annual report to the nasa administrator by the aerospace safety advisory panel on the space shuttle program

part II—summary of information

ALT flight readiness

OFT development status

march 1977

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ERRATA FOR VOLUME II of the Annual Report

PAGE NO.	ERRATA
23 7th line from bottom	add letter "g" to "-raphitar"
24 2nd line below "4."	add words "control for the"
30 4th line from bottom	add the letter "t" to "constrain-"
38 2nd line from bottom	add the letter "m" to "fro-"
74 3rd line from bottom	"abondanment" should be "abandonment"
95 11th line from the top	add the word "The" before "----data base..."
216 1st line in "Introduction"	the word "just" is replaced by "first"
220 3rd line from the top	remove the letter "n" from the word "ration"

ANNUAL REPORT TO THE NASA ADMINISTRATOR

by the

AEROSPACE SAFETY ADVISORY PANEL

on the

SPACE SHUTTLE PROGRAM

Part II - Summary of Information Developed in the Panel's Fact-Finding Activities

March 1977

CONTENTS

I. INTRODUCTION

The Panel focused its attention this past year on those areas we consider most significant for flight success and safety. Thus the Panel focused on the elements required for the Approach and Landing Test Program (ALT), the Orbital Flight Test Program (OFT), and those management systems and their implementation which directly affect safety, reliability and quality control.

To manage our limited manpower effectively in terms of our priorities, we have organized our ten members and consultants into task teams for specific areas of ALT and OFT.

The number of individual fact-finding sessions conducted by the individual Panel members and by larger groups within the Panel averages four or five a month. Such fact-finding is conducted principally at NASA sites and at contractor and subcontractor plants, and as appropriate with other government agencies such as the United States Air Force.

In the process of fact-finding and inspection, the Panel has reviewed considerable detail which is summarized here so the reader can understand the data base upon which Volume I is based. This data base includes doumentation reviewed in preparation for review as well as the questions and answers of the reviews themselves. Because the Panel review is on-going, special addendums are incorporated in each section to assure the reader has the most update material upon which to evaluate the current posture of the program and its elements.

The task teams and their objectives are outlined here.

A. Approach and Landing Test Program (ALT)

1. Management System for Mission Planning

The objectives of our reviews in this area is to assess the degree to which:

a. The program management system has defined a set of mission rules that provide a reasonable basis for confidence that the normal flight plan can be successfully executed.

b. The flight planning process has used a conservative approach in planning the nominal mission and providing for contingency and abort situations including emergency separation and jettison.

2. Management Systems for Certification of the Flight Vehicles

The objectives of our reviews in this area are to assess the degree to which:

a. Both vehicles are being subjected to a rigorous system of reviews to assure they will meet mission certification requirements.

b. There has been a satisfactory program of test and analysis to assess the mated configuration in terms of mated aerodynamics, performance and flight controls or to their effect on structures and pilot control.

3. Management System for Certification of the Avionics System

Because of the significance of this system, one of our members dedicates his efforts to monitoring the development of the hardware and software and their integration into a flight system.

4. Management System for Facilities, Communications and Ground Support Equipment.

The objective of our review is to assess whether the test and simulation program appears to be adequate to demonstrate the ability and reliability of each of these elements to support the mission requirements.

5. Management System for Risk Assessment

The objective of our review is to assess the system for the preparation of the ALT Project Mission Safety Assessment Report and management's review of the risks being accepted for these flights.

A second objective is to assess the configuration management system which should assure that the hardware as built is the same as the design on which risk assessments are based.

B. Orbital Flight Test Program (OFT)

The major elements that are not being tested on ALT are the Main Engine, External Tank, Solid Rocket Booster and Orbiter Thermal Protection System. Because of the significance of these elements for the success and safety of OFT we have dedicated member monitoring and evaluating their development and manufacture.

1. Space Shuttle Main Engine (SSME)

The dedicated member monitors both component and all-up engine development testing and the resolution of specific high-risk problems as they arise. The objective of our review is to assure that the management system is developing an adequate basis for flight certification. The interaction of the engine with the Orbiter, External Tank and Solid Rocket Booster is also considered.

2. External Tank

The purpose of the review here is to consider those areas that might cause the OFT and operational flights to be below nominal expectations. Areas that receive attention include the structural adequacy of the tank, the external insulation and its ability to support the SSME operation and Orbiter/ET separation. Reviews also focus on the tests such as the Main Propulsion Test and Ground Vibration Test.

3. Solid Rocket Booster

Since the objectives of the reviews in this area are to assess the reliability of these critical elements, particular attention is given to the launch and ascent, structural integrity of the Solid Rocket Motor, adequate/reliable performance from the APU's and the thrust vector control system. Since these units are subjected to repeated use, the Panel also focuses on the systems for recovery and refurbishment.

4. Orbiter Thermal Protection System (TPS)

The significance of this new method of protecting vehicles during return from earth orbit prompted the Panel to assign this area to a dedicated member. The objective of our review is to assure that the TPS meets the aerothermodynamic requirements to assure that a safe return is accomplished. This includes an examination of the management, test programs, installation and maintenance activities, and the interface effects between TPS and other Shuttle elements.

II. THE APPROACH AND LANDING TEST PROGRAM

A. Introduction

The Approach and Landing Test Project (ALT) is scheduled to begin February 18, 1977. It is now scheduled for completion in time for the Orbiter to be delivered to MSFC by March 17, 1978 for use in the Shuttle vehicle ground vibration test program.

The purpose of this section of the report is to provide an introduction to the management system. This then provides the lead-in for the following sections of the report covering the flight and ground hardware/software and facilities.

B. Observations

1. ALT Documentation and Utilization

The ALT program is considered a Level III or "project" element of the Shuttle program but it combines the Orbiter, the Shuttle Carrier Aircraft and numerous ground facilities and GSE. Therefore, a number of Level II requirements must be applied to the management and flight associated with the ALT work. Some major items are noted below:

a. "Program Structure and Responsibilities," Volume II, JSC 07700, October 21, 1976. This document defines the overall program in terms of organizational and work breakdown structure and describes the responsibilities of the major program participants. All the Space Shuttle Program Directives issued by Level II are listed. Many of these have a direct bearing on the ALT Program, e.g., (1) #1A "Space Shuttle Program Simulation Planning," (2) #21 "Space Shuttle Program

Flight Test Program Panel," (3) #66 "Space Shuttle Program ALT Flight Techniques Panel" issued June 23, 1976.

b. "Shuttle Master Verification Plan," Volumes I and II, JSC 07700-10-MVP-01 Rev. A. This detailed plan covers the ALT program, establishes and documents the approach, requirements and plans for verification of the Shuttle system for operational use.

c. "Flight Test Requirements," Volume I and II, JSC-08943 which cover: Volume I - Shuttle Carrier Aircraft, and Volume II - Orbiter Approach and Landing. Volume I has the flight test requirements necessary for the qualification of the NASA 747 (N905NA) aircraft as an air launch platform for the Shuttle Orbiter Approach and Landing Test program. This volume also includes the verification requirements for the qualification of the 747 as a long-range ferry carrier. Volume II has the flight test requirements necessary to verify the free-flight subsonic airworthiness of the Orbiter and the pilot-guided and an automatic systems approach and landing capability.

d. "Approach and Landing Test Mission Objectives Document," JSC 09918, dated September 30, 1976. This document establishes the number and sequence of flight tests to be conducted during the ALT program and includes basic objectives and flight test activities for each test.

e. Management of the ALT process and operations is described in a system of specific directives and instructions:

(1) The objectives and scope of Approach and Landing Test Program Directives (APD's) can best be described by a quote from APD

No. 001 (Rev. 1), dated November 2, 1976. "A system of ALT directives is established for providing management direction from the ALT Manager to the NASA and contractor elements involved in ALT. APD's and Management Instructions (MI's) will be issued to supersede those parts of the ALT Project Management Plan and the Ground Operations Management Plan which no longer apply."

(2) ALT Management Instructions document procedures and agreements between two or more ALT elements which have been approved by the ALT Manager. They address the operational matters involving internal and external organizational interface requirements, the procedural requirements in effect, and the duties and responsibilities of the organizations involved. Almost sixty (60) have been published.

2. The Flight Techniques Panel (FTP)

This Level II operation was established under authority of Program Directive No. 66 issued June 23, 1976. This panel provides a forum to coordinate the efforts of those involved in the development of flight techniques for trajectory, attitude control, and avionics systems management. The FTP is now a part of Flight Director's Reviews.

One of the more interesting products of this group is a set of memoranda called "ALT Flight Technique Briefs" to support the development of flight mission rules and the flight data file. These widely distributed briefs deal with very specific ALT issues where there should be a clear and common understanding among all those involved on the ALT work or where additional work is requred that must be handled in an expeditious manner. Each contains background, specific techniques, and any open issues that may exist at the time. ALT Flight Techniques Brief #1 on "APU Consumables Management" is described in Table II-I as an example.

The Panel was particularly interested in such topics as:

a. Since tailcone-off flight control system limits are loaded into the computer memory (called I-load requirements), the Panel seeks to assure that the values of I-load are compatible with the planned inflight flight control system checks and with the Flight Test Requirements.

b. The degree to which the mated or Orbiter aero data bases should be updated between ALT flights is under review. An area of interest is the determination of the size of an effort to validate and update a selected subset of parameters or candidate list of parameters, and the form in which the data would be required, as well as the minimum turn-around time that it would take.

c. The Panel's reviews considered the methods for ground/flight crew confirmation of separation, mated performance penalty variations with atmospheric temperature conditions, the flutter envelope for the Orbiter with no hydraulic power restraining the control surfaces, ALT weights and c.g.'s.

3. Flight Profiles

The individual ALT flights are being meticulously planned in every known detail to assure the greatest return while conducting the missions under the safest of conditions. An example of the ALT mission calculations is shown in the "sample" sheet designated as

Table II-II. A sample of the ALT Free Flight Profiles and timelines is shown in Figures II-1 and 2.

4. ALT Review System

The procedures for certifying the flight and ground equipment and personnel for the ALT missions follows the basic system used on prior manned programs. Modifications have been made to meet the specific requirements of this flight program. The major review system includes the Design Certification and the Flight Readiness Reviews. In each case the work goes on for many months and culminates in a series of formal "board" meetings at higher and higher levels of management. In addition to these certification reviews the Orbiter systems have been going through an extensive test program and the results have been monitored and evaluated through a series of Customer Acceptance Readiness Reviews or Configuration Acceptance Reviews.

The ALT Design Certification Review had two phases. The first phase consisted of a project Center level review in November. The second phase provided a report to a senior Space Flight Management Board chaired by the Associate Administrator for the Office of Space Flight. This was conducted on December 9-10, 1976 at JSC. The early February ALT Flight Readiness Review (FRR) will provide management another opportunity to assess the readiness of the "as built" hardware/software for the first ALT mission. There will be subsequent FRR's for such major milestones as the first captive flight (February 1977), first manned captive flight (May 1977), first approach and landing mission (July 1977), and the first flight with tail-cone off (November 1977).

Since all of the review effort is directed toward flight readiness, it is worthwhile to indicate what the FRR is expected to accomplish in terms of (1) what the FRR should answer, (2) who must assess and certify readiness, and (3) the areas of review.

What the FRR Should Answer

(1) Has all applicable hardware and software been verified ready for the next ALT flight phase?

(2) What problems have been encountered since the previous review and what are the remedial actions being taken, and will they accomplish the job?

(3) Are the flight crews and flight control teams ready to conduct the mission from the viewpoint of nominal and possible off-nominal conditions?

(4) Are the ground support teams prepared and ready?

(5) At the "L-2" (launch day is "L") meeting, what are the remaining actions to be taken prior to actual flight?

Who Is To Make The Assessment and Certification

Usually the same organizations that have accomplished the Design Certification Review in a two phase review just as the DCR.

Review Areas

All those covered by the Design Certification Review plus the operational readiness of the flight crews, flight control teams and the ground support teams.

5. NASA Acceptance of Orbiter 101

As noted before, the ALT missions are scheduled for completion in time to meet the scheduled movement of the Orbiter to MSFC for major test programs there. Such movement requires a formal NASA acceptance decision transferring the vehicle from contractor ownership to NASA ownership, the form used is designated as Form DD-250. The uniqueness of the reuse of the Shuttle Orbiter leads to a somewhat different arrangement than that used on past space programs and is worth noting.

(1) Rockwell International, the contractor, is responsible for the Orbiter 101 until the ALT program is completed. Thus the DD-250 accepting the Orbiter as NASA property will occur at DFRC at the end of 1977 or the first month of 1978.

(2) The Orbiter would then be returned to Rockwell International as Government Furnished Property (GFP) so that they may accomplish those modifications needed to meet the requirements of the MSFC test programs (Vibration type tests).

(3) Upon completion of the MSFC test program the Orbiter 101 will be returned to Palmdale for, as GFP, for modification to the operational configuration. This then will be delivered to DFCR for delivery to KSC. NASA then accepts the modifications to its GFP.

(4) On the other hand the Orbiter 102, to be used on the OFT flights, will be formally accepted by NASA, with proper DD-250 forms, when it is ready to leave Palmdale to go to DFRC. It will then be transferred to KSC by means of the 747-ferry aircraft.

This method of control should reduce the paperwork to a minimum and allow for more complete and timely configuration control.

TABLE II-I

ALT FLIGHT TECHNIQUES BRIEF #1

APU CONSUMABLES MANAGEMENT

BACKGROUND

The baseline APU management plan is designed to keep a minimum of two APU's running in the pressurized mode (3000 psia) from takeoff -11 minutes through rollout, and for all three systems to be in the pressurized mode for critical periods of mated flight and throughout free flight. This keeps fuel consumption at a minimum, while providing sufficient safeguards against flutter and the potential structural problems it can produce. Running three systems continuously is the desired mode of operation, but current fuel consumption data indicates that this may not always be practical. A minimum of two systems will be pressurized at all times due to the fast flutter onset following the loss of the last hydraulic system in the high pressure mode. Two systems operating in the depressurized mode (500-1000 psia) will not be relied upon to prevent flutter. While flying with two systems pressurized and one off, the crew will respond to a failure of one of the active systems by commanding on the third system.

The time required for the APU to come up to speed and bring its hydraulic system to full pressure is two to three seconds. Three switches must be thrown, the fuel tank valve to open, the hydraulic pump pressure switch to LOW, and the APU control switch to START/RUN for an APU to be brought on-line. The APU heater switches will be in auto and the controller power switch ON even when an APU is off line. Once the APU has started, the hydraulic pump pressure switch will be set to NORMAL. Hot starts represent no problem if the catalytic bed is maintained at operating temperatures.

For real time planning purposes, it should be noted that the APU's burn approximately 2.30 lbm/min or 138 lbm/hr. Each of the three tanks contains 295 lbm, including an unusable plus uncertainty of 30.5 lbm. This equates to a run time of approximately 115 minutes for each APU. Since there is no crossfeed between the three hydrazine tanks, the APU's must be operated alternately to achieve the maximum duration two system capability. It must be stressed that these numbers are functions of many variables not yet completely determined (i.e., altitude profile, hydraulic pump efficiency) and will be updated as hardware testing and mission planning continue.

Three acceptable techniques have been identified for managing APU fuel. Plan A (see enclosure 1) involves switching the three systems on and off to approximately balance their operations and cause all three to reach the fuel redline (unusable + uncertainty) at the same time. Plan B (enclosure 2) involves depleting system 2 or 3 down to the redline (30.5 lbm) level and completing the mission on the remaining system (2 or 3) and system 1. Plan B will support a longer mission since the maximum return allocation for the depleted system can now be in effect distributed between the remaining two systems. Plan C is the straightforward technique of powering up all three systems for the entire mission. When the final APU hardware data and mission profiles are acquired, a decision will be made as to which plan to use for each flight. Plan C is the most preferable approach and Plan A is the second choice. The most preferable plan that will support the normal mission duration plus a 20-minute contingency will be selected on an individual flight basis.

SPECIFIC TECHNIQUES

In Plan A (see enclosure 1) system 1 is left off initially and the longest of all three, since it is the most heavily loaded and, therefore, runs out of fuel the fastest. It is then alternated with system 2 until approximately five minutes prior to pitchover when all three systems are turned on. All three systems are left on until the abort maneuver is complete or until three minutes after touchdown if a separation is performed. If an abort is performed, system 3 is turned off after the abort pull-up and sequencing continues until five minutes prior to the next pitchover. Assuming the enclosure 1 timeline is followed, Plan A as described will cause the switching valves to be cycled 16 times during a flight.

Plan B (see enclosure 2) involves depleting system 2 or 3 by running it continuously until it reaches the unusable + uncertainty level. The other two systems are alternated as necessary to keep their fuel reserve balanced and to have all three running for separation attempts and/or free flights. The fuel normally brought home in one system is distributed between the other two and thus a longer duation is achieved at the cost of a slight reduction in failure tolerance. Assuming the enclosure 2 scheme is followed, the switching valves will be cycled 17 times.

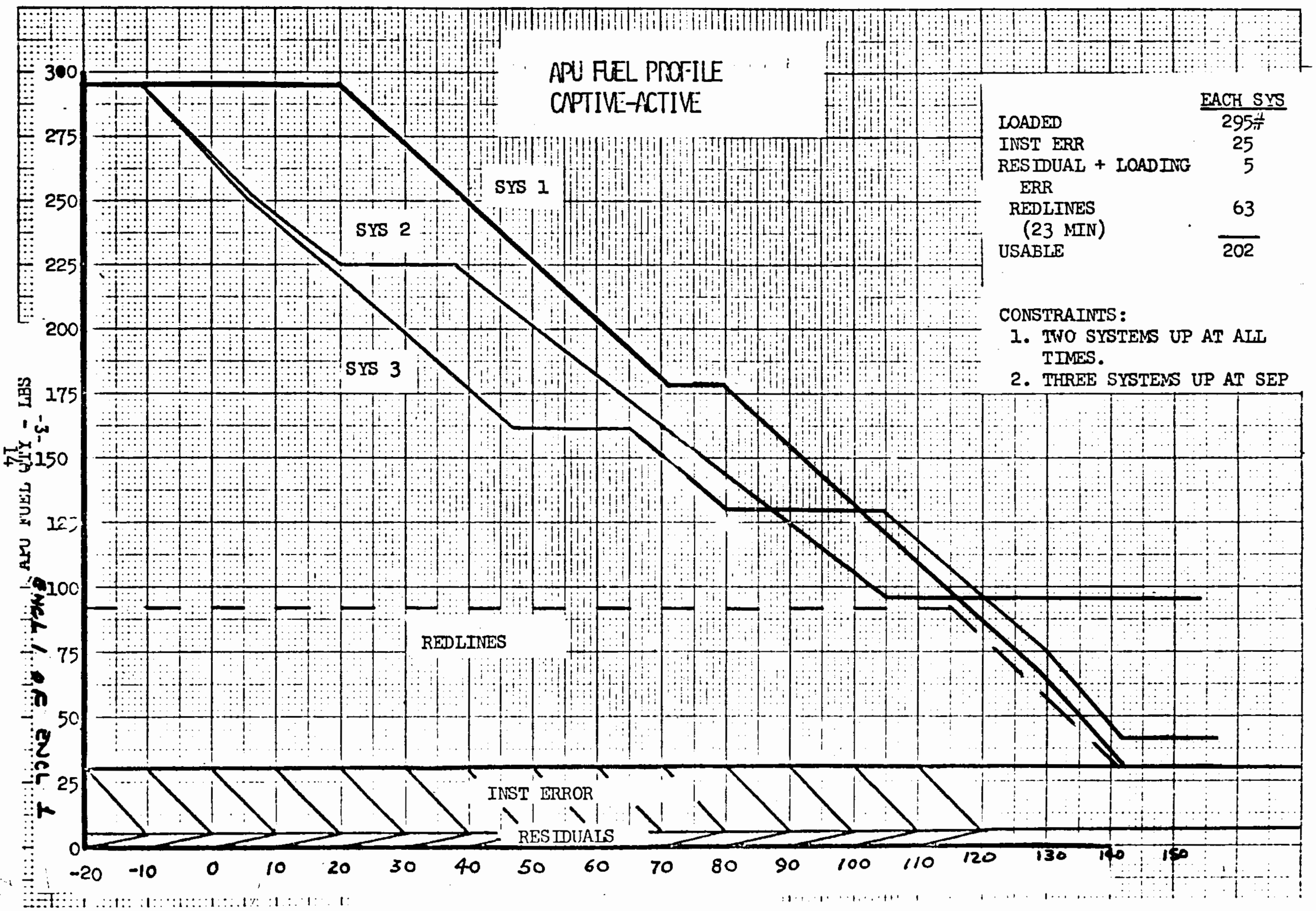
Using current specific fuel consumption data plans A, B, and C can support 142, 160 and 105 minute APU missions respectively. Current mission durations (APU) vary between 107 and 123 minutes (20-minute reserve included).

OPEN ISSUES

- Rockwell is studying a potential problem concerning cold hydraulic fluid in the lines to the actuators. There is some potential that each system will have to be flowed for a period of time prior to SCA takeoff and that an APU management plan that calls for a system to be powered down in flight would also carry a minimum flow cycle requirement to preclude cold spots in the loop.

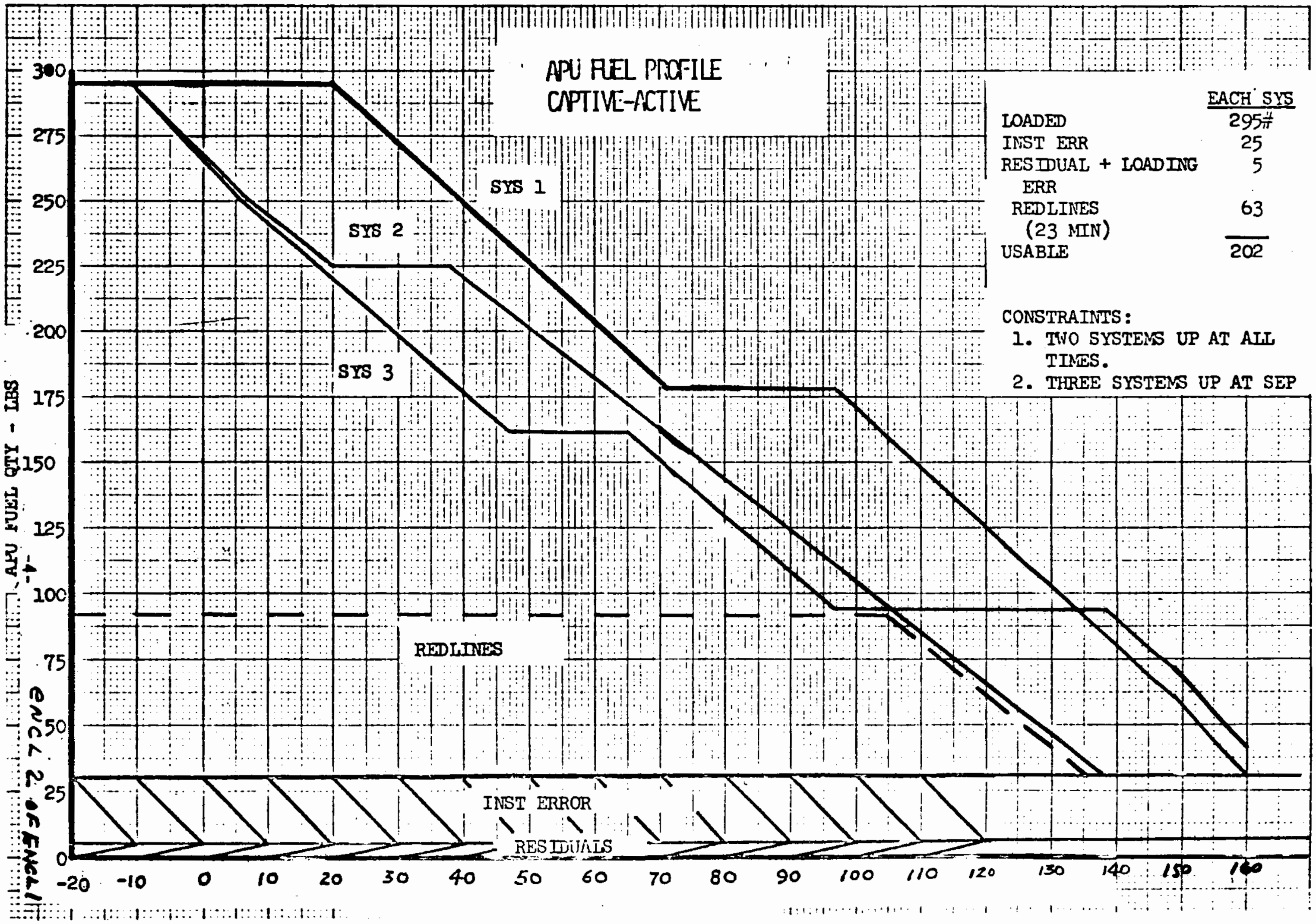
PLAN A

FIGURE FOR ENCLOSURE, TABLE II-I



SET - III - 14
-3-
ENCL 1 / #6 ENCL 1

PLAN B FIGURE FOR TABLE II-I



encl 2 of Encl 1

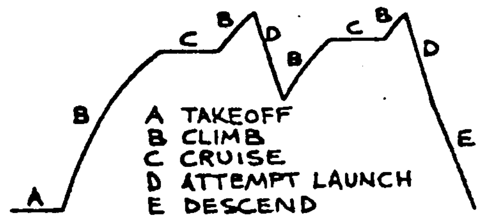
TABLE II-II

SAMPLE A.L.T. MISSION CALCULATION, DOUBLE LAUNCH ATTEMPT

JT9D-7AH Engines

Tailcone On

TAKEOFF WT.	558,912 LB
ZERO FUEL WT. AT LANDING	484,400 LB
CRB WEIGHT AT LANDING	150,000 LB
FUEL LOAD	73,700 LB
TEMPERATURE	Standard Day
FIELD ELEVATION	2,300 FT
ORBITER INCIDENCE	6°

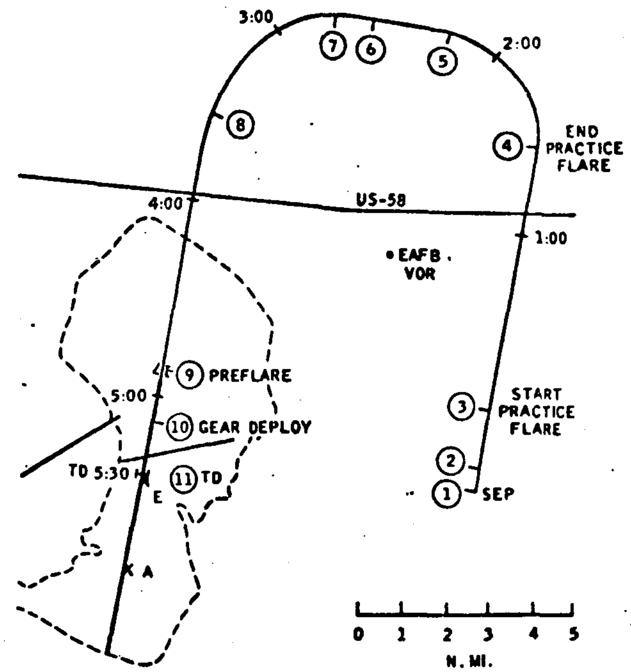


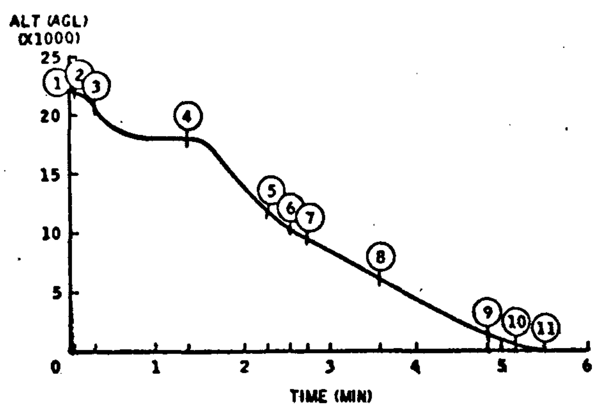
MISSION SEGMENT	FUEL BURNED (LB)	WEIGHT AT END OF SEGMENT* (LB)	ALTITUDE AT END OF SEGMENT (FT)	TIME (MIN)	DIST (NM)
TAKEOFF ALLOWANCE	3,500	554,600	3,800	21.0	0
CLIMB TO 200 FPM CEILING	18,200	536,400	25,600	26.2	125
CRUISE (15 min @ M .48)	7,500	528,900	25,600	15.0	75
CLIMB TO 200 FPM CEILING @ SPECIAL RATING	5,100	523,800	28,000	8.3	40
LAUNCH ATTEMPT	500	523,300	19,000	2.0	10
CLIMB TO 200 FPM CEILING	8,800	514,500	26,600	15.0	70
CRUISE (15 min @ M .48)	7,000	507,500	26,600	15.0	75
CLIMB TO 200 FPM CEILING @ SPECIAL RATING	4,800	502,700	29,200	8.4	45
LAUNCH ATTEMPT	500	502,200	19,000	2.0	10
DESCENT	700	501,500	2,300	6.3	30
TOTALS	56,600			119.2	480
RESERVES					
1/2 HR HOLD	13,400	488,100			
5% of INITIAL FUEL	3,700	484,400			

* EXCLUDES ORBITER CONSUMABLES OF 812 LB WHICH ARE INCLUDED IN TAKEOFF WEIGHT ONLY.

ALT FREE FLIGHT 1

ITEM	TIME	ALT (AGL)	KEAS	α	θ	ACTION
1	0:00	22100	260	10	.5	SEP; $\dot{\theta}$ = 2°/SEC, 3 SEC; $\dot{\theta}$ = 0, 2 SEC
2	0:05	21900	250	7	6.5	ROLL RIGHT ϕ = 20°; $\dot{\theta}$ = -1°/SEC AT θ = -5° ROLL ϕ = 0; CONTINUE $\dot{\theta}$ = -1°/SEC TO θ = -10
3	0:18	20400	270	6	-10	AT AS = 270 INITIATE PRACTICE FLARE $\dot{\theta}$ = 2°/SEC; CONTINUE FLARE TO HOLD $\dot{h}$ = 0, AS = 185
4	1:25	17900	185	11	11	AT AS = 185 $\dot{\theta}$ = -1°/SEC TO θ = -6°; ROLL LEFT TO ϕ = 30°
5	2:15	12000	240	8	-6	AT ψ = 265° ROLL TO ϕ = 0
6	2:35	10000	265	6	-6	AT AS = 265 $\dot{\theta}$ = 1°/SEC TO θ = -2 TO HOLD AS = 270
7	2:45	9300	270	5	-2	ROLL LEFT TO ϕ = 30° TO LINE UP ON RUNWAY ψ = 175°
8	3:35	6000	270	5	-2	TURN COMPLETE HOLD AS = 270
9	4:55	900	270	5	-2	INITIATE PREFLARE
10	5:10	350	250	6	4	AT AS = 250, DEPLOY GEAR
11	5:30	0	175	11	11	T.D. AS < 220; $\dot{h}$ < 10 fps
12	5:45	0	100	--	--	AT AS = 100, GENTLE BRAKING TO AS = 80
13	6:00	0	50	--	--	AT AS = 50, ENGAGE NWS





WT = 150,000

CG = 64.5 % (1070.24)

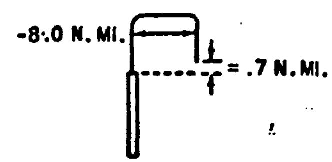
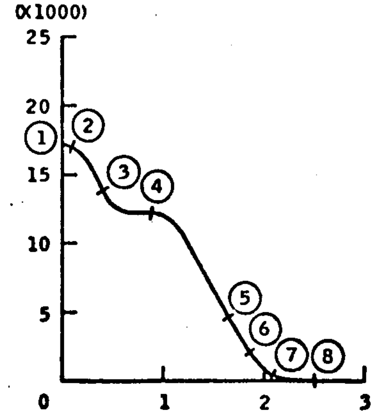
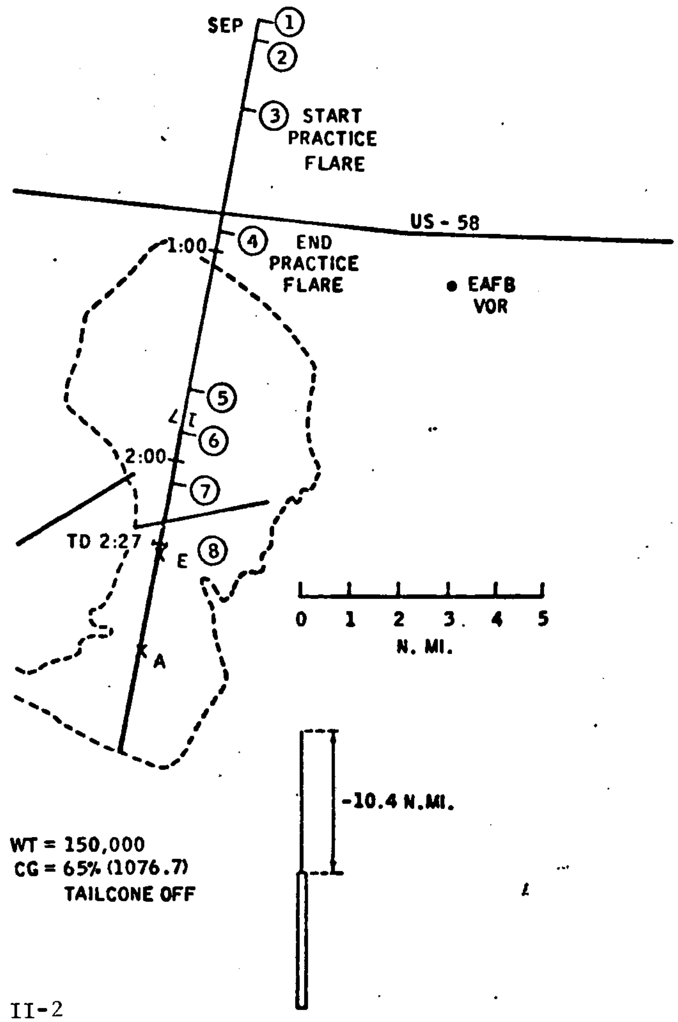


FIGURE II-1

ALT FREE FLIGHT 6

ITEM	TIME	ALT (AGL)	KEAS	α	θ	ACTION
1	0:00	17200	260	10	.5	SEP; $\dot{\theta}$ = 2°/SEC, 3 SEC; $\dot{\theta}$ = 0, 2 SEC
2	0:05	17000	244	8	6.5	ROLL RIGHT ϕ = 20°; $\dot{\theta}$ = -2°/SEC AT θ = -5° ROLL ϕ = 0; CONTINUE $\dot{\theta}$ = -2°/SEC TO θ = -22°
3	0:23	14300	255	5	-22	AT AS = 255 INITIATE PRACTICE FLARE $\dot{\theta}$ = 2°/SEC, CONTINUE FLARE TO HOLD $\dot{h}$ = 0; AS ≈ 185
4	0:55	12200	180	11	11	AT AS = 185; $\dot{\theta}$ = -2°/SEC TO θ = -22°
5	1:40	4600	285	4	-22	AT AS = 285 $\dot{\theta}$ = 1°/SEC TO θ = -17° TO HOLD AS = 290
6	1:52	2000	290	4	-17	INITIATE PREFLARE $\dot{\theta}$ = 2°/SEC
7	2:07	350	250	6	3	AT AS = 250 DEPLOY GEAR
8	2:27	0	175	11	11	T.D. AS < 220; $\dot{h}$ < 10 fps
9	2:30	0	160	--	--	BRAKE AS REQUIRED





WT = 150,000
CG = 65% (1076.7)
TAILCONE OFF

FIGURE II-2

III. ORBITER 101

A. Introduction

The first flight Orbiter (101) has been subjected to a management review process as systematic as the ones on prior manned flight programs. The progress of the design has been critiqued through a system including a Preliminary Requirements Review (PRR), a Preliminary Design Review (PDR), Critical Design Review (CDR) for all major subassemblies and finally the Design Certification Review (DCR). The progress of the flight hardware and software through the verification test program has been monitored and critiqued through a series of Customer Acceptance Reviews.

B. Observations

1. General

This section of the report discusses the Orbiter systems. As for the interface definition and separation monitor and control system this is shown in Figure III-1 and the mechanical system is shown in Figure III-2. These interfaces and the electromagnetic compatibility and various hardware/software interfaces received verification by analysis, and varying levels of actual equipment testing. Mostly this verification testing was done at the system level

2. Structures

The internal program reviews and printed material have provided the Panel ample opportunity to review the structures in terms of design requirements and verification as well as material control. The Panel has given particular attention to open work and areas of concern that need to be resolved before the ALT flights.

Briefly the structural design requirements cover the following areas:

a. Ultimate factor of safety of 1.4.

b. No skin buckling prior to entry. (OFT requirement)

c. Fracture mechancis considerations.

d. 65,000 pound payload up and 32,000 pound payload down. (OFT)

e. 350° F. maximum external skin temperature. (OFT)

f. Landing sink speeds.

g. Acoustic environments. (OFT)

There has been little difficulty in meeting these requirements except in the area of landing sink speeds and to a lesser degree the acoustic environments. These areas have received appropriate program attention during the design and test program. The landing sink speed has been specified at no greater than 9.6 feet per second with a 32K payload, and there is a requirement of 6.0 feet per second when the Orbiter has an abort landing with a 65K payload. The acoustic environment specification is 150-165dB to meet payload requirements.

Certification of dynamics requirements by analysis (SD 75-SH-0032-1) are supported by horizontal ground vibration tests conducted with the Orbiter 101. Such tests have shown minor deficiencies in the mathematical model used in the analysis. Corrections to this model are now in process and should be completed by mid-January 1977. A rerun of the analyses can then be made, particularly with regard to flight control stability, flutter stability and loads.

There are a number of items in the process of being closed in the area of material control certification. The following items are to be completed: materials tests at White Sands Test Facility, approval of subcontractor material control plans and use, single-barrier failure analysis, review of closeout photos, material usage agreements for the off-the-shelf hardware, ground support equipment hazardous fluid review and the insertion of all materials data into the MATCO system.

Other items in the process of being resolved include:

a. Proof load test of nose landing gear door.

b. Five open RID's on the Tail Cone.

c. Tests to assess whether the Thermal Protection System on the vertical stabilizer and the Auxiliary Power System pod must be redesigned because of a possible increase in temperatures from exhaust products.

d. Certification tests on the Orbiter purge, vent, and drain components. These are small items such as clamps, screens, adapters, etc.

While the elevon seal panels have been a problem, the current work indicates these have been satisfactorily resolved. Finally, there is a large amount of work deferred from the Palmdale plant that will need to be finished at DFRC.

Orbiter 101 will carry the following development flight instrumentation to gather data on structural response to flight conditions:

Quantity	Type	Purpose
216	Strain Gauge	Primary Structure Response
74	Accelerometer	Structural Dynamics, Flutter
3	Microphone	Structural Dynamics
4	Differential Pressure	Flutter

3. Auxiliary Power Plant and Propulsion Simulation

The main propulsion system and the orbital maneuvering system and reaction control system are all simulated or modeled with inactive equipment. For instance the three main engines are simulated as to mass and envelope. There are stiff braces in lieu of thrust vector control actuators as well as simulated engine-mounted heat shields. The forward reaction control system is a boiler-plate module without any actual or simulated subsystem hardware. The Orbital maneuvering system and reaction control system pod contains a simulated structure to achieve the proper aerodynamic moldline, and no system hardware is required.

The Auxiliary Power Unit Subsystem (APU) consists of three independent systems that provide mechanical shaft power to the hydraulic pumps, using one pump for each APU. Each APU system consists of a fuel tank, fuel distribution and servicing system, auxiliary power unit and controller, lubrication system, exhaust duct assembly, fuel/lube oil vents and drains, and a thermal control subsystem. The fuel used is monopropellant hydrazine. The pressurizing gas is helium. There are displays and controls and sensing devices to permit the crew and ground-based stations to monitor the operation of the overall and specific segments of the APU system. The power output to each hydraulic pump is 135 HP normal speed and 148 hp at maximum speed. Normal speed for the turbine is about 73,000 rpm. The APU operation during manned captive flight is as shown in Figure III-3, and for free flight in Figure III-4. Note that in each case the APU's are required to be shut down and restarted during the flight period. Three significant problems have to be resolved.

a. Shutdown Soak-Back Temperature. This appears to be caused by the fuel control valve response which permits burning of fuel in the exhaust area. There are several investigations in process. These include consideration of injector/standoff changes to reduce peak temperature and an assessment of the fire hazard with insulation removed and the use of a shield to allow convective cooling.

b. Low Fuel Pump Volumetric Efficiency. The bearing design and/or material causes this loss in efficiency thereby limiting peak APU horsepower. It is a time-dependent problem which means that the APU will work well for awhile and then have a drop off in efficiency. Investigation revealed that the raphitar (carbon with binder) material used for the bearing have less swell than development bearings contributing to large clearance and greater loads. Other graphitar materials swell too much and cause the bearings to seize. The approach for ALT is to machine a new bearing and match their geometry and tolerances to the "swell" characteristics of the machine. As for the long term solution, a more extensive test program is planned which will include consideration of other materials.

c. Turbine Wheel Life. There has been a failure of an APU wheel at just under 60 hours of operation. Analysis of the failure showed that the electron beam welding machine failed to make the necessary penetration. The wheel design and manufacturing procedures are being changed to improve producability and non-destructive test procedures are being added. These problems may impact delivery schedules for the necessary APU's for the integrated test program. There is, of course, a means of conducting the integrated tests without the APU's, but this is not desirable.

4. Avionics.

The Orbiter 101 avionics provides the flight control and automatic flight

ALT free flights as well as to support manual operations, management of the Orbiter systems, and determination of vehicle status and operational readiness. The avionics system consists of the flight control and data management subsystems on which the Panel focuses. In addition, there are the subsystems for guidance, navigation and control, crew station displays and controls, communications and tracking, electrical power and the flight instrumentation. The structure of the Orbiter 101 software is shown in Figure III-5. Verification of the avionics hardware and software is accomplished through a program of reviews, analyses and tests shown in Table III-1. The following sections briefly describe each subsystem.

a. Flight Control Subsystem FCS.

This system consists of sensors and controls providing inputs to the computer system which drive the vehicle effectors (actuators) and conditions the actuator command signals to assure that there is effective control and stabilization of the vehicle. This primary system is designed to meet the following safety criteria:

Level 1. Capability to complete nominal mission after one failure with normal system performance.

Level 2. Capability to return safely after a second failure and limited operation outside of design boundaries.

The hardware for this system includes what are called line replaceable units (LRU's), the crew controls, sensors, control system software, and the actuation subystem.

The software for this system is identified in terms of software programs for specific phases of the test and flight program.

1. The VU-101 (OPS-1) program was used for early confidence testing of the FCS and support to the test program for the LRU's installed in the vehicle as well as the Horizontal Ground Vibration Tests.

2. The ADL5B (first OPS 2 delivery) is to be used for all single string testing.

3. The ADL 5 is to be used for multistring testing including verification of the FCS.

4. The SAIL dropout program is a preliminary or interim version (flt S/W) for use at the Shuttle Avionics Integration Lab in testing to support the free flight missions of the Orbiter during ALT.

5. The ALT CI is the version to be used on the ALT flights.

The Panel has given particular attention to the program to certify the software flightworthy and lfight ready. An important part of the verification program is the "Acceptable Fault Tolerance Verification" phase. This part of the program demonstrates the ability of the system to detect failures and protect against false alarms, and demonstrates acceptable level of vehicle transients due to system failures. The subsystem stability and performance and redundancy management certification tests will be conducted on ADL/FCHL. The testing of this program provides important information on the crew's inter-action with the system that helps plan the timeline for redundancy management.

A good deal of work in the certification program remains to be completed at the time of this report. Much of it is to be done as part of the integration testing on Orbiter 101 as well as ADL, SAIL system tests and qualification tests on certain of the LRU's. Manned and automatic closed loop flight simulations are planned for ADL and SAIL as a major part of the flight control verification program.

b. Data Processing

This subsystem comprises the major processing elements for computation and control and interface linkage. This includes: (1) computers for handling the sensor inputs and performing the computations for control, guidance, navigation and data management functions, (2) magnetic tape memories for large volume bulk storage and organizational information related to individual display presentations, (3) digital data buses to accommodate the data traffic between computers and the other Orbiter subsystems, (4) remote interface units to convert and format data at various interfacing subsystems, and (5) display unites to monitor and control the orbiter and its mission by presentation, insertion or change of selected variables.

These elements of the data processing system are configured in redundant quantities mainly because of the overall avionics fault tolerance, partitioning, and functional isolation constraints. One of the major components of this system are the Multiplexer/Demultiplexers (MDM) which are used in numerous remote locations of the orbiter to handle the functions of serial data time multiplexing and demultiplexing associated with the digital data buses, and of the interface signal adaptation. These units are multipurpose bus terminals which provide compatible interfaces between the Input/Output Processors and various interfacing subsystems. All data transfer operations of the MDM are initiated and controlled by the Input/Output Processors.

There are a number of problems that are being worked at this time:

(1) The display unit has had a corona problem. The high voltage power supply has an arc path which could cause the display unit to fail. The interim fix for the Orbiter 101 is a corona shield made of Kapton tape. The effectiveness of this fix has been demonstrated by analysis and test at the vendor's facility. During test at higher temperatures (78C vs 50C) the unit ran for 1142 hours before failing. At the nominal temperature of 50°C this translates into an expected 2000 hour life. Final changes are planned for the unit.

(2) The MDM has had difficulties passing the vibration portion of the qualification tests. The vibration levels used are those for Orbiter 102. However, since the Orbiter 101 ALT environment is considerably more benign than that for the Orbiter 102 there is no expected problem during ALT flights. The final solution required for Shuttle operational flights is to pot the power supply with foam and rerun qualification. In another area of the

MDM the sequencer/sequential control unit (SCU) has had "halts" in which the MDM ceases to operate on one data bus until power is recycled. The work-around is to switch to the backup data bus. One potential contributor to the problem was a manufacturing error which resulted in some MDM's having a 5K ohm resistor in the sequence control logic. All critical MDM's have been corrected. Although this has a very low frequency of occurance it will be monitored closely during the integrated tests to assure that it is acceptable for ALT missions.

(3) A power supply failure in the central processing unit of the general purpose computer has been caused by internal shorts. The short current was sufficient to cause severe charring of components inside the unit (power supply) and the loss of the general purpose computer. The problem is under intensive investigation at this time including failure analysis, but the problem still is open for positive identification of th cause.

c. Integrated Guidance, Navigation and Control (GN&C)

The GN&C system is, of course, critical to the operation of the flight control system. The requirements for this system are depicted in Figure III-6 and the remaining activities to get the system ready for ALT are shown in Table III-II.

d. Displays and Controls

This subsystem includes the integrated arrangements of functions dedicated and general purpose display units, switches, meters, status indications, cathode ray tubes and associated keyboards and encoding-decoding-conversion electronics associated with interfacing instruments and manual controllers. It also includes the interior and integral lighting and the very important caution and warning subsystem. The caution and warning setup provides the crew with timely alerts about actual or potential orbiter system failures or out-of-tolerance conditions. A memory is provided in this arrangement so that the crew may determine whether preselected system annunciator lights have been energized previously.

Problem areas, which are in the process of being resolved, include:

(1) The driver display unit development tests indicate that the radiated electromagnetic interference may be out of specification by as much as 24 dB at certain frequencies. This radiation level would still be about 20dB below that specified as the susceptibility threshold for Line Replaceable Units (electronic boxes). The capability for proper mission performance will be verified during the integration testing in progress on SAIL/ADL and the Orbiter, and does not appear to pose undue problems for flight at this time.

(2) The altitude vertical velocity indicator did not meet electrical susceptibility requirement. It was about 17 dB below specified level at the one frequency of 7.4KHz and this might affect the buses and possibly cause both altitude verticle velocity meters to malfunction. This will also be re-examined during integrated system test and SAIL and does not appear to pose a problem for orbiter active flights at this time.

Here again there are a number of final reports that are due in the January-to-March time frame to complete the certification program.

e. Communication and Tracking

This system consists of the radio frequency processing and distribution equipment necessary for (1) reception, transmission and distribution of Orbiter and ground-originated voice, (2) transmission of operational and DFI Pulse Code Modulated intelligence, (3) Shuttle Carrier Aircraft relay of S-band PCM data, (4) TACAN navigational aids, (5) radar altitude, (6) microwave scanning beam landing system(MSBLS),(7)C-band beacon. TACAN is usable throughout both captive andfree flight. MSBLS is usable only during the straight-in-portion of the approach. The radar altimeter provides useful data following separation at altitudes less than 5,000 feet and the 747 FM relay transceiver relays orbiter PCM data during mated flight through separation.

There appear to be no concerns regarding this subsystem at the time of this report.

f. Electrical Power Distribution and Controls

This electrical power distribution and control system converts DC power to AC power and distributes AC and DC power

all vehicle elements. Based on the verification program, the electrical power system appears to be in good shape with no single failure points that would lead directly to loss of the vehicle. There are about eleven (11) certification activities on the electrical subsystem that have to be completed in January and February 1977. These are a constrain on the inert Orbiter 101 flights and are expected to be completed prior to active Orbiter flights.

g. Instrumentation

There are two types of instrumentation systems - development flights instrumentation (DFI) and Operational Instrumentation (OI). The DFI will be removed after the development phase of the program. The functions of the DFI are essentially the same as those of the OI, except that the emphasis is on acquisition of information for use in evaluating the Orbiter 101 performance. Instrument location and types are shown schematically in Figure III- 7 .

Development activities for the instrumentation subsystem include both testing and analysis. With the exception of off-the-shelf equipment, the development activities began at supplier facilities. The objective for suppliers was to establish confidence that the equipment design will satisfy mission requirements over all combinations of operational environments. For off-the-shelf equipment, design confidence has been established by showing that the equipment has previously been demonstrated to meet criteria that are equivalent to or more stringent than operational requirements.

5. Backup Flight Control System (BFCS).

The BFCS is functionally separate from the primary Orbiter avionics system to provide an alternative means of control in case of a "surprise" or generic problem in the multistring system. It is, therefore, a simple single string system. To achieve independence between the primary and backup systems, the software implementation of these control laws in the BFCS was done separately from the software implementation in the primary FCS. and is operated in a separate computer from the four primary computers. The software implementation is a simple design and is an adaptation of the control laws of the primary system. The operational flight program is mechanized in a straight-line fashion with a very simple executive function. All functions except the display and pulse code modulation (PCM) outputs are scheduled at a single interation rate and in a fixed sequence. As each function is executed, operation is returned to the executive function. The functions used are: executive, flight control, displays and controls, telemetering, fault detection, error handling, input/output, housekeeping, and ground support.

The system has a separate dedicated computer, since this is a single string backup system using a simple program. The program has accepted single failure points that could cause loss of vehicle. However, this system will only be engaged if there are catastrophic software failures in primary system. The only function other than flight control performed by the BFCS is the collection, display and formating of air data computer parameters for the down-link data transmission system.

Two modes are available with the BFCS. The primary mode of operation is the command augmentation system (CAS) with an emergency manual direct mode. The CAS mode contains a down-mode capability in the event of a detected air data computer failure.

Assessment of the performance capability and design maturity of the BFCS is being accomplished through the following test program:

(1) Development tests. The Charles Stark Draper Laboratory (MIT) conducted development tests on the BFCS operational flight program to evaluate each module with all branches and end-to-end unit tests for each function. Dynamic tests were conducted to evaluate closed-loop performance of the BFCS digital autopilot and functional

capability in an F-8 Navy fighter with Shuttle dynamics. RI/SD conducted design verification tests in the Avionics Development Laboratory to evaluate software coding, linkages, support functions and end-to-end verification. They also conducted software interface and compatibility tests with line replaceable units and a single-string subsystem as well as a closed-loop test to verify subsystem operation and capability.

(2) Verification tests. JSC and RI conducted software verification tests in the SAIL. This was followed first by subsystem integration tests to verify design compatibility between software and hardware and then by closed-loop tests to verify their operational compatibility. The subsystem verification tests are now in process.

(3) Acceptance tests. The tests conducted at Palmdale checked out the subsystem copper (hard-line) path. Single-string closed-loop tests verified low gain with the air data computer off. Delta testing is in process at the time this section is written. It is to verify single-string closed-loop with the air data computer on. Integrated tests are to verify parallel system compatibility and limited ALT mission objectives because of static environments. The remaining activities associated with the BFCS include the performance of rollout simulation, complete bending compensation, reverification of the BFCS software in the SAIL, an update of the supporting documentation and a complete system verification in SAIL. The system will then be reviewed and accepted at a Customer (Configuration) Acceptance Review Board in May 1977.

6. Orbiter Crew Station.

Since the crew display and controls and caution and warning subsystem are described under the avionics section, this section will focus on two crew safety subsystem. The crew escape subsystem is to enable the crew to escape at any time throughout the entire profile of the ALT program. It also will permit the crew to escape during the ascent phase of OFT up to an altitude of 75,000 feet and a velocity of Mach 2.7. The subsystem also provides for crew escape on the pad, except where a fireball occurs.

There are two side-by-side rocket propelled seats. The ejection seat system is a modified Lockheed F-12 system. Above the seats are an inner and outer panel which are jettisoned by pyrotechnic devices. The inner panel is part of the crew module overhead integral structure, while the outer panel is part of the forward fuselage integral structure.

Figure III-8 shows the escape events, and Table III-III shows further detail on the sequence of events. The status of this system is as follows: (Production orbiters, 103 and subs do not have ejection systems)

a. The ejection panel severence system, Figure III-9 has an oversize cavity between the detonating charge and the panel. To eliminate the problems induced by excess cavity volume all production panels will be filled withRTV silicone rubber.

b. One-way transfer devices, which prevent seat ejection during emergency ground egress or rescue ingress, did not function properly and are being replaced with a previously qualified device from supplier.

Emergency ground egress for the Orbiter 101 is through the side hatch, utilizing a hatch-mounted deployable boom, "sky genie" descent devices which provide a controlled rate of descent, and safety tethers. An alternate egress procedure is provided by jettisoning the overhead ejection panels (see previous section) and using similar egress equipment stowed on the flight deck. Figure III-10 shows the primary egress method. The ground egress boom installation and descent devices verification tests and analysis report are scheduled for the last week of February 1977.

7. Environmental Control and Life Support and Power System.

The Environmental system includes the atmospheric revitalization subsystem, life support functions, and the active thermal control system. The life support functions include the water storage and smoke detection and suppression. The fire detection and suppression subsystem is required to detect smoke in the avionics bays and the crew compartment. Portable fire extinguishers are required for each avionics bay and can be actuated from the flight deck.

The major "open" items at this time include the verification analysis, scheduled for completion by February 1977 and the certification completion by March 1977.

The electrical power generation subsystem consists of three fuel cells, each rated at 7KW continuous maximum and 12KW peak power. Two fuel cells are required to provide 4.0 to 14 KW of continuous power as well as 24 KW of peak power in case one fails and the other has to handle the total demand. There is no requirement at this time for storage batteries to be placed on board the Orbiter, although this can be done if it is deemed necessary. The electrical power generation subsystem and certification tests are expected to be complete by January 1977.

The high pressure gas storage system for the ALT provides hydrogen and oxygen fuel cell reactants. The pressure ranges are:

	Hydrogen	Oxygen
Storage, primary	2400-250 psig	2200-900 psig
secondary	2400-200 psig	2200-800 psig
Regulated, primary	350 psig	900 psig
secondary	200 psig	800 psig

8. Mechanical Systems.

Mechanical systems include the following: (a) hydraulics, (b) actuation mechanisms and surface control, (c) separation systems, (d) landing/deceleration, and (e) payload bay doors mechanism. These are shown in the schematics or outlines shown in Figures III-11, -12 and 13.

Since the payload doors will not be in use during the ALT flights the Panel has focused on the other areas.

a. Hydraulic Subsystem.

The Orbiter hydraulic subsystem consists of three independent hydraulic power systems with main pumps driven by independent APU's. The design and installation of the subsystem are in accordance with MIL-H-5440F, Type II, Class 3000 system, amended by SCN 01-0218 to the Orbiter Contract End Item Specification. The fluid distribution system utilizes titanium tubing and swagged fittings. MIL-H-83282 hydraulic fluid is used in the system as the working fluid.

The principal development and qualification problems and their resolution at the time this section is written are:

a. Leak failure occurred on the elevon actuator crossover joint quill seal during development tests. There was a non-standard seal design combined with a large misalignment.	Stepped the quill seal to reduce extrusion gap (opening of the circumference). Also provided wider seal and backup barrier seal. The modified quill successfully passed 102,000 cycle pressure-impulse tests.
b. Structural failure of the main pump front housing (case) in the fillet area where attach flange and housing meet.	Failure analysis concluded failure was caused by improper impulse test circuit setup and improper test circuit relief valve setting. Pump housing does meet requirements.
c. Filter module shutoff valve failure due to broken valve spring.	Redesigned the valve to eliminate spring.

Line resonance has not been found to be a problem but the means of verifying this is a problem.

The aerosurface actuators that are to be used in FCHL as part of testing will be the same configuration as the flight actuators except for the seals. The actuators to be used in qualification certification test will be the same configuration including the seals. Functional certification testing for the hydraulic subsystem is to be completed in March 1977. Since that system will not have the Phase II modifications, further certification testing is required on the system when those modifications have been made. This delta certification testing is scheduled to be completed by May 1977.

b. Actuation Mechanisms

Aerodynamic control surface movement is effected by hydraulically powereed actuators that position the elevons and by hydraulically powered drive units that position the body flap and combination rudder-speed brake through geared rotary actuators. Three redundant 3,000 psi systems supply the necessary hydraulic power.

The elevon actuator or servoactuator is single balanced using two switching valves tied to the three hydraulic systems and is commanded by four independent avionic signals. Failure detection through servo valve delta pressure and piston delta pressure are used by the avionics system to detect failures and provide stable actuator operation.

Three problems can be noted:

a. The elevon actuator switching valve requires excessive time to switch to second standby system. The "trigger" valve was redesigned and successfully tested. Qualification and flight hardware are being retrofitted to the Phase II configuration with the design fix.

b. Significant leakage at the unrestrained end of the return transfer tube of actuator is due to failure of retaining pins and transfer tube displacement. A failure analysis was made and a design change approved. The retention device has been redesigned and successfully tested, and this retention device will be installed during the Phase II retrofit period.

c. Testing continues at the Flight Control Hydraulic Laboratory to understand and correct the actuator/flight control instability at 16 Hz.

Other major known problem areas are: (a) the pitting of the body flap outboard gear teeth due to improper masking fro the acid etch bath. Gears have been replaced with non-pitted teeth.

(b) rudder/speed brake motor shaft failure caused by improper test setup and procedures, since corrected and now being implemented at the Flight Control Hydraulic Laboratory at Rockwell/Space Division, and (c) Rudder/Speed Brake seal leakage and Delta-Pressure transducer strut failure corrected by redesign at Palmdale.

c. Separation Subsystem.

The separation subsystem provides the capability to release the Orbiter from the 747 carrier aircraft. This is effected by a dual frangible bolt at the forward attach point and by three frangible bolts on each of the two aft attach points. The pyrotechnically operated frangible bolt design is the same for all three attach points and is designed to separate at a predetermined section, and each uses two cartridges, each of which is capable of causing bolt separation. The certification summary is shown in Table III-IV. There are problems in certifying the flight hardware. Separation of the electrical umbilical connectors is accomplished by pull-apart connectors subsequent to the structural separation using relative separation motion to do this. Load sensors at each of the structural attachment interfaces provide the measurement of the relative loads between the orbiter and the 747 during all mated phases of the ALT missions.

Additional loads data are obtained to determine the entire flight and ground regime load envelope.

(d) Landing and Deceleration.

The major open items at this time include: (a) the need for main gear shimmy dampling (to be determined from Bendix stability tests which are scheduled to be completed by January 1977), (b) completion of the tire certification for long landing roll (test scheduled for January 1977), and (c) off-limit testing of the brakes at 1500 psi pressure (scheduled for completion by end of February 1977).

Program safety personnel have stipulated tests that should be carried out before the system can be fully certified.

TABLE III-I

VERIFICATION OF AVIONICS SUBSYSTEMS

SUBSYSTEM	ANALYSIS	DESIGN REVIEWS	SIMU-LATORS	TESTING						
				QUAL	ADL	FCHL	SAIL	SSC/O	ICO	SDL
ELECTRICAL POWER DISTRIBUTION & CONTROLS	✓		✓	✓	**		✓	✓	✓	
DISPLAYS & CONTROLS	✓	✓	✓	✓	✓		✓	✓	✓	✓
INSTRUMENTATION	✓			✓	✓		✓	✓	✓	
COMMUNICATIONS & TRACKING	✓			✓	✓		✓	✓	✓	✓
DATA PROCESSING SYSTEM	✓			✓	✓		✓	✓	✓	✓
FLIGHT CONTROLS	✓		✓	✓	✓	✓	✓	✓	✓	✓
GUIDANCE, NAVIGATION & CONTROLS	✓		✓	✓	✓		✓	✓	✓	✓
BACKUP FLIGHT CONTROLS	✓	✓	✓	✓	✓	✓	✓	✓	✓	
AVIONICS SUBSYSTEM GROUP (AVIONICS SYSTEM)							✓ *		✓ *	✓

SSC/O = SUBSYSTEM CHECKOUT } VEHICLE
ICO = INTEGRATED CHECKOUT } VEHICLE

*ALL SUBSYSTEMS FULL-UP & RUNNING
**RETS/HOUSTON

TABLE III-II

INTEGRATED GUIDANCE, NAVIGATION, AND CONTROL
SUMMARY OF REMAINING CERTIFICATION ACTIVITY

ITEM	ACTIVITY REMAINING	CAR SUBMITTAL DATE
IMU	COMPLETE QUAL TEST, PREPARE & SUBMIT EAR & CAR	
GUIDANCE, NAVIGATION, & CONTROL SUBSYSTEM	COMPLETE SUBSYSTEM FUNCTIONAL & INTEGRATION TESTS, PREPARE & SUBMIT CAR PACKAGES	4-15-77 (MATED FLIGHT) 5-30-77 (FREE FLIGHT 1) 7-31-77 (FREE FLIGHT 3) 10-30-77 (FREE FLIGHT 6)

TABLE III-III

Crew Escape System - Sequence of Events

TIME (sec)*	Below 15,000 Feet	Above 15,000 Feet
0.0	D-ring pulled, panel jettisons, power shoulder reel retracts, foot actuator retracts.	Same
0.3	Catapult ignition	Same
0.55	Drogue gun deploys drogue chute	Same
0.75	Drogue chute full-open	Same
1.0	Rocket burns out	Same
1.7	Separation, lap-belt releases, shoulder straps cut, foot cables cut, D-ring cable cut, separator actuates	Separation initators armed but are blocked by aneroid device.
1.9	Drogue gun deploys main parachute	
2.0	Upper drogue chute risers cut	
3.4	Main parachute full open	
10.3	Lower drogue chute risers cut	Lower drogue chute risers cut
At 15,000 feet		Aneroid unblocks, initiating complete separation sequence, deploying main parachute 0.2 second later, and cutting upper drogue chute after 0.3 sec

* Times shown are for the right-hand seat, all events for the left-hand seat occur 0.50 seconds later

SPACE SHUTTLE ORBITER

TABLE III-IV

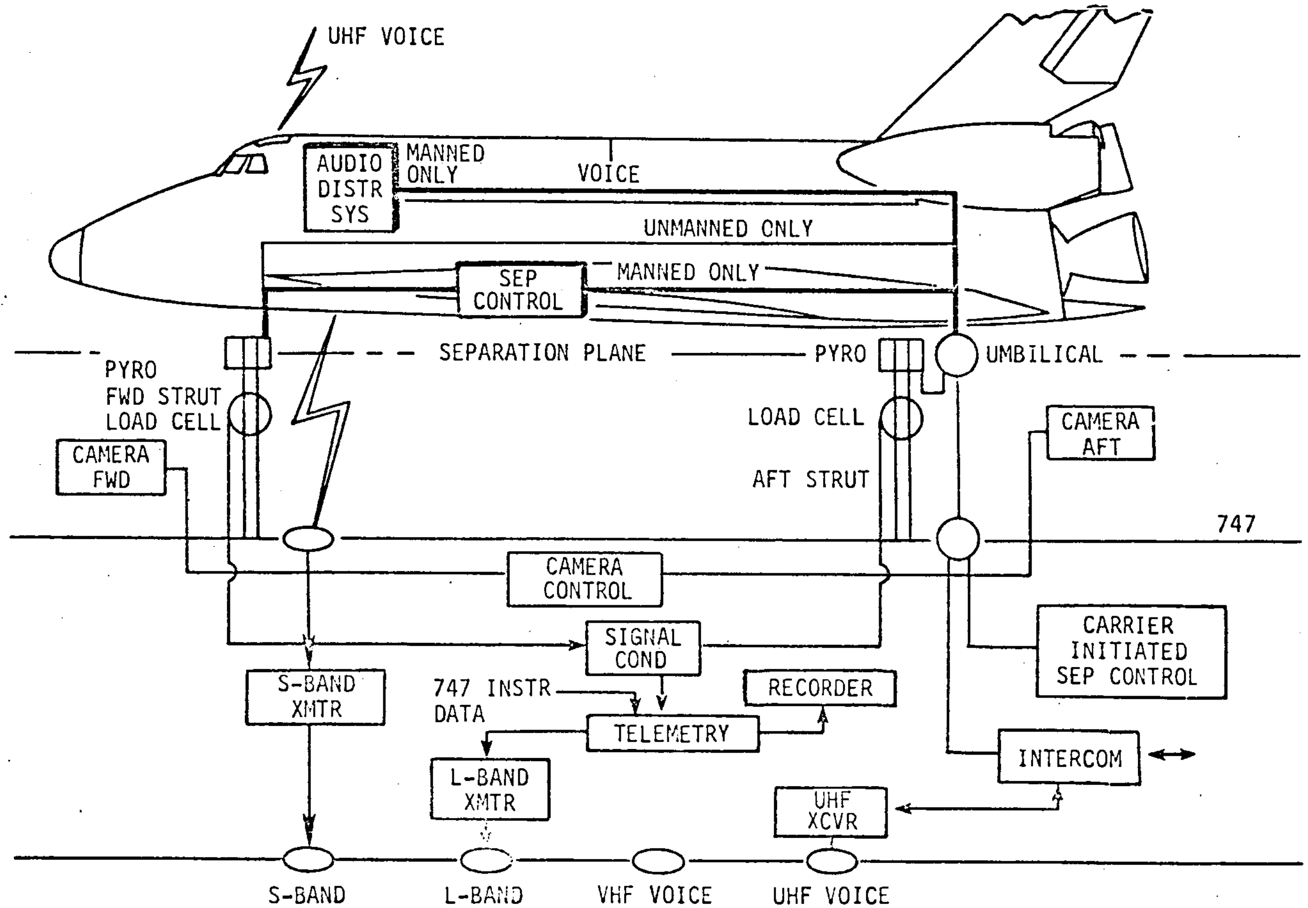
ORBITER/CARRIER SEPARATION SYSTEM CERTIFICATION SUMMARY

CERTIFICATION LEGEND: T = QUAL TEST, S = SIMILARITY, A = ANALYSIS

ITEM	INDUCED ENVIRONMENTS														NATURAL ENVIRONMENTS	QUAL SITE APPROVAL (QSA) COMPLETION DATE
	TEMP			VIBRATION			SHOCK		ELECTROMAGNETIC COMPATIBILITY	LIFE CYCLE	STRUCTURAL				FUNGUS, OZONE, SALT SPRAY, SAND/DUST	
	HIGH	LOW	CYCLE	SINE	RANDOM	TRANSPORT	HANDLING	PYRO/SEP			LIMIT	ULTIMATE	DESTRUCTION			
FORWARD & AFT SEPARATION SYSTEM					A	A		T	A		T	T			A	1-7-77
LOAD MEASUREMENT SYSTEM	T	T	T	T	T	A	A	T	T	T	T	T			A	1-7-77
ELECTRICAL UMBILICAL SYSTEM					T	A		T							A	1-7-77
SEP BOLT	T	T			T						T	T			A	1-7-77

INTERFACE DEFINITION
SEPARATION MONITOR AND CONTROL SYSTEM

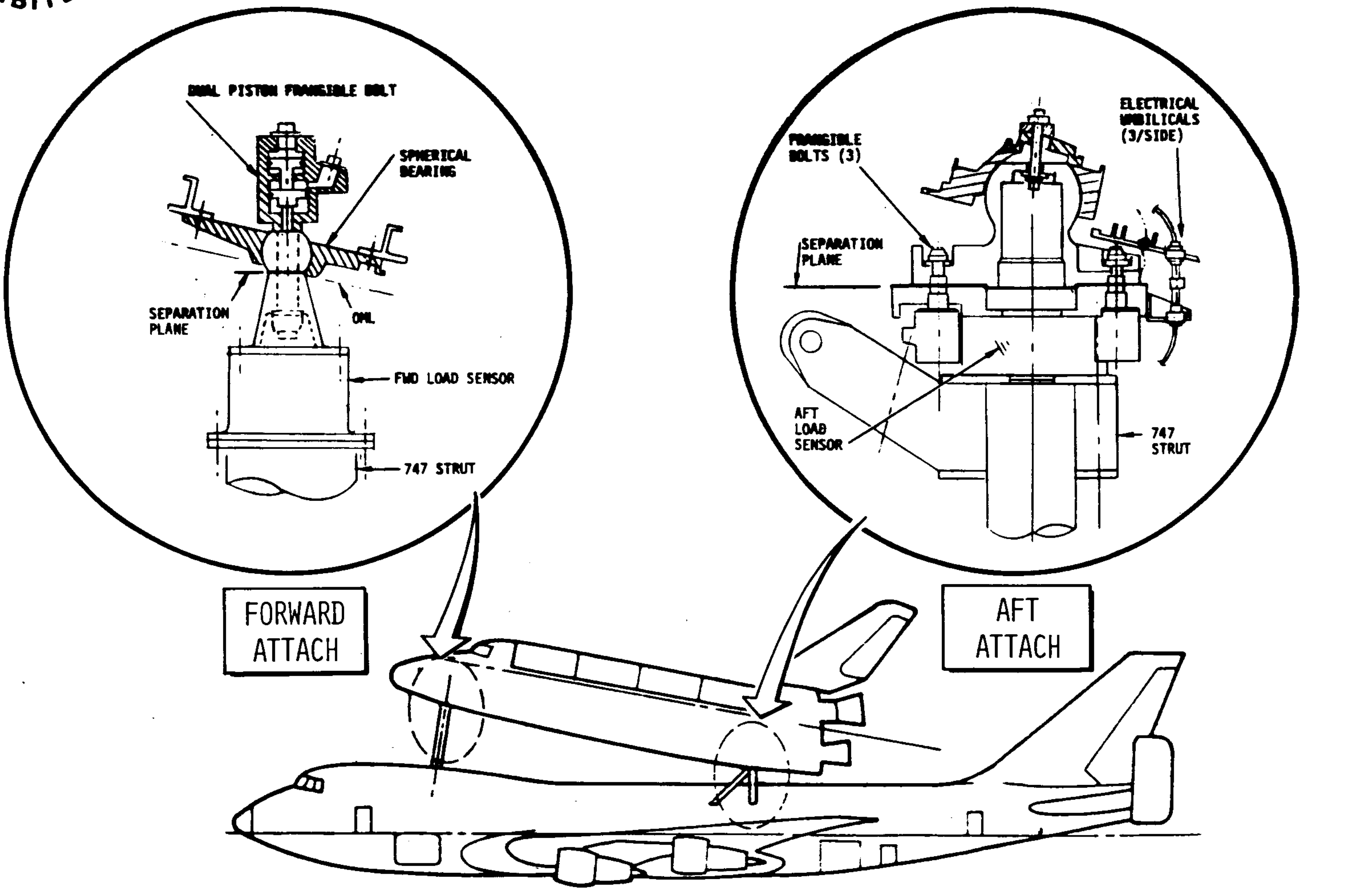
FIGURE III-1



45

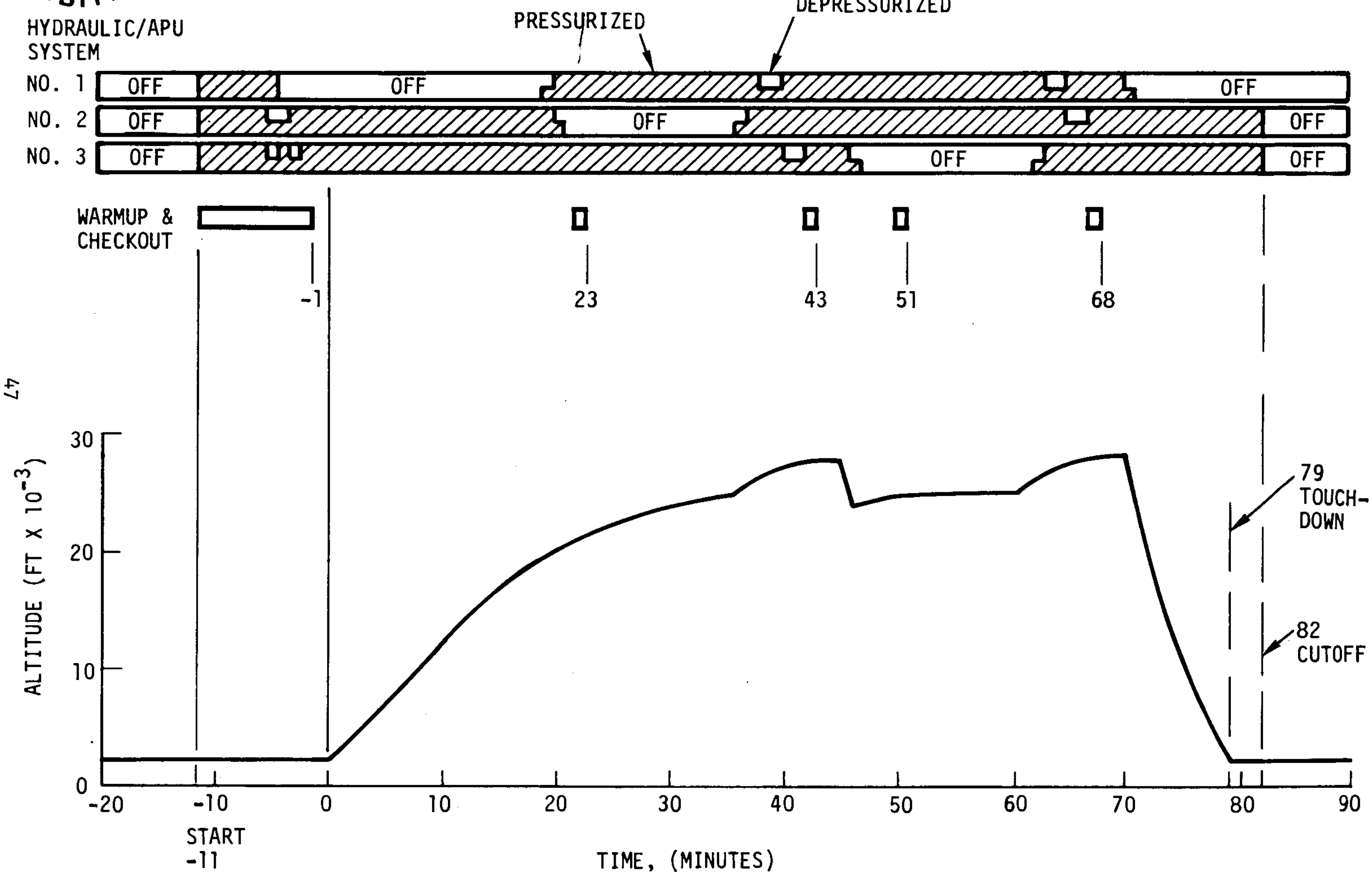
FIGURE III-2

MECHANICAL SEPARATION SYSTEM



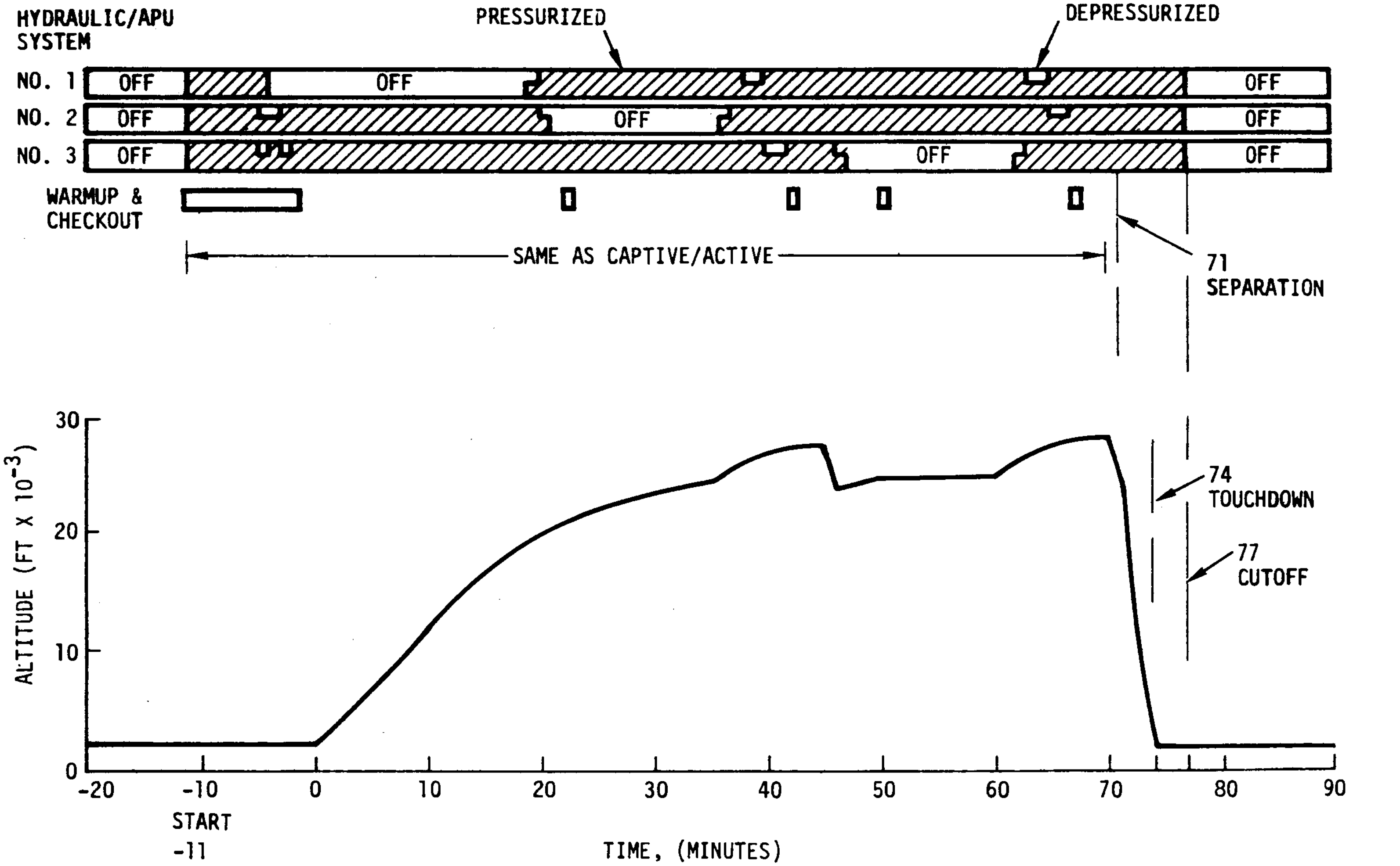
APU/HYD ALT OPERATION
MANNED CAPTIVE FLIGHT

FIGURE III-3



APU/HYD ALT OPERATION
FREE FLIGHT

FIGURE III-4



INSTRUMENTATION EQUIPMENT LOCATION
OV 101

FIGURE III-5

(1) FWD AVIONICS BAY 1
- DEDICATED SIG COND (1)
- 01 DATA MDM (1)
- MASTER TIMING UNIT (1)

(2) FWD AVIONICS BAY II
- 01 DATA MDM (1)
- PCM MASTER NO. 1 (1)
- MAINT RECORDER (1)

(3) FWD AVIONICS BAY IIIA
- DEDICATED SIG COND (1)
- 01 DATA MDM (1)
- PCM MASTER NO. 2 (1)

(3A) FLIGHT DECK MDM (1)

(4) AFT AVIONICS BAY IV
- DEDICATED SIG COND (1)
- 01 DATA MDM (1)
- WIDEBAND SIG COND (4)

(5) AFT AVIONICS BAY V
- DEDICATED SIG COND (1)
- 01 DATA MDM (1)
- WIDEBAND SIG COND (2)

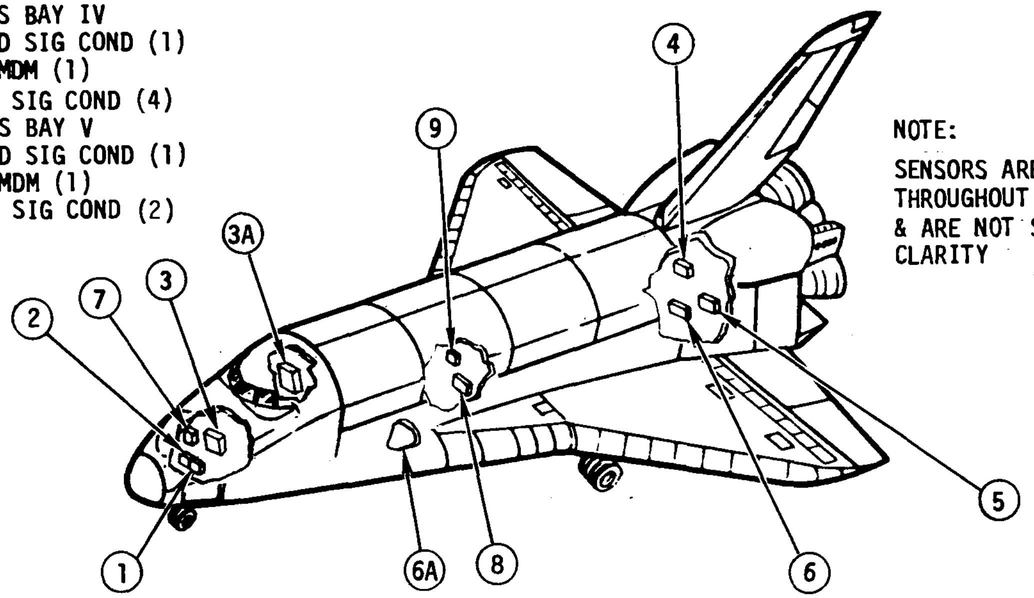
(6) AFT AVIONICS BAY VI
- DEDICATED SIG COND (1)
- 01 DATA MDM (1)

(6A) FUEL CELL DSC (1)

(7) FWD DFI CONTAINER
- S-BAND TRANSMITTER(1)
- WIDEBAND RECORDER (1)
- FDM (1)
- DEDICATED SIG COND (1)
- DFI DATA MDM (1)
- WIDEBAND SIG COND (21)
- STRAIN GAUGE SIG COND (5)

(8) MID FUSELAGE DFI CONTAINER (L)
- FDM (1)
- DFI DATA MDM (1)
- DEDICATED SIG COND (1)
- WIDEBAND SIG COND (28)
- STRAIN GAUGE COND (27)

(9) MID FUSELAGE DFI CONTAINER (R)
- FDM (1)
- DFI DATA MDM (1)
- DEDICATED SIG COND (1)
- WIDEBAND SIG COND (31)
- STRAIN GAUGE SIG COND (33)



NOTE:

SENSORS ARE LOCATED THROUGHOUT THE VEHICLE & ARE NOT SHOWN FOR CLARITY

GN&C SYSTEM REQUIREMENTS

FIGURE III-6