedure. For this case, do not change the uncertainties because a PLOAD was generated for a valid measurement (i.e. use the smaller 1 sigma LOX/LH2 uncertainties from SPAD Table 8.4).

- The propellant measurement is assessed and Ascent Support gives you the PLOAD EOR numbers. You select "With PLOAD" in ARDTools' dropdown menu, then enter the EOR loadings. However, MED updates are not required because ARDTools computes deltas that are too small to warrant an update. This does not mean that you should change the uncertainties by selecting "Without PLOAD". You do, in fact, have a PLOAD measurement, and ARDTools is computing things properly (i.e. use the smaller 1 sigma LOX/LH2 uncertainties from SPAD Table 8.4).
 - The PLOAD EOR data is not provided to you. This will occur if the measurement was erroneous for some reason. For this case, you first select "Without PLOAD" in ARDTools' dropdown menu, then you will input the TDDP loadings (AOA/TAL LOX and LH2 loaded values) in place of the EOR values. Since a PLOAD was not provided, the uncertainties must be increased (i.e. use the larger 1 sigma LOX/LH2 uncertainties from the SPAD Table 8.4). Once the updates and deltas are calculated, the deltas are large enough to require the MEDS to be shipped.
 - The PLOAD EOR data is not provided to you. This will occur if the measurement was erroneous for some reason. For this case, you first select "Without PLOAD" in ARDTools' dropdown menu, then you will input the TDDP loadings (AOA/TAL LOX and LH2 loaded values) in place of the EOR values. Since a PLOAD was not provided, the uncertainties must be increased (i.e. use the larger 1 sigma LOX/LH2 uncertainties from the SPAD Table 8.4). Once the updates and deltas are calculated, the deltas are not large enough to require the MEDS to be updated, so no update is applied. This case will probably never occur.
9. L-3:35 hours: When the KSC loadings are received, run the ARDTools Loadings Tab per the scenarios of Step 8. If a PLOAD is provided, be sure to use the Use the End Of Replenish (EOR) data. Never change the loadings or uncertainties that ARDTools was originally brought up with. These remain the TDDP (for loading) and SPAD (for uncertainties) values.
- To decide what updates need to be made, referencing the FDO Console Handbook (page 5.3-47), we generally update for > 10 lbs. on Fuel Bias and > 50 lbs. on everything else. This is somewhat subjective though, and will ultimately be decided by FDO. Ship the MED updates with ARD Tools only upon FDO concurrence.. Notify TRAJ/FDO when you are happy with the database.
 - Give a copy of the new Loadings tab in ARD Tools to Abort Support, FDO, and TRAJ. Keep one for yourself/records.
Copies to: FDO____ TRAJ____ Abort Support ____ DYN ____
 - Once the PLOAD is assessed, MEDs are shipped and QA'd (if any), run the Build Launch Hold Table function in ARDTools. Give copies to FDO, TRAJ and DYN.
Copies to: FDO____ TRAJ____ DYN ____
 - If the launch looks like it will slip significantly into a long launch window (like 90 minutes into a 2.5 hour), request another PLOAD update and repeat the process. Of course, this is N/A for short windows like ISS flights.
 - Note that although the K67 ET Jett weight gets updated, we do not update MCWTET since it is a first stage parameter only and would require the TRS to be unlocked.

- 10. L-3:15 hours: Perform the second database check. Run DBCHEK, use “flt_CONF_wD2” as reference. If PLOAD updates are input, you should see those 6 miscompares, and you should see another 21 miscompares if IYs were changed in LWLT.
- 11. L-3:00 hours: DOLILU OPS - Abort Support will let you know when the DOLARD data for this step is ready.
 - o Read these notes:
 - K87 Items: 1 CONT, 2 ATO, 3 TAL, 4 RTLS, 5 OA FLAG, 6 OA; K66 Items: 3 ATO, 4 TAL, 5 RTLS.
 - The SECDs may appear to change dramatically (SECD07). We have seen this at least twice before. This is OK but can stir up some people. If you see any change that looks unreasonable, ask questions. Input of these F02s will require the server to be unlocked.
 - All changes in DOLCOM that we care about are also in DOLARD; plus, the DOLCOM changes don’t go into the TRS, they only go onboard. Therefore we don’t need to check DOLCOM changes.
 - o Obtain the MEDCV table, which contains the throttle table, FO2s, etc. from Ascent Support. File location is given below (confirm with Abort Support), where XXX is the flight number. To obtain a hardcopy, type: lpr -Olandscape DOLARD.mcc.MEDCV

/users/ascdol/Database/SSPXXX/MIS/Iloads/DOLARD.mcc.MEDCV

Copy to: TRAJ_____

- o Verify the “DSNAME” with Abort Support and DYN before proceeding.
- o Check the new K61 SSME ignition time in ASCT-47 with the first line in the new throttle tables. They should match. If they don’t, find out why before proceeding.
- o As with any Group MED throttle table procedure, make sure you run the “K69 Prep” first to setup the throttle tables, before loading the new data. Ensure that all throttle table entries are wiped clean, including the hype mode. Note that the hype mode gets wiped AFTER the actual mode, so the K69 Prep may still be going once it appears to have stopped with the actual mode.
- o Once FDO concurs, have DYN load the DOLARD group MED.
- o Verify all updates either on the displays and/or DBCHEK. It may be easiest to use the throttle table displays to verify all throttle table entries, and then use DBCHEK to verify the remaining 11 changes. Verify miscompares against DBCHEK Updates Checklist #6 (below) using “flt_CONF_wD2” as the reference. Make absolutely sure you understand every change; there should NOT be any unexpected ones.
 - Note that the second MET entry in the throttle table HM can be wrong. Double check that this value is correct.
 - Number of Miscompares is 11 + Any engine configuration differences (total ~307).

Table D-6. DBCHEK Updates Checklist #6

Row	Description	Comment	Notes
3163	AGT reference time (SECD02)		

Row	Description	Comment	Notes
3166	AGT Throt-to-wt factor - hot SRB (SECD05)		
3167	AGT Throt-to-wt factor - cold SRB (SECD06)		
3168	AGT time-to-wt factor - hot SRB (SECD07)	Most likely to remain zero	
3169	AGT time-to-wt factor - cold SRB (SECD08)	Most likely to remain zero	
3170	AGT array 1 - throttle velocity (SECD09)	Most likely to remain 60	
3171	AGT array 2 - throttle velocity (SECD10)	Most likely to remain 384	
3172	AGT array 3 - throttle velocity (SECD11)		
3173	AGT array 4 - throttle velocity (SECD12)		
4122	TGT 19: OMS-2 Mnvr TGT D/O DV	Should be blank vs. blank	
4160	TGT 21: OMS-2 Mnvr TGT D/O DV	Should be blank vs. blank	
5054-5059	Pt 3-8: C SSME - Act Throt MET		
5174-5179	Pt 3-8: C SSME - ISP MET		
5202-5231	Pt 1-30: C SSME - MR		
5234-5239	Pt 3-8: C SSME - MR MET		
5294-5299	Pt 3-8: L SSME - Act Throt MET		
5414-5419	Pt 3-8: L SSME - ISP MET		
5442-5471	Pt 1-30: L SSME - MR		
5474-5479	Pt 3-8: L SSME - MR MET		
5534-5539	Pt 3-8: R SSME - Act Throt MET		
5654-5659	Pt 3-8: R SSME - ISP MET		
5682-5711	Pt 1-30: R SSME - MR		
5714-5719	Pt 3-8: R SSME - MR MET		

ARD SUPPORT NOTES:

- Check that the only values to change in the throttle tables are the times & sometimes ISP. Ensure the changes are reasonable.
- Double check that 67 sec is still an OK time (i.e. past end-of-throttle-up) for pre-67 sec performance cases.
- When all differences are explained, go to Data → Save Cur as Ref using file name format: XXX_DOL where XXX is the three digit mission number (e.g. 111_DOL). Note that DBCHEK will save the file under Local_REFs.
- Make sure you get the new AGT chart from Abort Support! You don't want to blow the bucket call, look like a phool, and cause confusion (or panic!). Make sure FDO & TRAJ get a copy (Abort Support will usually distribute copies). Abort Support may also have a DELWT adjustment graph on DOL, depending on the winds. Don't worry about it now - just be aware that it is possible. Might have to ask Abort Support to format the AGT to your liking, i.e. on two pages only.

Copies to: FDO_____ TRAJ_____

12. L-3:00 hours (right after DOLARD updates): Configure the stuck actuator tool.

- In \$ARD_DB, create a directory called "Stuck_Actuator". The GAs may need to create this directory along with all the others for each MCC cycle (e.g. Tools, OMS_Data, etc). Copy over the six files from another flight/cycle (center2.csh, center3.csh, center5.csh, side2.csh, side3.csh, and side5.csh).
- Update the Isp in each file (433.4665 in the example line below).
 - \$DH/Exec/DH_sendmed -hBOTH -mK69,\$1,433.4665,,,L,100.1,,A\$
 - Isp_NEW = (TH_NEW/104.5)*Isp_INITIAL
 - TH_NEW from Table 4-2 in Section 4.2.3.4 (different for each case)
 - Isp_INITIAL is the Isp for each engine at 104.5% throttle (from throttle tables including DOLARD update) - note an average of the left and right SSME is sufficient for side
 - For an MS Excel tool that will do the calculation for you, see the following file. If you use this method, do at least one hand calculation to double check.

S:\Divisions\DM\Private\DM46\ARDSTUFF\STUCK ACTUATOR TABLE\Stuck Actuator Table.xls.

13. L-2:30 hours (approx.): Abort Support will compute a new expected nominal AM MPROP and Trend Prediction. Make a note of them somewhere you can see them during powered flight to give you insight on the ARD health.

- Nominal MPROP Prediction = _____
- Nominal Trend Prediction = _____ fps/min
- Pass both to: TRAJ_____

14. L-1:30 hour: Record IYs for use during launch.

- X = _____
- Y = _____
- Z = _____

15. L-1:15 hour: Run DBCHEK in preparation for Checkpoint at L-1:00 hour using XXX_DOL as the reference.
16. L-1:00 hour: Sometime in the latter part of the count, DYN may make a call that they are going to "Zero-out the ARD" (they'll always zero-out the ARD, but may or may not make the call that they're doing it). This always stops a few hearts, but it is a harmless step where they flush out some old telemetry in some data slots. I need to investigate why they even do this. Bottom line: don't sweat it. You can follow along on MSK 2021 if you like. You will do another database QA between now and T-9 anyway, so you should catch it if anything goes astray here.
17. L-55 minutes: Call up all necessary DOL displays: ARD Output, ARD Maintenance, Prepare ascent procedures and checklists. NEW: CALL UP "ARD ET MASS" Display.
18. L-40 minutes: Obtain predicted TMECO from Ascent Support (based on L-2:15 balloon data) using latest simulation data & pass to TRAJ. This is equal to time of zero thrust - 8.7 sec for tail off. Write the time somewhere you can see it during powered flight.
 - o TMECO Prediction = _____ (sec, from Abort Support)
 - o TMECO Prediction = _____ (mm:ss.tenth, you compute)
 - o Pass mm:ss.tenth value to: TRAJ_____
19. L-30 minutes: Run DBCHEK again using XXX_DOL as the reference.
20. Deploy any important flight notes on a piece of paper under the console glass or somewhere you can see it, like your powered flight worksheet/checklist. (Example: Hype config, Pre-SRB ignite mass delta, 1, 2, and 3 wiped bucket mass deltas, Item 9 ATO dump quantity, predicted MPROP and TMECO, etc.).
21. Get stopwatch ready in case of launch hold. In the confusion, you may be the only one timing the hold. To use the PC stopwatch perform: Start > MCC Menu > Flight items > Timer.
22. Monitor the weather situation - if FDO switches AOA sites late in the count in order to be GO for launch, then the OMS-2 targets and corresponding MECO underspeed curves will change. Notify FDO which curves have changed when you see the updates in DBCHEK. D23C should not change - it's used to compute deorbit targets, yes, but it is irrelevant when evaluating the pre-canned targets.
23. The FDO and/or the TRAJ should handle getting the correct limit line data loaded on the DEC's for the new displays to use!. They do this through our group GA. Remind them in case they forgot (always, not just for late pad changes). You don't want an "Amber Zone" call (or worse) due to this.
24. If launch is scrubbed, see Section 4.1.4.11.

D.11 T-9 MINUTE HOLD CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

None.

PROCEDURE

1. Tagging up with TRAJ here can be a good idea to be focused on ARD tasks now that the pre-launch scramble with weather and other junk is over. It may have been 5 or more days (due to delays) since your last sim, and you may have a new TRAJ, procedure, or ARD upgrade. IT'S TIME TO START THINKING ARD OPS!. Use your judgment, and only cover pertinent items that could use review. Some examples are.
 - Any flight-specific or DOLILU charts (like TDEL), tables, etc., that need attention brought to them.
 - Launch Hold procedure.
 - Don't switch to TLM right in the middle of the TAL call. This causes a jump in the margin, but the margin rate is fairly high on TALs anyway.
 - Review "103.99" thrust limiting cases; did you manually make corrections in the delta files? or will a realtime adjustment be required in such a case?
 - Review OME interconnect status for RTLS, TAL, and ATO.
 - Re-confirm the following values with TRAJ:
 - Stuck-in-bucket throttle lock times:
 - HOT: _____ sec (as close to end of ARD high throttle setting pre-bucket)
 - COLD/NOM: _____ sec (as close to end of ARD low throttle setting in bucket)
 - OMS Full Tank Value: _____ lb
 - One-sided OMS Assist Value: _____ lb
 - 3 Low Level Sensor Failed Dry Qnty: _____ lb (ENA) _____ lb (INH)
 - Review HYPE engine out configurations.
 - Review DVIS failure telephone dialing procedure. We are at x38705.
2. Scan at least these parts of the database as late as possible (under T-9 min.): ARD AME INIT, and the 3 throttle tables. Also, confirm the IYs in ARD Maintenance.
3. Remember: During ascent use the boundary log in ARD Output to record the boundary times and velocities. Near the end of the ascent or just after MECO, HARDCOPY the DV Margin so you get a full plot history, ARD OUTPUT (with boundary log), and ARD Maintenance.
4. After you are inside drainback starting at L-4:55, be prepared to begin timing any launch hold.
5. If launch is scrubbed, see Section 4.1.4.11.

D.12 REALTIME CHECKLISTS

STS-____ Cycle: ____ ARD: _____ Date: _____

NOMINAL FIRST STATE CHECKLIST

- IF* Launch Hold within L-4:55
 - NOTE: Updates must be completed prior to SRB sep
 - Record hold init time= _____
 - Record hold total time= _____
 - ✓ Hold duration w/ TRAJ
 - Use ARDTools to ship MEDs
 - ✓ Inputs
 - Post-bucket
 - ✓ FDO passes new T_L/O to DYN
- Liftoff Confirmed**
 - ✓ T_L/O's
 - ✓ IY Option = _____
 - ✓ ET Mass Track (✓ MEP @ K61 ____ sec, increasing after, ARD-AME Init)
 - ✓ TDEL screen up
- After ARD begins cycling**
 - ✓ ARD Output Runways OK
 - RTLS = _____ (Prime)
 - TAL = _____ (Prime)
- TDEL Available (~L/O+0:20)**
 - ✓ TDEL & ΔWT (TDEL 1σ=0.3 sec)
 - ✓ SIGN ΔWT = -TDEL
 - CALL bucket, ΔWT good/bad
- Bucket Ops**
 - ✓ O/B Throttles (*IF* No Joy: prob w/ guid or h/w, or ARD Support error)
- Post-Bucket Ops**
 - IF* Hold, ✓ all updates before staging
- Staging**
 - Copy VE & HDOT (important for low perf cases)
 - ✓ IY's
 - IF* PASS & MATCH
 - CALL "Good IY's"
 - ELSE IF* BFS
 - ✓ ARD ADI Yaw Rate within 0.2°/cycle
 - ✓ MPROP trend
 - ELSE IF* NO MATCH
 - CALL "Bad IY's"
 - ✓ L/O times (GRND matches O/B)
 - ✓ IY Option = _____
 - IF* No Joy: CALL "Grab O/B IY's"
 - IF* 1st Stage EO: VMEO = VE @ Staging
 - IF* OA Manifested: CALL "OA Start on 1 or 2"
 - IF* NO OA: ✓ TMECO's
 - ✓ Throttles

NOMINAL SECOND STAGE CHECKLIST

- L+2:25 OR After 2ETAL Thrust Update
 - Copy AM NOM MPROP
 - Confirm that NONE are true: EO, Abort, Stuck in bucket, Past 5:30 MET
 - IF mismatching #OMS burning WAIT until burn done
 - CALL "GOTO TLM"
 - Watch for Go Flag at ~3:00 (ONLY VALID 3:00 – 6:00!)
 - ✓ Trend Sign (ARD TMECO > O/B → Trend > 0)
 - CALL "GO FLAG: (TREND IS) X"
 - IF |TREND| < 4 fps/min → No Trend taken
 - ELSE IF $4 \leq |\text{TREND}| \leq 30.0$ fps/min & MET 3:00-6:00
 - ✓ Update Indicator = "ALL" OR "C" or "L" or "R" for suspect engine
 - ✓ Thrust: Frozen = Comp
 - IF Error: CALL TRAJ "Bad Freeze" & re-freeze on next Go Flag
 - ✓ Improved TMECO agreement, ARD vs PASS
 - ✓ Margin shift toward deadband
 - ELSE IF |TREND| > 30.0 fps/min & no other indications of off-nom perf
 - CALL TRAJ: "ARD NO-GO"
 - Begin real-time DB✓
 - GOTO FLTR
- L+3:00 OR OA Stop (if manifested)
 - CALL "Assist Stop"
 - ✓ & CALL ARD Health; ✓ Trend wiped if Perf Case entered
- L+4:00
 - ✓ & CALL ARD Health; ✓ Trend wiped if Perf Case entered
- L+5:00
 - ✓ & CALL ARD Health; ✓ Trend wiped if Perf Case entered
- PTM (~6:00)
 - ✓ HM={0,0,104} for single engine calls (2 best out)
- L+6:00
 - ✓ & CALL ARD Health; ✓ Trend wiped if Perf Case entered
- L+7:00
 - ✓ Trend wiped if Perf Case entered
- Pre-MECO
 - ✓ U/S Prediction
 - ✓ Selected source to TLM automatically
- MECO
 - Copy MECO MET
- VI stabilizes
 - Copy MECO VI and O/U Speed
 - IF TLM loss at MECO: CALL "Push MECO button" (to transfer mass to AME)
 - Restore DMT-1 and DMT-2 for Targeting

SSME OUT CHECKLIST

- ✓ Remaining engine thrusts & correct if necessary
- VMEO/TMEO:
 - IF* pre-staging:
 - ✓ VMEO = 3500 fps (initial guess)
 - At Staging, update with VREL
 - IF* post-staging: Verify TMEO on DV Margins (ARD TMEO = PASS – 1 sec)
 - DO NOT update VMEO if ATO prior to EO
- ✓ Throttle tables updated
- ✓ HM, 2HM

- IF* EO Behind Data Path
 - Lock Throttle = 0% at actual EO time (have TRAJ confirm TMEO with BSE)
 - TMEO = O/B push-button time

- IF* EO pre-end-of-bucket & off-nominal SRBs
 - IF* throttle-up pre-bucket
 - Δ WT Override = 0 (Bucket Wipe)
 - ELSE IF* EO and/or PB in off-nominal portion of bucket (Cold or 1st step of Hot)
 - Δ WT Override = [% orig. bucket flown * DELWT]
 - ELSE IF* EO behind Data Path in off-nominal portion of bucket
 - Δ WT Override = Σ [% orig. bucket flown * (DELWT/3) for each engine]
- ELSE IF* Nominal SRBs: No Action Required

- IF* SSME Perf case, tell TRAJ recompute FPR

- IF* EO was a drifter
 - Update FPR
 - No DV adjusts required
- IF* a remaining engine is drifting
 - Reconfig ARDTOOLS
 - Pass new DV adjusts to FDO

- IF* 2nd EO
 - Follow all 1st EO procedures
 - IF* TAL
 - IF* CONT DUMP O/B
 - ✓ K60 (Item 6) AM CONT ABT ENA – ON
 - Reset Cont dump ignition time, K64 (type C)
 - IF* TAL post 2nd EO: time of O/B TAL dump start
 - IF* TAL before 2nd EO: dump log time of O/B cont dump start
 - ELSE* ✓ ITEM 9 = TAL % called by FDO/TRAJ

SSME OFF-NOMINAL CHECKLIST

Hydraulic L/U, Electrical L/U, Command Path (Stuck Throttle)

- IF* necessary: Remove Trend (restore any thrust update)
- IF* Pre-Bucket
 - ✓ Case entered at actual time
 - Δ WT Override = $[(n/3) * DELWT]$ where n = # good SSMEs
- ELSE IF* In-Bucket
 - IF* L/U in 1st step of HOT bucket, case entered at last full sec of 104.5% = ____
 - ELSE* case entered at last full sec before throttle up = ____
- ELSE* ✓ Case entered at proper time
- ✓ FPR updated
- IF* Hyd L/U
 - ✓ ARD HYD FAIL PB clicked
 - Configure ARDTOOLS for possible drifter
 - IF* Drifter
 - Remove Trend (restore any thrust update)
 - ✓ Case: Hyd L/U, Lvl, (Low, Mid, High), MET = 15:00
 - IF* drifter is post EO, tell TRAJ to have DYN do:
 - K69, E, ISP, ISP TIME, MR, MR TIME (if different), LINE # \$
 - Finish config of ARDTOOLS
 - Pass Total DV adjust if > 10 fps to FDO "Drifter DV adjust is _ at _ min"
 - ✓ FPR updated
 - IF* subsequent Bad EO: No DV adjust required
 - IF* subsequent Good EO: Update ARDTOOLS & pass new DV adjust
- IF* Restrung of stuck-in-bucket (Cmd Path)
 - Watch for throttle-up time and pass to TRAJ (Hyd L/U Lvl 0)
 - ✓ Throttles

Performance Case

- Remove Trend (restore any thrust update)
- IF* Earlier than 67 seconds
 - ✓ Throttle at 1:07 / 67 seconds
 - ✓ ISP & MR at actual BSE time
 - Use ARDTOOLS to ship Δ WT Override and verify correct value on ARD Maint
= $(104.5\% - \text{Throttle}) * (67 - \text{BSE time}) * 10.4 + \text{any previous adjustment}$
- ✓ Entry of case in throttle tables
- ✓ FPR updated
- ✓ Future throttle changes: apply same throttle bias
- IF* low MR: Tell Abort Support
- IF* PC Shift
 - ✓ FDO sets HM = 0/156/156
 - IF* GOOD (bad Pc channel turned off)
 - WATCH for time that throttle returns to normal
 - ✓ Level 0 adjust to nom throttle
 - ✓ FPR updated

ABORT CHECKLIST

RTLS

- ✓ Throttle chasing (include any biases from perf cases, 69% if 3E running)
- ✓ RTLS selected for ARD & O/B
- ✓ Abort Proceed MET vs. Dump Start Time
- ✓ K51 landing site & AM pushbuttons
- ✓ Dump
 - ✓ INCT status for ARD & O/B
 - ✓ Start time ("I1") = Abort proceed MET + delay if OMS stop within last 30 sec
 - ✓ Dump stop MET < TMECO
- Dump Stop: ✓ ARD Health & CALL "Dump Stop, ARD is ____" (go / no-go)
- MECO: ✓ targets: VE & R; CALL "On the RV"
 - IF No Match, CALL +Over/-Under status (actual – predicted)

TAL

- ✓ Throttle chasing (include any biases from perf cases, 67% if 3E or late 2E)
- ✓ TAL selected for ARD & O/B
- ✓ Abort Proceed MET vs. Dump Start Time
- ✓ K51 landing site & AM pushbuttons
- ✓ Dump
 - ✓ INCT status for ARD & O/B
 - ✓ Start time ("I1") = Abort proceed MET + delay if OMS stop within last 30 sec
 - ✓ Dump stop MET < TMECO
- IF TAL after 2nd EO: ✓ ITEM 9 = TAL % called by FDO/TRAJ
- IF CONT DUMP O/B
 - ✓ K60 (Item 6) AM CONT ABT ENA – ON
 - Reset Cont Dump Start Time, K64 (Type C) = time of O/B TAL dump start
- Dump Stop: ✓ ARD Health & CALL "Dump Stop, ARD is ____" (go / no-go)
- MECO: ✓ targets: VI & R; CALL "On the RV"
 - IF No Match, CALL +Over/-Under status (actual – predicted)

ATO

- ✓ IY's: IF PASS & Match, CALL "Good ATO IY's"
 - IF BFS
 - IF BFS VMEO < V_MSSN_CNTN: ✓ BFS IY's selected
 - ELSE Grab Nom IY's > 10 sec after BFS engage or ATO select
 - IF PASS & No Match: CALL "Bad IY's, Grab IY's"
- ✓ ATO selected for ARD & O/B
- ✓ Abort Proceed MET vs. Dump Start Time
- ✓ Dump
 - ✓ INCT status for ARD & O/B
 - ✓ Start time ("I1") = Abort proceed MET + delay if OMS stop within last 30 sec
 - ✓ Dump stop MET < TMECO
- Dump Stop: ✓ ARD Health & CALL "Dump Stop, ARD is ____" (go / no-go)
- MECO: ✓ +Under/-Over Speed

OMS OFF-NOMINAL (LEAKS & FAILS) CHECKLIST

OMS Engine Fail and OMS GN2 Tank Fail

NOTE: Do not fail an OMS engine if usable for abort dumps

- ✓ Failed OMS Engines = 1
- Pass TRAJ: $\Delta OMS = -20 * \Delta t_{fail}$ (Δt_{fail} = total time bad eng ON (OA + abort dump))
- ✓ ATO INCT = ENA

OMS Helium Leak (if pre-MECO dump required & tank fail not expected)

- ✓ Failed OMS Engines = 1 (after 2ETAL)
- ✓ Item 9 per Prop (slip OA start time if necessary)
- For leaking OME expected total dump time, using He Leak tables
 - $\Delta OMS = -(LB \text{ TRAPPED}) - (20 * \Delta t_{good \text{ dumped}})$ $\Delta t_{good \text{ dumped}} = \text{good eng burn}$
- Δt
 - $\Delta RCS = +(LB \text{ TRAPPED})$
 - IF Dump cutoff by MECO, update $\Delta OMS/\Delta RCS$
 - NEW Total Dump Time = (TMECO – 10 sec) – dump start time
 - $\Delta OMS = - (LB \text{ TRAPPEDNEW}) - (20 * \Delta t_{good \text{ dumped}})$
 - $\Delta RCS = + (LB \text{ TRAPPEDNEW})$
- ✓ TAL INCT = INH
- IF needed to eval ATO Capability, per TRAJ: $\Delta OMS = - \text{good OME dumped}$
- IF subsequent ATO
 - ✓ Re-input Item 9 blowdown dump
- IF subsequent RTLS/TAL
 - ✓ Failed OMS Engines = 0
 - $\Delta OMS = +20 * \Delta t_{GOOD \text{ OME OFF or RTLS/TAL lbs heavy from PROP}}$
- IF subsequent He Tank FAIL:
 - ✓ Item 9 updated to match actual dump duration
 - Pass TRAJ: $\Delta OMS/\Delta RCS$ to match actual dump duration

OMS Prop (Hyd or Ox) Leak / Prop Fail / He Tank Fail

- ✓ Failed OMS Engines = 1
- ✓ K64 Dump Cutoff = Time of good engine off
 - IF pre-OA: OA Start + 1 sec
 - IF TAL/RTLS or TAL Delay: Initial Guess = He/Prop Fail Time + 2:00
- For bad OME total dump time OR expected total dump time, using Prop Fail / He Tank Fail tables
 - Expected Total Dump Time = (TMECO – 10 sec) – dump start time
 - $\Delta OMS = - (LB \text{ LOST})$
 - $\Delta RCS = + (LB \text{ TRAPPED})$
 - IF Total Dump Time different than predicted, update $\Delta OMS/\Delta RCS$
- ✓ ATO/TAL/RTLS INCT = INH
- IF FAIL occurs: ✓ K87 TAL/RTLS timers to 2:00 (unless TAL/RTLS already)
- IF needed to eval ATO Capability, per TRAJ: $\Delta OMS = - \text{good OME dumped}$
- IF subsequent ATO
 - K64 'I1' Dump Cutoff = I1 start + 1 sec
- IF subsequent RTLS/TAL
 - K64 'I1' or 'I2' Dump Cutoff = Time of good engine off (**after** relight)
 - Initial guess: good OME on + 2:00

OMS & RCS OFF-NOMINAL (MISC.) CHECKLIST

ITEM 9

NOTE: Wait until OA Start to model Item 9 in ARD

- ✓ Item 9 K64 Quantity on ARD Maint
- IF* Item 9 Start is after OA Stop
 - ✓ K64 Dump Type 'N', Start Time = OA Start + OMS Off Duration
- IF* Item 9 is Interconnected (also INCT OA)
 - ✓ ATO in ARD when O/B INCT Dump Starts
 - ✓ Onboard IYs reselected
 - ✓ ARD ATO INCT = ENA
 - ✓ K65 RCS On Time = O/B INCT Start (dump log)
 - ✓ Abort Proceed Time = O/B Item 9 Start
 - ✓ Item 9 = Amount Voiced to Crew (usually cont dump %)

INCT Switch During Abort (I1 or I2) Burn

- IF* Item 9, see Item 9 Procedures
- ✓ INCT = ENA
- IF* INH to ENA
 - ✓ RCS Start Time = ENA Time
- IF* ENA to INH
 - ✓ RCS Stop Time = INH Time

RCS Manifold Failure

- Note: ARD assumes 2+10 or 2+24 for entire dump; stop time will differ from O/B
ARD is NOT modeled until dump has stopped both O/B and in ARD
- Call TRAJ: "Manifold Fail"
- ✓ "MAN 1/2 FAIL LOGIC" or "MAN 3/4/5 LOGIC" = ON
- IF* manifold fail NOT recognized onboard:
 - IF* manifold fails partially into dump
 - $\Delta\text{OMS} = -32 * \Delta t_{24}$ (Δt_{24} = time of normal operation (1+24 or 2+24))
 - IF* manifold recovered after failure:
 - ✓ "MAN 1/2 FAIL LOGIC" or "MAN 3/4/5 LOGIC" = OFF
 - $\Delta\text{OMS} = +32 * \Delta t_{24}$

Fwd RCS Leak

- IF* ballasting required, per TRAJ:
 - ✓ $\Delta\text{OMS} = -(\text{Ballast Qty})$
 - ✓ $\Delta\text{RCS} = +(\text{Ballast Qty})$
 - NOTE: any additional $\Delta\text{OMS}/\Delta\text{RCS}$ must keep Ballast Qty accounted for

NON-STANDARD PROCEDURES CHECKLIST

TMECO Mismatch

- ✓ IY's
- ✓ Valid Vector Source
- ✓ Trend (may need to be removed)
- TRAJ ✓ with BSE for Perf case
- ✓ ET Mass Track
- IF* no other modeling options
 - Update Δ ETP using ARDTools
 - NOTE: Δ ETP = f(TMECO) ARD later \rightarrow + Δ TMECO \rightarrow ARD heavy \rightarrow - Δ ETP
 - ✓ WT Error w/ Trend (2.1 fps/min/1000 lb wt err, 2:30-4:00)

Three Low Level Cutoff Sensors Fail Dry

- Δ ETP = -32,000 lbs
- Δ ETD = +32,000 lbs
- Once TAL/RTLS or TAL Delay is declared, model cutoff at arming mass as:
 - IF* NEG Abort Margin: ✓ RCS INCT = INH
 - IF* TAL Dump will be Cutoff by MECO:
 - Δ ETP = -(32,000 + PREDICTED TAL/RTLS DUMP QTY - OA)
 - Δ ETD = +(32,000 + PREDICTED TAL/RTLS DUMP QTY - OA)
 - ELSE* TAL Dump will finish normally:
 - Δ ETP = -(32,000 + TAL/RTLS OMS DUMP QTY - OA)
 - Δ ETD = +(32,000 + TAL/RTLS OMS DUMP QTY - OA)

Flow Control Valve Anomaly / Manual Throttle for Low LH2 NPSP

- TRAJ: set HM = 95/95/95
- Chase throttles quickly (\rightarrow 95 \rightarrow 80 \rightarrow 67; will be called by BSE, watch for O/B time)

SSME Thrust Vector Control (TVC) Hardover

NOTE: Applies to CE stuck in pitch up, LE or RE stuck in yaw outboard

- TRAJ: Model throttle setting and Isp with ROSS Alarm
- ✓ Throttle setting and Isp for stuck engine
- ✓ Failure time (0 < t_{fail} < 2:30 = 2:30; 2:30 < t_{fail} < 3:30 = 3:30; 3:30 < t_{fail} < MECO = 5:00)
- ✓ HM, 2HM Config (sick EO for 2E calls)

Bad Recycle at Liftoff (i.e. trend of +24 like STS-111)

- Pre-SRB ignition SSME throttle-up propellant usage = TDDP AOA Propellant Inventory "loss for thrust buildup & SRB ignition delay" total quantity
 - Set Δ ETP = -11267 (computed in L-1 Week)

No ARD Procedures for:

- No ARD Procedures for:
 - Ullage Gas Leak (watch for man throttles)
 - Aft RCS Leak
 - Three low level sensors failed wet
 - SSME He Leak
- No INCT INH during CONT dumps
- BFS Engaged: No SERC, No CSS, No CONT dumps starts (any in progress will continue)

D.13 POST MECO (DOL) CHECKLIST

STS-___ Cycle: ___ ARD: _____ Date: _____

NOTES

None.

PROCEDURE

1. Record OMS quantities dumped during ascent, with and without OA.
 - o L OMS Burned During OA = _____ lb
 - o R OMS Burned During OA = _____ lb
 - o L OMS Burned Post OA, Pre-MECO = _____ lb
 - o R OMS Burned Post OA, Pre-MECO = _____ lb
2. If (and only if) any large trends or anything else off-nominal occurred during the ascent After MECO, do a "Get Current" in DBCHEK then save a post-launch checkpoint.
3. Reset the ARDTools, Workstation FPR, and Workstation OMS back to the nominal sim values so you don't (or worse, some unprepared trainee doesn't) get a surprise next time you use these in a sim.
4. Set the electronic "Thrust Limiting" tags back to their sim configuration. There may be a future sim on the old load.
5. Set the delta file links back to the sim configuration and use Engine Selection to re-copy the reference directory data to the delta directory data. You will need the help of GA to do this. Again, it would be very bad for an unprepared trainee to try to fix this in the minutes before the next sim.
6. You will compare boundary times with FDO and Co. on MPSR DYN A, post-OMS-2. After that, you are usually released. DO NOT LOG OFF UNTIL YOU OBTAIN PERMISSION FROM WSS.

What you have done will someday allow men to kick the dust of other worlds from their boots!

D.14 POST DOL CHECKLIST

STS-____ Cycle: ____ ARD: _____ Date: _____

NOTES

None.

PROCEDURE

1. Be sure and update the Thrust Update History spreadsheet (link below) based on this flight. Don't forget to add cell notes to the spreadsheet files where called for. You will also have to update it when the reconstruction data comes in a few weeks.

s:\dm46\ARDSTUFF\RECORDS\THUPDATE\HISTORY.XLS

2. Clean out the V: at some convenient time, ensuring the most recent versions of all files is on the S:.
3. Put all pertinent ARD launch data in the file cabinet/bookshelf for the ARD Historical Preservation Society. It goes in Flight order, not numerical order. Don't forget to update the label on the drawer (even if your folder went on the bookshelf instead of the drawer)!
4. Update the following checklists with any changes, things you have learned, clarifications, etc., that you think need to be made or would help any future ARD Support, especially a new one on their first launch. This is one of the most important steps! Don't forget to update the 6 DBCHEK Updates Checklists with any additional miscompares you encountered, all the way back to the ILC, if they will be showing up regularly from now on. Do not remove any rows unless absolutely sure that's the right thing to do.

Since this checklist is part of the ARD Console Handbook, this step requires a CR. Work with the handbook manager (S. Graybeal) to have a CR opened, and to obtain a copy of this appendix to edit. Before editing, make sure that all previous changes have been accepted. During edits, make sure "Track Changes" (under the Tools menu) is ON. When done with changes, send an e-mail to all ARD Supports to screen the changes you made. Don't assume you're done with this step until all ARDs have agreed to your changes. Once all ARDs have agreed, the handbook manager will release a PCN before the next launch attempt.

- D.8 L-1 Week Checklist
- D.9 L-1 Day Checklist
- D.10 Launch Day Checklist
- D.11 T-9 Minute Hold Checklist
- D.12 Realtime Checklists
- D.13 Post MECO (DOL) Checklist
- D.14 Post DOL Checklist

D.15 ASCENT FDO ELECTRONIC DATA PACK

STS-____ ARD: _____ Date COMPLETED[@]: _____

[@] At L-3 days, be sure to check all FADS directories for product deliveries after this date!

FLIGHT DOCUMENTATION

GROUND RULES AND CONSTRAINTS, at:

<http://mod.jsc.nasa.gov/dm/fdm/lvla/lvlaframes.html>

TRAJECTORY DESIGN DATA PACKAGE

ARD SUPPORT GENERATED CONSOLE DATA

ASCENT EVENTS SUMMARY

ATO OMS DUMP PLOT (optional)

CONSOLE DATA GENERATED BY OTHER DISCIPLINES

FDO LEAK LEVELS (from PROP)

MAIN ENGINE TABLES (from BOOSTER)

ASCENT FDO/TRAJ/ARD SUPPORT PRODUCTS

Product	Description	File(s)
ASAB 16	ABORT MODE BOUNDARY BAR CHART	asab16.abrtchrt.plt
ASAB 20	FDF - OMS CREW CHARTS (ALL SITES)	asab20.ccht.asc, asab20.ccht.prt, asab20.cuecard.prt, asab20.zontrg.prt
ASAB 20A	RENDEZVOUS RECOVERY	asab20a.rndzrec.prt
ASAB 23	ASCENT MODE BOUNDARY VELOCITIES	asab23.checkl.prt, asab23.mbound.prt, asab23.reslctdg.asc, asab23.nocommdg.asc
ASAB 25	ARD BIAS TABLES	asab25.xls
ASAB 28	RTLS STUCK THROTTLE PERFORMANCE	asab28.stkthrot.plt
ASAB 30	FDF - OMS TGT TABLE FOR AOA TO ALL SITES	asab30.omstgt.prt

Product	Description	File(s)
ASCT 06	NOMINAL DELTA-Vs AND STATE VECTOR	asct06.nsv.asc
ASCT 08	ASCENT ILOADS	asct08.iloads.asc
ASCT 17A	NOMINAL ASCENT DATA	asct17a.aerosumm.asc, asct17a.trajsumm.asc
ASCT 21	ASCENT RANGE SAFETY BOUNDARY LINES	asct21.tabularA.asc, asct21.tabularB.asc
ASCT 22A	ARD MCC TRAJ INPUTS AND SUPPORT TABLES	asct22a.agt.asc, asct22a.wtsfpr.asc
ASCT 44	DOL UPLINK ILOADS	asct44.iloads.asc
DATA 22A	MCC SERS DATA (System Parameters)	data22a.cnst.asc
DATA 22B	MCC SERS DATA (MEDCVs)	data22b.ame.asc, data22b.gtt.asc, data22b.ltn.asc, data22b.secd.asc, data22b.dae.asc, data22b.jvt.asc, data22b.lwlt.asc, data22b.tacn.asc, data22b.dct.asc, data22b.lst.asc, data22b.mit.asc, data22b.tast.asc, data22b.depd.asc, data22b.ltt.asc, data22b.mls.asc, data22b.tmtt.asc, data22b.fft.asc, data22b.lttk.asc, data22b.mpt.asc
DSCT 05	MAXIMUM CROSSRANGE	dsct05.maxr.prt

Product	Description	File(s)
DSCT 13	EOM DEORBIT TARGETS	dsct13.buildup.prt, dsct13.eisv.prt, dsct13.nomeomdst.prt, dsct13.wx1eomdmr.prt, dsct13.doigsv.prt, dsct13.lm100sv.prt, dsct13.nomeomgap.prt, dsct13.wx1eomdst.prt, dsct13.dsum.asc, dsct13.mccdata.prt, dsct13.wx1dsum.asc, dsct13.wx1eomgap.prt, dsct13.eim5sv.prt, dsct13.nomeomdmr.prt, dsct13.wx1eim5sv.prt
DSCT 17	DDS Landing Site Tables	dsct17.dds.ls.asc
DSCT 28	RECOVERY PREBANK	dsct28.rpbtables.prt, dsct28.rpbcurves.mif *, dsct28.rpbcurves.prt
DSCT 30	TARGET SUMMARY SHEET	dsct30.sum.prt
DSCT 41	LAST TAL BOUNDARY	dsct41.ltalbnd.prt
DSCT 66	EDS DDS ELEMENT FILE	dsct66.eds.dds.bnr.dec ^
PROP 02	PROP SEQUENTIAL MASS PROPERTIES	prop02.fopchart.asc

ASCENT FDO/TRAJ/ARD SUPPORT DOL PRODUCTS **

Product	Description	File(s)
ASCT 47	MCC TRAJECTORY INPUTS	asct47.agt.asc, asct47.icddata.asc, asct47.wtsfpr.asc, asct47.chg.asc
ASCT 99	DOL OMS ASSIST ILOADS	asct99.iloads.asc
ASAB 32B	AME MCC SUPPORT TABLES	asab32b.ameinput.asc, asab32b.medcv.asc
PROP 31	ARD DATA	prop31.arddata.asc

ASCENT/ENTRY TRAINER PRODUCTS

Product	Description	File(s)
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Product	Description	File(s)
ASCT 03	ASCENT/ENTRY TRAINER INPUTS	asct03.ard_namelist.asc, asct03.massprop.asc, asct03.mrbil.asc, asct03.propsrb.asc, asct03.fswinitl.asc, asct03.mdde.asc, asct03.posatt.asc, asct03.propssme.asc
DSCT 35	ASCENT/ENTRY TRAINER DATA	dsct35.aero.descent.asc, dsct35.hal.descent.compools.asc, dsct35.solar.flux.data.asc, dsct35.atmos.eom.asc, dsct35.iloads.descent.asc, dsct35.state.asc, dsct35.deriv.asc, dsct35.mass.descent.eom.asc, dsct35.tps.asc, dsct35.eom.m.asc, dsct35.prop.descent.isp.asc, dsct35.gps.almanac.asc, dsct35.rollout.asc, dsct35.gravity.asc, dsct35.sensor.descent.asc

LSO PRODUCTS

Product	Description	File(s)
DSCT 04	APPROACH AND LANDING ILOAD	dsct04.al.targets.mif * , dsct04.ds04alil.fcf #
DSCT 36	EOM GROUNDTRACK DATA	dsct36.grndtrks.plt, dsct36.table.prt
NAVO 10	LANDING SITE TABLE	navo10.landsite.prt
NAVO 16	SAIL NAV DATA PACK	navo16.lsd.asc, navo16.lsm.mif *
NAVO 16A	SPOC INPUTS	navo16a.PCfiles.asc
NAVO 16B	GPO COTM DATA PACK	navo16b.changlog.asc, navo16b.datafile.asc, navo16b.descript.asc

ORBIT FDO PRODUCTS

Product	Description	File(s)
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Product	Description	File(s)
DSCT 01	DEORBIT DELTA V	dsct01.sum.asc
DSCT 26	DESCENT SUMMARY	dsct26.maps.plt, dsct26.plot.plt, dsct26.text.prt
ONOR 03	PRELIMINARY SEQUENCE OF EVENTS	onor03.trajsoe.asc
ONOR 05	BETA ANGLE DATA	onor05.bmaxmin.asc, onor05.betahis.asc
ONOR 09	LANDING OPPORTUNITIES	onor09.landopts.asc
ONOR 29A	RENDEZVOUS LAUNCH TARGET DATA	onor29a.ltp.asc, onor29a.tsvdmps.asc, onor29a.osvdmeco.asc, onor29a.osvdmmps.asc, onor29a.tsvdmeco.asc, onor29a.tsvogmt.asc
ONOR 29A	TARGET STATE VECTOR USED TO GENERATE RNDZ01B	onor29a.tsvdogmt.asc
ONOR 37	LAUNCH WINDOW	onor37.lwbchart.mif *, onor37.lwplot.doc *
PROP 34	MCC DATA	prop34.abbrvrep.asc, prop34.mccdata.asc, prop34.fluidbud.asc
RNDZ 01A	RNDZ/PROX MANEUVER SUMMARY	rndz01a.rndzeval.mif *, rndzgpmp.asc
RNDZ 01B	OMS-2 TARGET ALT VS. PHASE ANGLE	rndz01b.oms2pa.prt
RNDZ 02	RNDZ/PROX OPS TARGET DRAG CHARACTERISTICS	rndz02.target.mif *
RNDZ 03	RNDZ/PROX OPS PROPELLANT BUDGET	rndz03.propcont.mif *, rndz03.propnom.mif *, rndz03.propsum.mif *

* NOTE: mif and doc files are delivered to the ARD Support customer by the Schedule and Data Management Group via email as PDF formatted files and include the file tracking form.

** NOTE: DOL ascent products may be provided as hardcopies to FDO and TRAJ, but are also stored electronically.

NOTE: Files with the "fcf" extension cannot be converted to a format that is viewable on the PC. This file in particular is for the LSO and a notice of its availability is emailed to Marty Linde.

^ NOTE: Dsct66.eds.dds.bnr.dec is not available on the PC because it is an IPS binary file.

D.16 STS-67 LAUNCH/GENERIC THRUST UPDATE TABLE

STS-67 LAUNCH/"GENERIC" THRUST UPDATE TABLE				
AM NOM MPROP TREND (FPS/MIN)	THROTTLE LEVEL ON EACH OF 3 ENG. (% RPL)	EQUIVALENT THROTTLE LEVEL ON 1 ENGINE (% RPL)	DELTA-WT (ΔETP) FOR BUCKET (LBS)	
FIND TREND ON	30	104.64	105.93	-1343
TLM 2:30-3:00	29	104.62	105.86	-1289
	28	104.59	105.78	-1235
VERIFY 3:00-3:30	27	104.57	105.70	-1182
WHILE PINGING	26	104.54	105.62	-1128
BOOSTER	25	104.52	105.55	-1074
	24	104.49	105.47	-1021
IF DEADBAND	23	104.46	105.39	-967
EXCEEDED AND	22	104.44	105.31	-913
NO T/L:	21	104.41	105.24	-859
	20	104.39	105.16	-806
<u>AUTO METHOD</u>	19	104.36	105.08	-752
1. CHECK GO	18	104.34	105.01	-698
FLAG	17	104.31	104.93	-645
2. FREEZE PBI	16	104.28	104.85	-591
3. CROSS CHECK	15	104.26	104.77	-537
WITH CHART	14	104.23	104.70	-483
4. EXECUTE PBI	13	104.21	104.62	-430
	12	104.18	104.54	-376
<u>MANUAL METHOD</u>	11	104.15	104.46	-322
1. K62 ADJUST @	10	104.13	104.39	-269
1:07 IN AM;	9	104.10	104.31	-215
CURRENT TIME IN	8	104.08	104.23	-161
HM.	7	104.05	104.15	-107
2.ΔETP IF REQ'D.	6	104.03	104.08	-54
IF >+/- 30 FPS ARD	0 Predicted Inherent Trend			
IS NO GO UNLESS	-6	103.97	103.92	54
OTHER CUES	-7	103.95	103.85	107
	-8	103.92	103.77	161
RE-INPUT AFTER	-9	103.90	103.69	215
SSME OUT IF:	-10	103.87	103.61	269
MANUAL METHOD	-11	103.85	103.54	322
USED ON 1 OR 3	-12	103.82	103.46	376
ENGINES.	-13	103.79	103.38	430
	-14	103.77	103.30	483
NO ACTION IF	-15	103.74	103.23	537
AUTO METHOD.	-16	103.72	103.15	591
	-17	103.69	103.07	645
RESTORE PBI	-18	103.66	102.99	698
BEFORE	-19	103.64	102.92	752
INPUTTING	-20	103.61	102.84	806
SUBSEQUENT T.L.	-21	103.59	102.76	859
DATA	-22	103.56	102.69	913
	-23	103.54	102.61	967
	-24	103.51	102.53	1021
	-25	103.48	102.45	1074
	-26	103.46	102.38	1128
	-27	103.43	102.30	1182
	-28	103.41	102.22	1235
	-29	103.38	102.14	1289
	-30	103.36	102.07	1343

ARD HEAVY
 POSSIBLE
 HIGH THRUST
 ONBOARD

ARD LATE
 TMECO

USUALLY
 DISREGARD THESE
 SMALL DELTAWTS

ARD LIGHT
 POSSIBLE
 LOW THRUST
 ONBOARD

ARD EARLY
 TMECO

NOMMETH= 469494 LBS SIGFT= 2577 LBS/1 SIGMA CLUSTER THRUST
 DEADBAND= 4.53 FPS/M TRUST= 7.10 TREND/1 SIGMA THRUST
 TIME INP= 67 SEC NOMISP= 452.74 SEC
 File: s:\dm46\ardstuff\prod\thup9501.xls 1488 LBS/1 SIGMA SE THRUST
 As of: Mar-21-95 8:06 AM

Figure D-1. STS-67 Launch/Generic Thrust Update Table

D.17 PLUGGED POST FLIGHT HISTORY

Flight	L-7 TDDP			Main Engine Tables and Floppy Disks
	Center (1)	Left (2)	Right (3)	
61	0	3	0	0
60 **	1	2	4	1.5
62	0	0	2	0
59	0	3	0	0
65	0	9	0	0
64	0	0	2	0
68	0	3	0	0
66	9	2	0	1
63	0	0	2	0
67	1	3	0	2
71	0	2	4	1
70	0	0	0	0
69	0	0	2	0
73	0	0	0	0
74	1	0	4	0
72	0	0	0	0
75	3	2	1	0
76	0	0	0	0
Total Average	0.83	1.61	1.17	0.31
Median	0.00	1.00	0.00	0
One Sigma	2.18	2.25	1.54	0.62

original STS-61 - 67 data: DM46/W.D. Clarke, Mar-21-95
 STS-71 - 76 data added: DM46/C.M. Boykin, Jan-30-01

Plugged Posts were only a concern for these missions. After this, each engine was modeled individually for performance cases.

Figure D-2. Plugged Post Flight History

D.18 NON-STANDARD DATABASE CHANGE DESCRIPTION

This section shows a sample non-standard database change description letter, for STS-112.

Non-Standard Database Change Description

The parameters listed below have been changed from OCF cycle for the close-to-launch delivery for STS-112. They are non-standard updates and therefore appropriate approval must be obtained to change the values, and they must be verified in the MCC environment (see Ascent FDO Console Handbook section 4.3, ARD/AME Database Procedures). The parameters, their new values, and a brief description are as follows:

1) System Parameters

MDTSRB01 = 6164346.6
 MDTSRB02 = 6164346.6
 MDTSRB03 = 6164346.6
 MDTSRB04 = 6164346.6
 MDTSRB05 = 6164346.6
 MDTSRB06 = 6164346.6
 MDTSRB07 = 6164346.6
 MDTSRB08 = 6164346.6
 MDTSRB09 = 6164346.6
 MDTSRB10 = 6164346.6
 MDTSRB11 = 6164346.6
 MDTSRB12 = 6164346.6 (NO CHANGE)

These changes only affect the SRB thrust during the first 38 seconds of flight. These are needed to correct the ARD moment balancing error problem at liftoff, and should not have any other significant effect on ascent. The first flight they can make the change in the baseline is STS-114

This data will not be delivered in ASCT-47. These changes will be incorporated via an ARD Support generated Init Pad, as was done for the OCF cycle. Ascent #4 was verified to be simmed with these changes, and they will be verified additionally during the L-1 day ARD Checkout Run scheduled for October 01, 2002.

2) System Parameter

MCKTOL = 0.055 (OLD VALUE = 0.065)

The MCKTOL parameter update was made to reduce the likelihood of either non-convergence or inaccuracy in a thrust update.

This input will be delivered in ASCT-47, and verified during the L-1 day ARD Checkout Run scheduled for October 01, 2002.

These changes should be implemented.

ARD Designer/Andrew Kantor	<u>Andrew Kantor</u>	Date: <u>9/30/02</u>
ARD Supervisor/J. Davidson	<u>John Davidson</u>	Date: <u>9/30/02</u>

Flight Dynamics Concurrence

ARD Support/R. Mrozinski	<u>Richard B. Mrozinski</u>	Date: <u>9/30/02</u>
Ascent TRAJ/R. Jones	<u>Richard S. Jones</u>	Date: <u>9-30-02</u>
Ascent FDO/C. Sparks	<u>Carson W. Sparks</u>	Date: <u>9-30-02</u>
DM46/W. Powers	<u>William E. Powers</u>	Date: <u>9/30/02</u>

Figure D-3. Non-Standard Database Change Description

E MSK/VARIABLE NAME MAPS AND DESCRIPTIONS

The information in this appendix was relocated to the on-console tool, DBCHEK (See Section 5.1.4), as part of PCN 03-1.

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F ARD SUPPORT CONSOLE HANDBOOK DOCUMENTATION CHANGE PROCESS

- 1) The change initiator fills out a change request (CR) form. The CR form is available on the dm server at the following link. See page F-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.

S:\Divisions\DM\Private\DM46\ARDSTUFF\DOCS\ARDCHCR.doc

- 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 to 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.

- 14) The editor is responsible for consolidating the PCN into the electronic document and for posting an electronic notice of this occurrence to all impacted individuals. Cheryl Andrews will update the DM ISO9000 Organizational Master List, and Laz Gonzalez will update the web-based copy of the documents. The editor is responsible for updating the master hardcopy in the file cabinet.

ARD Support Console Handbook Change Request (CR)

Submit Date:	Volume:	CR #
<small>For Administrative Use Only</small>		
Subject:		
Description of Change or Addition:		
Reason for Change or Addition:		
Initiated By:	Assigned To:	
<small>For Administrative Use Only</small>		
Group Lead Authorization Signatures		
IMPLEMENT	CLOSE (PCN =)	

Revised July 1996

Figure F-1. Handbook Change Request Form