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STS-1 Operational Flight Profile

Volume I Groundrules and Constraints Cycle 3.1.1

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STS-1 OPERATIONAL FLIGHT PROFILE

VOLUME I
GROUNDRULES AND CONSTRAINTS
CYCLE 3.1.1

Prepared by
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REVISIONS

<u>Rev. no.</u>	<u>Change no.</u>	<u>Description</u>	<u>Date</u>
		Baseline Issue (reference PRCBD S04337)	2/10/78
1		QFP Cycle 2 (reference PRCBD S05109, dated September 27, 1978, "SS-1 QFP Groundrules and Constraints Document" for Cycle 2 Revision)	9/28/78
1	(Ref.: PRCBD S05217)	The changes in sections 4.1.5, 4.1.6, 4.1.13, 4.1.20, 4.2.1.1, and 4.2.1.15 are due to the addition of the appendix. (Reference approved CR 94B, October 17, 1978 FOP.) The change in section 4.9.12b is due to the modification of the approach and landing glideslope to agree with the approved Level II baseline. The change in section 4.10.5.2 is due to the modification of the separation pitch rate. (Reference approved CR 106, October 17, 1978 FOP.)	11/78
2	(Ref.: PRCBD S04869B and S04869C)	This revision reflects the Cycle 3 groundrules and constraints as baselined by the Flight Operations Panel (FOP) on August 7, 1979 and approved by Level II on August 10, 1979.	8/10/79
3	(Ref.: PRCBD)	This revision reflects the cycle 3.1.1 groundrules and constraints baselined by the Flight Operations Panel (FOP) in March 1980 and approved by Level II in April 1980.	4/23/80

FOREWORD

This document, Volume I, contains the approved groundrules and constraints to be used in generating the Space Shuttle flight-1 (SS-1) operational flight profile (OFP). Volumes II through VIII of the OFP (as defined in table 2-I of this document) will be based on these groundrules and constraints. Hardware development, software verification, and crew training should be consistent with the data presented within Volumes I through VIII of the SS-1 OFP.

Volumes I and II (Profile Summary) of the SS-1 OFP are approved and controlled by the office of the Space Shuttle Program Manager (Level II). Volume I was baselined using the standard Level II change process. Volume II will be baselined as outlined in JSC-07700, Volume IV, Appendix L (S04869).

Document maintenance for all volumes is assigned to the Data Systems and Analysis Directorate (JSC/FA), Mission Planning and Analysis Division (JSC/FM).



Robert F. Thompson, Manager
Space Shuttle Program Office

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1.0 CHANGE CONTROL MANAGEMENT PROCEDURES FOR OPERATIONAL FLIGHT PROFILE DOCUMENTS

1.1 AUTHORITY

This volume is prepared under the authority of the Space Shuttle Program Manager as specified in the Space Shuttle Program Requirements Control Board Directive - Level II - No. S04337, dated February 10, 1978, and as amended by No. S04869, dated June 13, 1978. The groundrules and constraints to be used in generating the STS-1 operational flight profile (OFP) are established in this volume.

1.2 PURPOSE

Orbital flight test (OFT) flight design activity has progressed to the point where configuration control of the OFP design products and recognition by the various organizations that use these products are required. The major producers of the OFP products are the Data Systems and Analysis Directorate (JSC-FA) and the Flight Operations Directorate (JSC-CA). The activities of these directorates are coordinated under the auspices of the Flight Operations Panel (FOP) with this panel acting as the focal point for OFP design issue resolution, except for those issues that are appropriate for Level II disposition. The initial baselining and change control for the OFP Volume I (Groundrules and Constraints) and Volume II (Profile Summary) will be approved and controlled by the office of the Space Shuttle Program Manager (Level II).

1.3 SCOPE

The following documents comprise the OFP design products to be developed for each OFT flight:

- Volume I - Groundrules and Constraints
- Volume II - Profile Summary
- Volume III - Detailed Ascent Profile
- Volume IV - Detailed Onorbit Profile
- Volume V - Detailed Deorbit-Through-Landing Profile
- Volume VI - Abort Analysis
- Volume VII - OMS and RCS Consumables Analysis
- Volume VIII - Nonpropulsive Consumables Analyses

Volume I was evaluated through a Level II Change Request for initial baselining. Subsequent OFP documents (Volumes II through VIII) will reflect the content of the baselined Volume I. Volume II (Profile Summary) was baselined according to the procedures in JSC-07700, Volume IV, Appendix L (S04869). All changes to Volume I and Volume II are controlled according to the detailed procedures described in section 1.4.

1.4 CHANGE CONTROL PROCEDURES

1.4.1 Scope

All proposed changes to the Operational Flight Design Groundrules and Constraints and the Operational Flight Profile Summary baselined by the Level II PRCB will be controlled in accordance with the procedures prescribed herein. Figure 1-1 shows schematically the processing flow. The following paragraphs refer to figure 1-1.

All proposed changes to the Operational Flight Design Groundrules and Constraints and the Operational Flight Profile Summary shall be documented on the Flight Design Change Request (FDCR) form (fig. 1-2). Proposed changes may be initiated at the Program (Level II), Project (Level III), or Design Activity levels. Change requests will be submitted to the organizational element responsible for coordinating change activity for the operational product being addressed.

1.4.2 Change Coordination, Assessment, and Categorization

The organizational element responsible for coordinating change requests for the operational product will log each change request, assign a completion date, and transmit the change request to the appropriate offices and/or working group(s). The recipients will review, analyze, and present evaluations, recommendations, and proposed change effectiveness to the organizational element responsible for establishing the content of the operational product. This organizational element will then categorize each proposed change into one of the following categories:

- a. Approved
- b. Approved with modification
- c. Withdrawn
- d. Disapproved

All categorized change requests, except those which are withdrawn or disapproved, will be forwarded to the Level II office of primary responsibility for the operational product being addressed.

1.4.3 Manager of the Level II Office of Primary Responsibility

The manager of the Level II office of primary responsibility will sign approved change requests requiring no further Level II action, submit them to the Level II PRCB secretary for PRCBD preparation, and subsequently approve the completed PRCBD for distribution. Change requests disapproved by the manager of the Level II office of primary responsibility will be returned to the originator. Change Requests requiring further Level II review and disposition will be presented to the OFT manager for further action.

1.4.4 OFT Manager

Change requests disapproved by the OFT manager will be returned to the originator. The OFT manager will approve and sign a PRCBD for those change requests not requiring further Level II review and disposition. Change requests requiring consideration by the program manager will be forwarded to the Level II PRCB secretary for review and disposition in accordance with Level II configuration management procedures.

1.5 APPROVED CHANGE IMPLEMENTATION

All changes that have been approved in accordance with the preceding paragraphs shall be provided to the organizational element responsible for publishing the affected operational product for implementation. A change page showing an up-to-date listing of all changes will be issued with each document change. This page shall be placed just behind the title page. Complete revisions of the product will be published as necessary and denoted by a revision number on the front cover. Changes will be made in accordance with the PRCBD.

1.6 OPERATIONAL PLANNING CHANGES AFFECTING PAYLOAD INTEGRATION PLANS (PIP's)

By participating in the Space Shuttle Program change review and disposition process, the Shuttle Payload Integration and Development Program Office (SPIDPO) will attempt to resolve conflicts between OFT operational documents or products and established PIP (or annex) requirements. When conflicts cannot be resolved in the course of this activity, SPIDPO will process a change request to the affected PIP as specified in JSC-13995 (Change Control Requirements and Procedures Manual), negotiating directly with the Space Shuttle Program Office prior to amending the payload agreement affected.

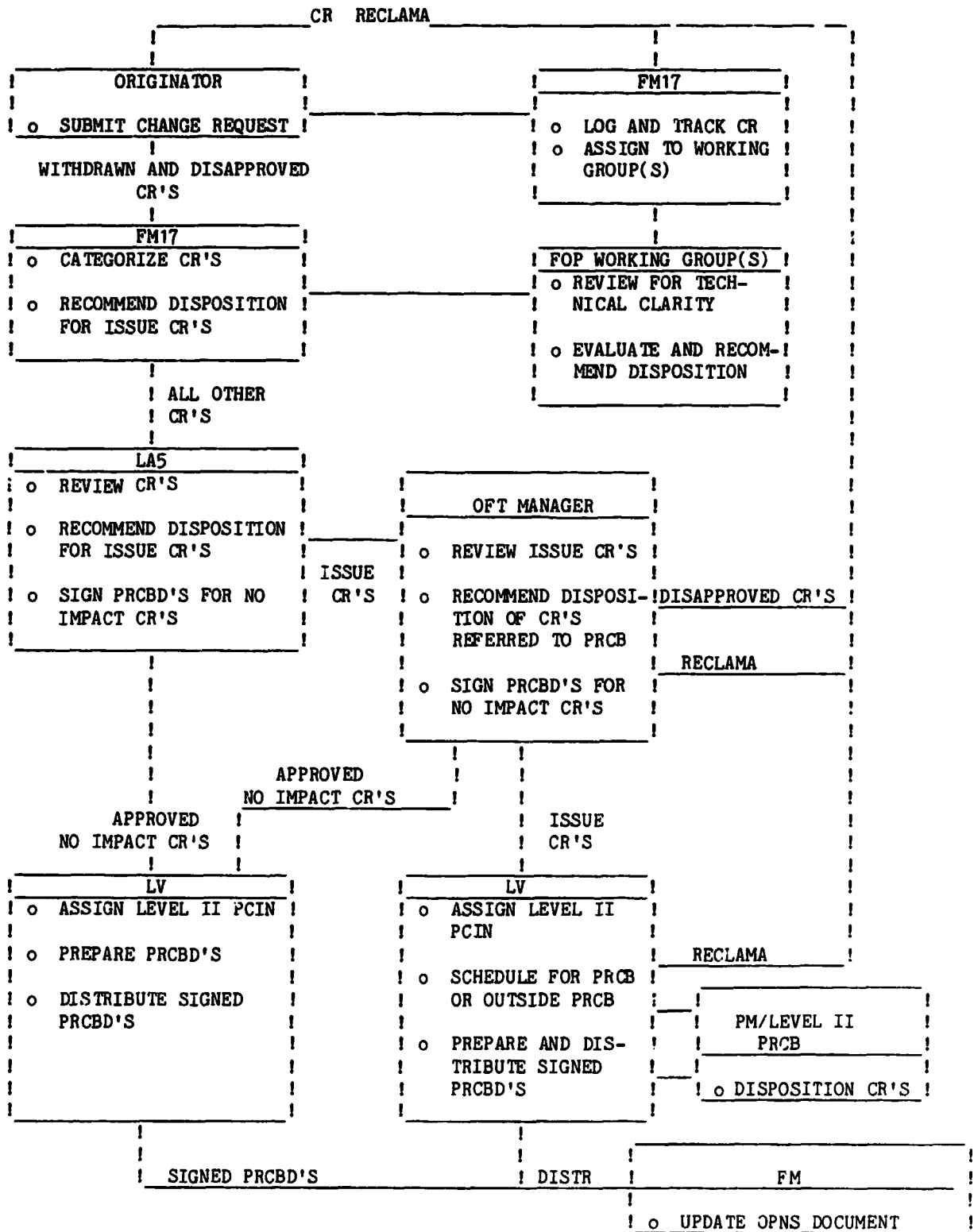


Figure 1-1.- OFT profile design change request flow.

PAGE 1 OF _____	FLIGHT DESIGN CHANGE REQUEST		CR. NO.
APPLICABLE TO FLIGHT _____ DOCU. _____	INITIATOR _____	PHONE _____	DATE _____ ORGANIZATION _____
CHANGE TITLE _____			
DESCRIPTION OF CHANGE			
REASON FOR CHANGE/IMPACT OF NONINCORPORATION			
			_____ AUTHORIZED SIGNATURE/DATE
FOP WORKING GROUP EVALUATION: RECOMMENDATION (INCLUDING EFFECTIVITY)			
			_____ WORKING GROUP CHAIRMAN/DATE
FOP DISPOSITION			
<input type="checkbox"/> APPROVED	_____	_____	
<input type="checkbox"/> APPROVED WITH MOD			
<input type="checkbox"/> DISAPPROVED	_____	_____	
<input type="checkbox"/> WITHDRAWN			
<input type="checkbox"/> LEVEL II ACTION REQ	<input type="checkbox"/> ISSUE PRCBD	DISPOSITIONING OPERATIONAL ELEMENT	DATE
	<input type="checkbox"/> FURTHER LEVEL II ACTION REQ.	_____	DATE
		LEVEL II	

Figure 1-2.- Flight design change request form.

2.0 INTRODUCTION

This document defines the groundrules and constraints baselined by Level II in April 1980 that were used in generating cycle 3.1.1 of the OFP for STS-1. These requirements are based on data contained in references 1, 2, and 3. This document is the first in a series that, taken together, will define cycle 3.1.1 of the OFP. All Cycle 3.1.1 STS-1 OFP documents and their scheduled distribution dates are listed in table 2-I. Section 3.0 presents a brief summary of the STS-1 flight. The guidelines and constraints currently baselined for STS-1 are presented in section 4.0.

TABLE 2-I.- S13-1 DOCUMENT PUBLICATION SCHEDULE

<u>Document</u>	<u>Scheduled distribution date</u>
Volume I - Groundrules and Constraints	July 1980
Volume II - Profile Summary	September 1980
Volume III - Detailed Ascent Profile	TBD
Volume IV - Detailed Onorbit Profile	July 1980
Volume V - Detailed Deorbit-Through-Landing Profile	TBD
Volume VI - Abort Analysis	TBD
Volume VII - OMS and RCS Consumables Analysis	TBD
Volume VIII - Nonpropulsive Consumables Analyses	TBD

3.0 STS-1 DESCRIPTION

The STS-1 will be a 54-hour flight with launch from Kennedy Space Center (KSC) on November 30, 1980, at 11:50 Greenwich mean time (GMT). The flight test will be achieved in a 150-n. mi. circular orbit with a 40.3-degree inclination. This orbit will be achieved by two orbital maneuvering system (OMS) maneuvers: OMS-1 and OMS-2. The OMS-1 maneuver will occur shortly after external tank (ET) separation with the OMS-2 maneuver occurring at the apogee of the orbit resulting from OMS-1. The payload bay doors will be opened as early as possible on day one. The Orbiter will be placed in a ZLV, X-POP (X-axis normal to orbit plane) tail to Sun attitude for most of the STS-1 flight. This attitude will be maintained unless other requirements (flight test requirements, inertial measurement unit alignment, etc.) preclude this Z-LV X-POP attitude. Deorbit will occur on December 2, 1980 with landing on a descending pass (orbit 37) to Edwards Air Force Base (EAFB). The ground elapsed time (GET) for the nominal landing will be approximately 54 hours 30 minutes.

4.0 STS-1 OFF FLIGHT DESIGN GROUND RULES AND CONSTRAINTS

4.1 GENERAL

- 4.1.1 Trajectory techniques will provide maximum vehicle subsystem margins from design specifications when possible. Priorities and trade analyses will determine the best compromise when conflicts exist.
- 4.1.2 The launch date is November 30, 1980 at 11:50:00 GMT (6:50 a.m. Eastern standard time (EST)).
- 4.1.3 The nominal orbit is 150/150 n. mi.
- 4.1.4 The nominal inclination is 40.3 degrees. This inclination will provide an ET groundtrack that, for excessive main engine cutoff (MECO) over-speeds, passes to the south of King Island and north of the Furneaux Group off the southern coast of Australia.
- 4.1.5 Nominal and abort-to-orbit (ATO) landings will be on Rogers Lakebed runway 23 at EAFB. Abort-once-around (AOA) landing will be on runway 17 at Northrup Strip. If unacceptable landing conditions exist at Northrup Strip at T - 36 hours, the AOA landing will be on runway 23 at EAFB. Landing for glide-return-to-launch site (GRTLS) will be on runway 15 at KSC. Because of the high probability of landing on either runway 15 or 33 for return-to-launch (RTLS), OFT performance assessment will be based on the capability to achieve either runway for RTLS. Nominal and abort landing site locations are given in appendix A.
- 4.1.6 Standard ground spaceflight tracking and data network (GSTDN) contact data will be provided for selected stations depending on the mission phase. Table II of appendix A establishes the acquisition-of-signal/line-of-sight (AOS/LOS) computational requirements for each phase. Minimum elevation may be computed assuming zero-degree or 3-degrees maximum elevation with no masking. However, normally all AOS/LOS are computed assuming zero-degree elevation with masking and keyholes considered. Exclusion of a site from table II, appendix A does not preclude it from being used in the tracking network.
- 4.1.7 All landings (nominal, abort, and contingency) will be no earlier than 15 minutes before sunrise (as defined on page 569 of ref. 4) and no later than 15 minutes after sunset. Also, no landings will be scheduled to occur when the Sun's azimuth is +10 degrees of runway heading and zero to 20 degrees elevation. For wind considerations, it is desirable that nominal and AOA landings at EAFB occur prior to 10:00 a.m. local time during February through June, and prior to 12 noon local time during July through September. Landings throughout the day are acceptable during October through January.
- 4.1.8 A 1-hour launch window (as a minimum) will be provided.
- 4.1.9 There is no on-time launch requirement.

- 4.1.10 There shall be two crewmen. Crew provisions will be loaded for 5 days.
- 4.1.11 The planned flight duration will be approximately 54 hours.
- 4.1.12 There will be landing opportunities at EAFB on at least four orbits each day.
- 4.1.13 The payload will include the development flight instrumentation, the induced environment contamination monitor, the aerodynamic coefficients identification package, and the Orbiter experiments tape recorder. Mass properties for total payload weight are given in appendix A.
- 4.1.14 The payload bay doors (PLBD) are to be opened as soon as operationally practicable after OMS-2. However, the contingency capability will exist to leave the PLBD closed for up to 8 hours following OMS-2.
- 4.1.15 (Deleted)
- 4.1.16 All nominal deorbit opportunities will be planned such that the entry crossrange is ≤ 550 n. mi.; however, a crossrange of ≤ 700 n. mi. is acceptable for AOA and contingency cases.
- 4.1.17 (Deleted)
- 4.1.18 Reaction control system (RCS) backup deorbit capability is required. For this contingency, propellant from both OMS pods is assumed to be available.
- 4.1.19 The deorbit targeting will be biased to accommodate the designated backup deorbit propulsion mode.
- 4.1.20 Aerodynamic data, atmosphere and wind models, I-load values, software baseline (including implemented change requests (CR's)), engine data, assumed constants, geodetic locations for Tacan/microwave scanning beam landing system (Tacan/MSBLS) launch and landing sites and mass properties data for the nominal, RTL, ATO, and AOA analysis are specified in appendix A. The limitations and constraints defined in volumes I and II of the Shuttle operational data book (JSC-08934) will be adhered to in the design of the nominal and abort OFP profile except as defined in appendix E (sec. 4.1.21.).
- 4.1.21 Appendix B summarizes the groundrules and constraints that deviate other from reference 2 or from reference 3 of this document.

4.2 NOMINAL ASCENT

4.2.1 General

- 4.2.1.1 (Deleted. Moved to appendix A.)

- 4.2.1.2 The first-stage pitch and yaw attitude profiles will be biased for the steady-state mean vector winds for the month of December. First-stage shaping will reflect an AOA landing at Northrup Strip with no yaw steering necessary. If unacceptable landing conditions exist at Northrup Strip, second-stage yaw steering will be incorporated to provide an acceptable AOA landing at EAFB. The solid rocket booster (SRB) propellant mean bulk temperature (PMBT) to be used for December is 63.31° .
- 4.2.1.3 The boost-phase pitchover maneuver will be initiated through open-loop attitude steering when the Orbiter relative velocity reaches a magnitude that corresponds to a vertical rise of 365 feet, including dispersions.
- 4.2.1.4 The undispersed Q_{\max} used for ascent shaping will be no greater than 580 psf. Launch opportunities and lift-off wind conditions will comply with the allowed max dispersed Q constraint of 660 psf.
- 4.2.1.5 The SRB impact ellipse will not be west of a line connecting the following points (including dispersions):
- $$\phi = 30.00^{\circ} \text{ N}, \quad \lambda = 80.310^{\circ} \text{ W and}$$
- $$\phi = 31.44^{\circ} \text{ N}, \quad \lambda = 79.895^{\circ} \text{ W}$$
- 4.2.1.6 The SRB descent dispersion will use the same in-flight winds as the ascent.
- 4.2.1.7 At lift-off, the Space Shuttle main engines (SSME's) will be at 100-percent thrust rated power level.
- 4.2.1.8 The SSME's will be throttled during the first stage for max q control.
- 4.2.1.9 The MECO conditions will be consistent with the ET impact constraints enumerated below.
- a. Planned ET impact locations for nominal cutoff, including dispersions, will be no closer than 200 n. mi. to land masses in the Indian Ocean.
 - b. MECO and ET separation will be within GSTDN coverage.
 - c. MECO target conditions (r, v, γ, Ω, i) will be the same for normal ascent, AOA, and ATO.
 - radius = 21 290 308 feet (60 n. mi. altitude)
 - inertial velocity = 25 668 fps
 - biased inertial flightpath angle = 0.526 degree

ascending node = optimum inplane

inclination = 40.3 degrees

4.2.1.10 (Deleted)

4.2.1.10a T_{fail} is a direct controlling parameter of the earliest time that a downrange intact abort resulting from one SSME out is possible. For nominal and abort shaping purposes, T_{fail} shall be set at 265 seconds (approximate RTLS abort mode boundary).

4.2.1.11 The ascent trajectory will be shaped for an acceptable propellant margin for nominal, intact aborts, and contingency aborts, respectively.

4.2.1.12 A single OMS engine failure will not preclude nominal orbit insertion.

4.2.1.13a As a minimum, communications (voice, command, and telemetry) above masking for a nominal mission are required through tracking station Bermuda (BDA) through OMS-1 ignition plus 5 seconds.

4.2.1.13b For nominal, AOA, and ATO, the OMS-1 time of ignition (TIG) shall occur no earlier than 102 seconds from Orbiter/ET structural release. The OMS-1 TIG = 120 seconds will include a nominal 18 seconds from MECO to structural release to accommodate tail-off, damp rates, and preparation for separation and 102 seconds for tracking, ground evaluation, and appropriate action prior to OMS-1 ignition.

4.2.1.14 The OMS-1 maneuver will provide an orbit with a nominal 150-n. mi. apogee. The OMS-2 cutoff will result in a nominal 150-n. mi. circular orbit.

4.2.1.15 Deleted. Moved to appendix A.

4.2.1.16 The FPR allowance for the nominal mission will accommodate the occurrence of both 3-sigma low SSME and SRB performance.

4.2.1.17 From T - 9 minutes to T - 1 minute 57 seconds, propellant capability for a 5-minute launch hold is available. A 5-minute hold after auxiliary power unit (APU) startup at T - 5 will preclude a 24-hour recycle.

4.2.1.18 All four nominal SSME throttle change commands provided by the first-stage guidance principal function are available for OFT mission planning.

4.2.1.19 Nominally, the Shuttle vehicle will fly a $+2.0^\circ$ angle of attack and a 0.0° sideslip profile after the $q\alpha$ and $q\beta$ constraint region.

4.2.1.20 Nominal SSME and SRB performance will be used for planning purposes.

4.2.1.21 The vehicle will be oriented on the pad with the -Z body axis (tail) pointed south.

4.2.1.22 During the first orbit, S-band telemetry, voice, and uplink communication coverage for a duration of 3 minutes is required at Madrid for ≥ 1 -degree elevation.

4.2.1.23 The ascent steering will be limited until GET = 150 seconds and altitude is greater than 200 000 feet to avoid post-SRB separation heating problems (total delta angle of attack less than 5 degrees from a ± 2 -degree angle-of-attack and zero-degree sideslip angle).

4.2.2 Space Shuttle Main Engine (SSME) Constraints

4.2.2.1 The general purpose computers (GPC's) will issue the same thrust command to each SSME controller; i.e., no differential throttling.

4.2.2.2 The SSME's must be reduced to and operated at minimum power level for at least 6 seconds before MECO.

4.2.2.3 For flight design analysis, the SSME power levels are assumed to be

Minimum throttle = 65 percent

Maximum throttle = 100 percent (nominal and aborts)

4.3 SEPARATION

The following groundrules and constraints will apply for nominal, ATO, AOA, RTLS, and contingency abort mission.

4.3.1 Orbiter-ET/SRB

4.3.1.1 The dynamic pressure at SRB separation will not exceed 75 psf and the pitch and yaw angles of attack will not exceed ± 15 degrees. Body rates at separation will not exceed $p \pm 5$ deg/sec, $q \pm 2$ deg/sec, or $r \pm 2$ deg/sec.

4.3.1.2 Orbiter/ET three-axis attitude hold will be maintained for 4 seconds after SRB staging to prevent recontact.

4.3.1.3 The time from SRB separation cue (primary or backup) to separation command will be 6 seconds.

4.3.2 Orbiter/ET

4.3.2.1 The Orbiter will perform a -Z-axis translational maneuver from the ET. The RCS translational delta-V will be at least 4.0 fps.

4.3.2.2 (Deleted)

- 4.3.2.3 Separation (nominal, ATO, and AOA) will occur at MECO inertial attitude. Measured attitude rates must be ≤ 0.5 deg/sec in all axes.
- 4.3.2.4 The Orbiter will perform a Y body-axis translational maneuver. This maneuver will be executed following the completion of the RCS -Z body-axis translational maneuver and the correction of attitude errors to within the acceptable dead band. If at ET separation the configuration is within the dead band, then the maneuver will be in the direction of the +Y body axis. If the configuration is outside the dead band at ET separation, the translational maneuver shall be in the -Y body direction for positive roll and in the +Y direction for negative roll. The RCS translational delta-V will be on for a duration of 24 seconds (4 fps).

4.4 ORBITAL OPERATIONS

- 4.4.1 It is planned that a minimum of two 3-minute STDN passes above masking be available on each of the first three orbits and at least one 2-minute station tracking and data network (STDN) pass above masking be available for each orbit.
- 4.4.2 The nominal mission orbital altitude will be 150 n. mi. circular to maximize the onorbit GSTDN coverage without jeopardizing the RCS deorbit capability or the post-MECO tracking requirement.
- 4.4.3 An inertial measurement unit (IMU) alignment will be required within 1.5 orbits before each major onorbit translation maneuver.
- 4.4.4 All three IMU's and all five GPC's will be on during the entire flight.
- 4.4.5 The onorbit attitude timeline and predeorbit thermal conditioning will be designed to provide thermal protection systems (TPS) backface temperature and Orbiter structural temperature gradients within defined limits during entry.
- 4.4.6 During the approximate 4-hour period before deorbit, the navigation requirements are as follows:
- a. Three tracking passes (at least 30 minutes apart) >2 minutes above a 10-degree elevation
 - b. A primary uplink pass (at least 30 minutes after last tracking pass) ≥ 1 minute above a 5-degree elevation
 - c. After the primary uplink pass, a backup uplink pass at least 20 minutes before deorbit
- 4.4.7 The uncertainties and translation effects of systems venting, aerodynamic drag, and the RCS after initiation of the tracking sequence for deorbit maneuver computation and state vector determination will be minimized consistent with reasonable operations techniques.

4.4.8 (Deleted)

4.4.8.1 The onorbit thermal attitude constraints are as follows:

- a. PTC is always acceptable
- b. +ZLV with X-axis in plane (Y-POP) is acceptable if $\beta \leq 35^\circ$ and unacceptable for $\beta > 35^\circ$.
- c. +ZLV with X-axis normal to the orbital plane (X-POP) and tail-to-Sun is acceptable for $\beta \leq 45^\circ$, marginal if $\beta > 45^\circ$ but $\leq 60^\circ$, and unacceptable if $\beta > 60^\circ$.

4.4.8.2 For thermal control purposes, the Orbiter will be placed in a ZLV, X-POP (X-axis normal to orbit plane) tail-to-Sun attitude whenever flight activities do not require other specific attitudes.

4.4.9 The OMS budget will include 80 fps (~ 1600 pounds of propellant) for use in correcting ascent navigation errors. If this propellant is not required for ascent nav error corrections, then an amount sufficient to ballast the longitudinal X-c.g. = 66.7 percent at Mach = 3.0 during entry will be reserved. The remaining propellant will then be allotted to perform onorbit OMS maneuvers to satisfy OMS DTO's.

4.5 ORBITAL MANEUVERING SYSTEM

4.5.1 Delta-V requirements >6 fps for +X translation (using two OMS engines) or >3 fps for +X translation (using one OMS engine) will be performed with the OMS.

4.5.2 Maneuver computations will be based on nominal engine performance.

4.5.3 All normal OMS maneuvers >6 fps will be performed with two engines. (Deorbit targeting will be biased to protect against one-engine out.)

4.5.4 It is desirable to plan all OMS maneuvers to occur within GSTDN coverage.

4.5.5 The interconnect will be used only for contingency conditions. However, the crossfeed will be used during nominal onorbit system tests.

4.5.6 An OMS engine failure will require that the propellant in the failed pod be used in equal amounts with the operating pod.

4.5.7 Propellant in the OMS retention tanks will be available to the RCS engines for all onorbit conditions.

4.5.8 Loss of both OMS engines will require that the RCS deorbit propellant be obtained from both OMS tanks.

- 4.5.9 Sufficient OMS/RCS propellant will be provided to allow deorbit to a minimum delta-V entry target line if the propellant in one OMS tank is unavailable for use.
- 4.5.10 Where possible OMS propellants will be used as a ballasting agent for longitudinal and lateral c.g. requirements.

4.6 REACTION CONTROL SYSTEM

- 4.6.1 Unless otherwise specified, exoatmospheric attitude maneuvers will be budgeted at 0.5 deg/sec except for time-critical maneuvers, which will be budgeted at 1.0 deg/sec.
- 4.6.2 Forward RCS propellant tanks will be loaded full; aft RCS propellant tanks will be overfilled by using the OMS/RCS interconnect prelaunch.
- 4.6.3 Nominal and contingency RCS entry control allowance will be available in either aft RCS pod. However, maximum aft RCS propellant, consistent with mission objectives and c.g. considerations, will be maintained for entry-through-landing control.
- 4.6.4 Maneuver computations will be based on nominal engine performance.
- 4.6.5 For nominal mission operation, maximum steady-state firing duration for aft thrusters will be 150 seconds. For abort mission planning, the aft RCS thrusters will be used only for separation/evasive maneuvers and attitude control; the $\pm y$ forward RCS thrusters will be used for the onorbit dump, and the burn schedule is 50 seconds on and 40 seconds off. For contingency mission operation, the maximum steady-state firing for aft thrusters will be 500 seconds.

4.7 AUXILIARY POWER UNIT, ELECTRICAL POWER SYSTEM, AND ENVIRONMENTAL CONTROL LIFE SUPPORT SYSTEM

- 4.7.1 All nonpropulsive consumable tanks will be assumed to be fully loaded except the potable and wastewater tanks. The potable and wastewater tanks will be offloaded to allow for storage of prelaunch fuel cell powerplant product water, atmospheric revitalization system condensate, and crew waste products.
- 4.7.2 Four potable water tanks will be available for nominal onorbit cooling using the flash evaporator with the PLBD closed. Two additional potable water tanks and the wastewater tank can be used for additional cooling.
- 4.7.3 The APU's will be assumed to be turned on 3 minutes before deorbit ignition and will remain on throughout landing and rollout.
- 4.7.4 (Deleted)

- 4.7.5 For nonpropulsive consumables budgeting, the following contingencies will be considered:
- a. A 24-hour hold without reservice.
 - b. The worst case of the following:
 - (1) Cabin puncture
 - (2) One extravehicular activity
 - (3) Last deorbit opportunity on mission extension day
 - (4) One cabin repressurization
 - (5) Deorbit one rev late
- 4.7.6 The electrical power system analysis is based on the Orbiter electrical equipment utilization baseline.
- 4.7.7 The flash evaporators (hi-load and topping) will be turned on during ascent at 140 000 feet and will be turned off during descent at 85 000 feet. The ammonia boiler will be turned on at 120 000 feet during descent and will maintain cooling, being supplemented as necessary by the flash evaporators until 85 000 feet, until ground support equipment connect.

4.8 DESCENT - DEORBIT

- 4.8.1 The IMU alignment will be designed to minimize the IMU misalignment at the entry interface. To maintain system performance margins, the maximum platform misalignment at entry interface will be 950 arc-seconds. For a contingency where degraded system performance margins are necessary during entry, the maximum IMU misalignment at entry interface will be 1900 arc-seconds.
- 4.8.2 The deorbit maneuver will nominally be performed using two OMS engines, but due to targeting and guidance flexibility, the capability will exist to downmode to other thruster configurations during the burn. Specifically, the TIG and targets will be selected so that if one OMS engine fails at TIG (or any time later in the burn), the deorbit maneuver can be successfully completed using the remaining OMS engine. Furthermore, if the other OMS engine should also fail at the same time (or any time after the first failure), the deorbit maneuver could still be successfully completed using the +X RCS engines.
- 4.8.3 Propellant-critical contingency deorbit will be based on a shallower-than-nominal targeting criteria to provide the best compromise between deorbit capability, RCS propellant availability for attitude control during atmospheric descent, and entry thermal environment.
- 4.8.4 Between the termination of the deorbit maneuver (except ATO) and entry interface for two OMS, one OMS, and RCS modes that result from the triple-downmoding operation, a minimum free-fall time of 15 minutes is required for entry preparation.
- 4.8.5 In addition to satisfying the entry velocity, flightpath angle, and range requirements, the deorbit maneuver will include an out-of-plane component to achieve an acceptable Orbiter entry interface center of gravity and weight.
- 4.8.6 The Orbiter entry weight will be minimized by reducing remaining consumables (such as OMS and forward and aft RCS propellant, etc.) consistent with reasonable operations techniques.
- 4.8.7 When selecting the nominal deorbit revolution, it is highly desirable to have communication with and tracking of the spacecraft postdeorbit.
- 4.8.8 During descent, the Orbiter shall operate within the limits established in Structural Flight Restrictions for Orbital Flight Test Program (SD78-SH-0121).

4.9 DESCENT - ENTRY THROUGH ROLLOUT

- 4.9.1 The environment model used for computing the nominal OFP will be a mean monthly atmospheric model for the planned entry date as defined by the Four-D Global Reference Atmospheric Model. The environment model for the nominal profile simulation will not include winds.

- 4.9.2 The entry profile will be shaped to achieve a balance between the TPS surface and bondline temperatures and Orbiter structural temperatures such that the TPS performance during entry is optimized. This balance will include allowances for aerodynamic heating and trajectory dispersions.
- 4.9.3 (Deleted)
- 4.9.4 Entry-through-landing profiles will conform to control surface hinge moment limits, aerodynamic load limits, actuator rate limits, and structural load limits. For actual Orbiter weights for nominal end of mission, the structural load limits are +0.3 to 2g normal load factor between a Mach no. of 5.0 and an Earth-relative speed of 24 000 fps and -0.3 to 2.0g normal load factor for a Mach no. ≤ 5 .
- 4.9.5 Optimization of the entry profiles will include consideration of sonic boom ground-level overpressures.
- 4.9.6 Nominal entry profiles will be targeted so that post-blackout target changes are not required. However, the profiles will be shaped to maximize post-blackout redesignation capability.
- 4.9.7 It is highly desirable to achieve a longitudinal c.g. of 66.7 percent at Mach 3. This will be achieved using consumables management assuming propulsive and nonpropulsive consumables usage of 750 pounds and 212 pounds, respectively. In the event that this is not possible to achieve, the entry longitudinal c.g. will be ballasted such that it is no farther forward than 66.7 percent at entry interface. At Mach 3 the lateral c.g. displacement will be 0.0 inches, and the nominal vertical displacement will be 375 ± 3 inches.
- 4.9.8 The terminal area energy management (TAEM) guidance reference dynamic pressure will be based on the concept of flying directly to the heading alignment circle without employing an S-turn in tailwind conditions.
- Additionally, this dynamic pressure will allow the TAEM/approach and landing interface constraints to be met in the presence of severe headwinds. The energy control will provide conditions suitable for the initiation of a manual approach.
- 4.9.9 The TAEM profile will be compatible with manual and automatic modes of operation.
- 4.9.10 The descent profile will be shaped to conform with the following dynamic pressure constraints:

Mach	Dynamics pressure, psf	Constraint	Comment
$M > 5.0$	300	Structural	Constant
$5.0 \geq M \geq 3.0$	342	Flight control	Constant
$3.0 \geq M \geq 2.5$	342 - 270	Guidance/flight control	Linear ramp
$2.5 \geq M \geq 2.0$	270 - 240	Guidance/flight control	Linear ramp
$2.0 \geq M \geq 1.0$	240 - 220	Guidance/flight control	Linear ramp
$M > 1.0$	340	Guidance	Constant

- 4.9.11 To conform to compartment venting constraints, the maximum descent rate and dynamic pressure will be 400 fps and 300 psf, respectively, in the transonic region. In addition, the minimum dynamic pressure on the nominal profile will be 150 psf in this flight region.
- 4.9.12a The approach-and-landing profile will be shaped with a modified autoland guidance to approximate the manually flown flightpath. An autoland I-load that approximates the manual profile will be loaded onboard.
- 4.9.12b The approach-and-landing profile will be optimized for the STS-1 Orbiter eight with the steep glideslope as shallow as possible, consistent with dispersion margin requirements. The steep-and-shallow glideslopes will be 20 degrees and 1.5 degrees, respectively.
- 4.9.13 Two steep-glideslope intercept points will be used to accommodate winds on the final approach. The objective for one set will be to accommodate 20-percent tailwinds to 60-percent headwinds and the second will be to accommodate 40-percent to 100-percent headwinds.
- 4.9.14 After the first flare, at least 5 seconds of flying time will be provided between the time the pitch rate is less than 0.5 deg/sec and the initiation of final flare.
- 4.9.15 An energy reserve equivalent to approximately 4 seconds of flight time at nominal main-gear touchdown will be provided for the range of wind conditions used to design the approach-and-landing profile.
- 4.9.16 The normal load factor during the pullup from the steep glideslope to the shallow glideslope will be designed for an average value of less than 1.5g's.

- 4.9.17 The landing-gear deployment will be initiated at an equivalent airspeed (EAS) such that deployment will be completed 5 seconds before main-gear touchdown, with 9.4 seconds allowed for worst-case gear deployment time.
- 4.9.18 The body flap will be retracted to zero degree at approach-and-landing initiation and will remain in this position through rollout.
- 4.9.19 The nominal descent rate at main-gear touchdown will be approximately 2 fps.
- 4.9.20 Nominal touchdown speed will provide adequate pitch margins for structural clearance. The maximum groundspeed at main-gear touchdown will not exceed 218 knots. The nominal speed will be targeted for approximately 185 knots EAS.
- 4.9.21 The nominal landing point will be selected to optimize MSBLS coverage and ensure that the main-gear touchdown is beyond the runway threshold in the presence of dispersions. The shallow-glideslope aimpoint will be 1500 feet beyond the runway threshold for all landing sites for all nominal and abort conditions. Nominal main-gear touchdown will be approximately 3000 feet downrange from the runway threshold.
- 4.9.22 After touchdown, the derotation and load relief technique will limit the main-gear tire loads to less than 100 000 pounds per tire. In determining tire loads, a 60/40 percent proportioning of strut loads will be used, thus the maximum allowable strut load will be 166 667 pounds. After main-gear touchdown, the speedbrake will be commanded to 50 percent HRL (49.3°), and a pitch angle of 6 degrees will be held until the EAS has decreased to 165 knots. Then derotation at a pitch rate of approximately 3 deg/sec will be used to lower the nose gear to the runway. The elevons will be lowered to 10 degrees down deflection after nose-gear contact.
- 4.9.23 The pitch rate at nose gear contact will not exceed 9.4 deg/sec (11 ft/sec at the nose gear). The nominal rate will be approximately 3 deg/sec (3.5 ft/sec at the nose gear). The total radial load (steady state plus dynamic) on the nose-gear tires will be less than 45 000 pounds per tire.
- 4.9.24 Three seconds after nose-gear contact, moderate braking will be initiated to stop the Orbiter without exceeding the 36×10^6 foot-pound brake energy reuse limit.
- 4.9.25 Nose-wheel steering will not be engaged until the groundspeed is less than 110 knots.
- 4.9.26 The profile will be designed for a left-hand turn on the final approach.

4.10 ABORTS

4.10.1 General

- 4.10.1.1 At all points on the ascent profile, the Orbiter with one SSME-out will have an RTLS capability allowing for a 3-sigma low-ascent performance, or will have an AOA/ATO capability allowing for a 2-sigma low-ascent performance plus 95 percent abort wind dispersions, and a 5-minute launch hold.
- 4.10.1.1a An SSME-out for all intact aborts is considered to be a benign failure, and a shutdown of one SSME will not affect safe operation of the remaining SSME's.
- 4.10.1.2 Based on ground advice, the crew will manually select the abort mode. A 10-second delay from the abort condition to initiation of the abort sequence will be provided to allow for the abort mode decision process and abort selection.
- 4.10.1.3 (Deleted)
- 4.10.1.4 If a single SSME-out failure occurs during powered ascent, the remaining two SSME's will be automatically advanced to 100 percent, except during the throttledown-for-cutoff sequence.
- 4.10.1.5 Provided intact abort capability exists throughout launch, ascent shaping will include a three-SSME-out capability from lift-off to SRB staging plus 30 seconds.
- 4.10.1.6 For all RTLS, the pre-MECO OMS and RCS burn/dump sequence shall primarily be designed to achieve the desired Orbiter c.g. For all downrange intact aborts, AOA/ATO, performance critical aborts, and time-critical aborts there shall be no pre-MECO burn/dump OMS/RCS propellant sequences.
- 4.10.1.7 The required c.g.'s for atmospheric descent resulting from aborts will be the same as for the nominal end of mission. Longitudinal c.g. = 66.7 percent, lateral c.g. = zero inches, and vertical c.g. = 375 ± 3 inches.
- 4.10.1.8 The Orbiter weight for ATO, AOA, and RTLS atmospheric descent shall be minimized within systems and operational constraints and Orbiter performance capability.
- 4.10.1.9 Flight safety and systems performance margins will not be compromised during aborts to achieve flight test objectives.
- 4.10.1.10 (Deleted)
- 4.10.1.11 The nominal end of mission, ATO, and AOA have the same angle-of-attack profile during entry.

4.10.1.12 (Deleted)

- 4.10.1.13 For time-critical aborts from orbit, GG cooler must be utilized if deorbit occurs less than 3 hours from the APU shutdown. The APU restart must occur within 120 seconds after the GG cooler is used. It should be recognized that this is a one-time-only operation and should restart not take place in the prescribed time (2 minutes) then the full 3-hour cool down will be required.
- 4.10.1.14 Downrange aborts will incorporate a post-MECO forward RCS dump that significantly decreases the OMS ballast requirements.
- 4.10.1.15 To avoid contingency ditch, the shallow target line will be used for AOA. The perigee resulting from the OMS-1 burn shall be no lower than 55 n. mi., and the AOA shallow targets will accommodate this constraint.

4.10.2 RTLS

- 4.10.2.1 The RTLS profile is shaped for moderate maneuver rates, minimum loads, and maximum control margins.
- 4.10.2.2 OMS/main propulsion system (MPS) propellant burns or dumps are designed to achieve the required Orbiter entry longitudinal c.g. specifications and minimize the entry weight. Pre-MECO OMS/RCS burn schedules are planned for completion at least 6 seconds prior to the powered pitchdown maneuver for the latest RTLS abort. Post-MECO MPS LH₂ dump and LO₂ vent will not be initiated until after the RTLS ET separation maneuver and will be terminated by 100 000 feet altitude.
- 4.10.2.2a To protect for a second SSME going out late in RTLS where single engine intact completion is possible requires holding approximately 900 pounds of OMS propellant in reserve for single-engine roll control. This additional weight moves the GRTLS longitudinal c.g. approximately 2 inches aft of the planned nominal end of mission c.g. The weight and resulting c.g. conditions at TAEM interface are shown below:
- Weight = 201 113 pounds
 Xc.g. = 1100.5"
 Yc.g. = 0.0"
 Zc.g. = 373.5"
- 4.10.2.3 MECO target conditions (range velocity) are selected to maximize glide-ranging potential and will be based on the Orbiter maneuver capability to achieve the target in the presence of dispersions. The RTLS will be targeted to provide energy management capability during GRTLS without the use of S-turns. This will be accomplished by extending the distance between the heading alignment circle (HAC) for the nominal and minimum energy points so that HAC redesignation will provide

an effective energy management capability. The targeting will provide a minimum of 3σ performance margin from the maximum ranging capability.

- 4.10.2.4 For RTLS, the ET impact ellipse will be no closer than 25 n. mi. to any landmass. No ET impact will be allowed west of a line connecting the following points (including dispersions):

$$\begin{array}{ll} \phi_d = 30.000 \text{ deg N} & \lambda = 80.310 \text{ deg W} \\ \phi_d = 31.440 \text{ deg N} & \lambda = 79.895 \text{ deg W} \end{array}$$

- 4.10.2.5 Automatic guidance is the primary mode for RTLS. However, the profile will be shaped for benign flight conditions to enhance manual takeover, if required. However, the profile will be shaped for benign flight conditions to enhance manual takeover, if required. Note the RTLS profile, guidance displays, and MECO targets are only compatible with normal pitcharound to meet the required MECO and ET separation constraints (sec. 4.3.2.2), none of which are designed to accommodate manual takeover for early turnaround.

- 4.10.2.6 Single RCS jet failures will not preclude a successful RTLS. This includes failures during the second-stage c.g. management, ET separation, and GRTLS. RCS-to-RCS crossfeed will not be considered during mated coast and ET separation.

- 4.10.2.7 The SRB's will not impact west of a line connecting the following points (including dispersions):

$$\begin{array}{ll} \phi_D = 30^\circ \text{ N} & \lambda = 80.31^\circ \text{ W} \\ \phi_D = 31.44^\circ \text{ N} & \lambda = 79.895^\circ \text{ W} \end{array}$$

- 4.10.2.8 First-stage SSME-out

- a. The engine-out steering will be the same as nominal for
 - (1) Vertical rise
 - (2) Mach numbers between 1.05 and 1.6 (to maintain structural margins in the event of an engine-out during max q)
 - (3) The time after 15 seconds prior to normal SRB separation to ensure steady-state conditions at dispersed separation conditions
- b. The rate of change of pitch attitude between engine-out and nominal steering after Mach 1.6 will prevent q_a from going below -4100 psf degrees.
- c. The maximum delta pitch attitude will be 5 degrees.
- d. Engine-out steering is designed to center the trajectory in the squatcheloid at approximately $M = 1.05$.

- e. Only one engine-out is considered.
 - f. The alternate SRB trim gibal tables allow the SSME's to remain in their null position in mean-wind conditions.
- 4.10.2.9 The last RTLS abort will be determined as the last time an SSME can fail and still make a guided MECO allowing for -3σ ascent FPR (6000 pounds), a 5-minute launch hold, and 95-percentile adverse winds (includes the 10-second abort-mode decision delay).
- 4.10.2.9a For nominal planning of continuous intact abort coverage, the last RTLS abort will be determined as the last time an SSME can fail and still make a guided MECO allowing for a 5-minute launch hold and a 10-second decision delay, which is compatible with AOA ascent flight performance reserve (FPR) and 95-percentile winds.
- 4.10.2.9b The last RTLS abort time will be determined as the last time an RTLS can be guaranteed and still make a guided MECO, allowing for adverse 3-sigma ascent FPR, a 5-minute launch hold, 95-percentile adverse winds, and a 10-second decision delay.
- 4.10.3 PRTLS
- 4.10.3.1 The abort steering will be limited in the same manner as nominal ascent to avoid post-SRB separation heating problems.
- 4.10.3.2 The pitcharound pitch rate will be commanded to 10 deg/sec.
- 4.10.3.3 Postpitcharound SSME throttle will be 95 percent with throttle for weight control and weight target set for 1-percent MPS remaining at MECO for early aborts (prior to V_LATE). For late aborts (after V_LATE), postpitcharound SSME throttle will vary from 95 percent up to a maximum of 100 percent for the last abort point and with only 3σ FPR remaining. For three SSME aborts, the throttle will be 67 percent prepitcharound and 70 percent postpitcharound with a maximum of 3-percent MPS remaining at MECO.
- 4.10.3.4 Powered pitchdown will be extended to approximately 20 seconds. Then the pitchdown rate and acceleration commands will be selected for slosh control. The SSME's will be throttled to 65 percent, and at least 5 seconds of flight will be provided at final attitude and rate commands prior to MECO.
- 4.10.4 RTLS Orbiter/ET Separation
- 4.10.4.1 MECO target conditions will be adjusted to achieve (1) five psf separation dynamic pressure without dispersions, (2) less than 3 percent MPS propellant excess remaining in the ET at separation, and (3) a flightpath angle of zero degree at ET separation.

4.10.4.2 The ET separation attitude and rate nominal target conditions are listed below. These conditions have an acceptable envelope for separation design being defined by the tolerances about the nominal target conditions.

- a. Angle of attack = $-4^{\circ} \pm 2^{\circ}$
- b. Sideslip angle = $0^{\circ} \pm 2^{\circ}$
- c. Roll angle = no constraint
- d. Pitch rate = $-0.25^{\circ}/\text{sec} \pm 0.5^{\circ}/\text{sec}$
- e. Yaw rate = $0^{\circ}/\text{sec} \pm 0.5^{\circ}/\text{sec}$
- f. Roll rate = $0^{\circ}/\text{sec} \pm 1.25^{\circ}/\text{sec}$

4.10.4.3 ET separation will occur 13.8 seconds after the MECO command. ET separation is followed by a -Z translation maneuver that is terminated when at least 10 seconds have elapsed since separation and when the angle of attack α is greater than 10 degrees. ET separation will be automatically inhibited for up to 6 seconds if any of the following attitude or rate inhibits are exceeded.

- a. Angle of attack: $-4^{\circ} \begin{matrix} +2^{\circ} \\ -85^{\circ} \end{matrix}$
- b. Angle of sideslip: $0^{\circ} \pm 2^{\circ}$
- c. Roll angle: no inhibit
- d. Pitch rate: $-0.25 \text{ deg/sec} \begin{matrix} +0.5 \text{ deg/sec} \\ -4.75 \text{ deg/sec} \end{matrix}$
- e. Yaw rate: $0 \text{ deg/sec} \pm 0.5 \text{ deg/sec}$
- f. Roll rate: $0 \text{ deg/sec} \pm 5 \text{ deg/sec}$

4.10.5 GRTLS

4.10.5.1 The GRTLS profile will be shaped to achieve benign atmospheric entry conditions by minimizing the max q (<400 psf) and by optimizing the pullout angle of attack experienced during the load-relief phase.

4.10.5.2 The Orbiter attitude and rates at the end of the -Z RCS separation burn phase will be within the RCS-aero surface recovery limits. The GRTLS attitude and attitude rate control requirements at the end of the -Z translational burn phase are as follows:

<u>Axis</u>	<u>Angle</u>	<u>Angle limit</u>	<u>Rate</u>
Roll	Roll	$-30^\circ \leq \phi \leq 30^\circ$	$-2^\circ/\text{sec} \leq p \leq 2^\circ/\text{sec}$
Pitch	Angle of attack	$\alpha = 20^\circ \pm 10^\circ$	$2^\circ \pm 1^\circ/\text{sec}$
Yaw	Angle of sideslip	$-3^\circ \leq \beta \leq 3^\circ$	$-1^\circ/\text{sec} \leq r \leq 1^\circ/\text{sec}$

4.10.5.3 The angle of attack for the alpha recovery phase will be 50 degrees to optimize the pullout angle of attack, and the N_z command for the N_z hold phase will be 2.0g's to provide an approximate 0.5g margin from the design limit.

4.10.5.4 (Deleted)

4.10.5.5 Orbiter maneuver pitch rates during the alpha recovery phase will be limited to 2 deg/sec.

4.10.5.6 The environment model used for computing the nominal OFP will be a mean monthly atmospheric model for the planned entry date as defined by the Four-D Global Reference Atmospheric Model. The environment model for the nominal profile simulation will not include winds.

4.10.5.7 All approach and landing groundrules and constraints for the nominal entry apply to GRTLS. All entry groundrules except 4.9.1, 4.9.2, and 4.9.10 apply to GRTLS. Entry rule 4.9.4 applies with the exception that the maximum load factor will be 2.5g's for GRTLS. Entry rule 4.9.8 is applicable except that an S-turn is incorporated in the nominal profile to cover dispersions during open-loop guidance phases.

4.10.6 AOA/ATO

4.10.6.1 For AOA/ATO, continuous S-band telemetry and voice communication coverage are required for ascent through MECO plus 2 minutes.

4.10.6.2 The AOA/ATO guided MECO conditions will provide ET impact locations no closer than 200 n. mi. (including dispersions) to landmasses in the Indian Ocean.

4.10.6.3 For Orbiter/ET separation, all groundrules and constraints that apply to the nominal mission also apply to AOA and ATO.

4.10.6.4 For ATO, the intermediate orbit will be targeted for the circular orbit, which results in the minimum post-MECO ΔV requirements for a full duration alternate mission. For STS-1, this has been determined to be a 105-n. mi. orbit. This orbit altitude will subsequently be built up to a maximum of 150 n. mi. using any excess OMS propellant as determined by the Mission Control Center.

4.10.6.5 (Deleted)

- 4.10.6.6 For AOA and ATO, the post-MECO OMS/RCS maneuvers will satisfy specific velocity, flightpath angle, and range requirements at entry interface, and also achieve an acceptable Orbiter weight and longitudinal c.g.
- 4.10.6.7 (Deleted)
- 4.10.6.8 For nominal planning purposes, the downrange abort mode boundary is the earliest time at which a single SSME failure can occur with a successful AOA to the nominal AOA target line, assuming
- a. A 5-minute launch hold
 - b. A 95-percent abort wind dispersion
 - c. No pre-MECO OMS/RCS burns
 - d. Managers margin (3000 pounds MPS)
 - e. A -2σ abort ascent performance
 - f. A -3σ OMS dispersion allowance
 - g. An 80-fps navigation dispersion allowance
 - h. Common OMS-1 targets for AOA/ATO (apogee restriction of 105 n. mi.)
 - i. Up to 1800 pounds forward RCS dump between OMS-1 and OMS-2 to maintain the X c.g. at entry interface while lowering entry weight and providing additional OMS for performance.
 - j. Minimum altitude between OMS-1 and OMS-2 ignition restricted to 55 n. mi.
- 4.10.6.8a For all MECO underspeed conditions causing AOA/ATO aborts, a post-MECO forward RCS burn/dump will be utilized between OMS-1 and OMS-2 for AOA and prior to the deorbit burn for ATO.
- 4.10.6.8b For planning purposes, the AOA shallow target set will be designed for an underspeed capability assuming
- a. Nominal day for systems and environment
 - b. No TIG slip
 - c. No y_{cg} ballast
 - d. An RCS burn of 1500 pounds to complete OMS-2
 - e. Alpha management to maintain alpha between $+20$ degrees from OMS-1 burnout to OMS-2 TIG minus 10 minutes
 - f. Minimum geodetic altitude of 55 n. mi.
- 4.10.6.9 For an AOA, the APU's will be on from prelaunch through MPS dump. The APU's will then be put in the depress mode until 300 000 feet. The systems will then be pressurized and remain so through stoproll. If one or more systems are failed, the remaining APU(s) will be placed in hi-speed prior to TAEM.
- 4.10.6.10 All descent-deorbit and descent-entry through rollout groundrules and constraints will be used for AOA entry profiles, except that the balance between surface and bondline temperatures will be biased to maintain the surface temperatures at the expense of higher bondline temperatures.

4.10.7 Contingency Abort

4.10.7.1 General

- 4.10.7.1.1 Unrelated failures beyond those causing the contingency situation will not be addressed.
- 4.10.7.1.2 SRB and ET impact ellipses should not be closer than 25 n. mi. to any land mass, whenever possible.
- 4.10.7.1.3 If two SSME's fail, the throttle of the remaining SSME is to be set to 100 percent (the maximum setting recommended to ensure continued operation). The remaining SSME is throttled to 65 percent at powered pitchdown.
- 4.10.7.1.4 Maximum loads and load factors during contingency aborts could stress the Orbiter to the structural load limit; i.e., operational but not reusable.
- 4.10.7.1.5 Contingency abort analyses shall be based on nominal aerodynamic data and nominal aerodynamic heating.

4.10.7.2 First Stage

- 4.10.7.2.1 Contingency abort trajectory design will endeavor to maintain structural loads within ultimate values (factor of safety = 1.0) for failure of two or three SSME's at any time.
 - 4.10.7.2.2 Should more than one SSME shutdown occurs in the first stage, and providing that the roll program has been completed, the CSS mode should be selected and followed by a "hands-off" procedure that allows auto-load relief to ensure load limiting and the required low q during control of SRB tail-off.
 - 4.10.7.2.3 The ejection seat is a survival path option up to an altitude of 120 000 feet, with increased risk of heating and instability problems above 100 000 feet. This survival path is subject to a self-induced fireball hazard due to the subsequent vehicle tumbling and ET rupture. This is in addition to SSME plume problems if the SSME's are not shut down.
 - 4.10.7.2.3b Single-engine powered pitchdown will be performed at a pitch rate of 5 deg/sec until an angle of attack of approximately zero degree (null angle of attack and sideslip to ± 5 deg), at which time a fast ET separation sequence will be initiated (auto MECO) to try to achieve separation before exceeding a dynamic pressure of 2 psf.
 - 4.10.7.2.4 One-sigma rather than three-sigma SRB tail-off thrust mismatch will be used.
- 4.10.7.3 (Deleted)

4.10.7.3.1 (Moved to 4.10.7.2.4)

4.10.7.3.2 (Deleted)

4.10.7.4 Second Stage

4.10.7.4.1 Manual control is the primary mode following the loss of two or three SSME's.

4.10.7.4.2 Single-engine burns will be used to minimize the maximum entry dynamic pressure. Nominal and intact abort OFT trajectories that exceed the 800-psf boundary defined in terms of instantaneous apogee altitude and velocity may have a contingency abort gap for failure of all three SSME's.

4.10.7.4.3 If two SSME's fail or are shut down, the Orbiter/ET will be manually controlled (aided by autopilot RCS roll control using OMS propellant) to a canned attitude sequence, as a function of initial conditions, to achieve a MECO where a safe ET separation and Orbiter entry can be achieved.

4.10.7.4.4 Maneuver rates under single-SSME control will be limited to 5 deg/sec in pitch and roll and 1 deg/sec in yaw.

4.10.7.4.5 Pre-MECO dumping of OMS propellant is performed by burning the OMS and aft RCS engines. These burns are initiated by item entry and can be terminated at propellant depletion, MECO, or item entry. The burns will automatically be reinitiated post-MECO (MM 602 only) if burn/dump and terminated automatically (propellant depletion or g's) or manually by item entry.

4.10.7.5 ET Separation

ET separation for 2-SSME failure will utilize the fast separation sequence (3 seconds, MM 601). The ET separation for 3-SSME failures will utilize the nominal sequence (16 seconds) when in MM 103 and the RTLS (12 seconds), or fast separation (3 seconds), when in MM 601. Dynamic pressure will be less than or equal to 2 psf, and attitude and attitude rates are the same as nominal. ET propellant remaining up to 100 percent is acceptable for separation.

4.10.7.6 Descent - Recovery, Load Relief, and Glide

4.10.7.6.1 An RTLS abort must be selected in order to provide the necessary software for recovery, load relief, and glide. If initiated from an ATO or AOA mission, the RTLS mode must be selected after the post-ET separation -Z translation maneuver phase and before OMS-1 ignition.

4.10.7.6.2 Recovery angle of attack (currently 50 degrees) shall be selected to minimize the maximum entry dynamic pressure and to allow adequate control.

- 4.10.7.6.3 The load-relief phase normal acceleration (N_z) command will not violate the maximum structural load that the Orbiter can endure and continue to function until ditching/ejection. The maximum load currently being used is 635 075 pounds for a factor of safety = 1.0.
- 4.10.7.6.4 If required, an OMS/RCS burn schedule is planned to dump propellants to achieve an acceptable entry longitudinal c.g. and to minimize Orbiter entry weight.
- 4.10.7.6.5 (Deleted)
- 4.10.7.6.6 RCS burns using OMS propellant must be terminated before a normal acceleration of 0.05 g's. OMS burns can be continued to depletion, and RCS (4 + X) burns using RCS propellant must be terminated before entry redlines are violated.
- 4.10.7.6.7 MPS onorbit LOX dump will be initiated at post-MECO OMS ignition and will be stopped at OMS cutoff and then switched to the RTLS MPS dump/vent sequence.
- 4.10.7.6.8 The Orbiter will be manually flown to a benign glide profile after pullout.
- 4.10.7.7 Post-MECO

If an ATO has been selected pre-MECO and another SSME fails, an AOA may be selected via the abort switch after the post-ET separation -Z translation maneuver phase and prior to the first OMS burn for intact abort capability and quick return. (This capability is highly dependent on the timing of the engine failures.) To facilitate downrange ditching, in some cases, RTLS must be selected no later than OMS-1 ignition.

5.0 REFERENCES

1. Space Transportation System Flight Requirement Document: Space Shuttle Orbital Flight Test (STS-1), JSC-10780, Basic, Rev. C, May 10, 1979.
2. Shuttle Master Verification Plan - Master Flight Test Assignment Document, Vol. X, JSC-07700.
3. Shuttle Operational Data Book, Vol. 1, rev. A; Vol. 2, Amendment 28, JSC-08934.
4. U.S. Naval Observatory: The American Ephemeris and Nautical Almanac for the Year 1980. U.S. Government Printing Office, 1978.

APPENDIX A
INITIALIZATION DATA FOR THE
OPERATIONAL FLIGHT PROFILE
CYCLE 3

TBD

APPENDIX B

SUMMARY OF DEVIATIONS FROM SHUTTLE MASTER VERIFICATION
PLAN (VOLUME X) AND SHUTTLE OPERATIONAL DATA BOOK

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