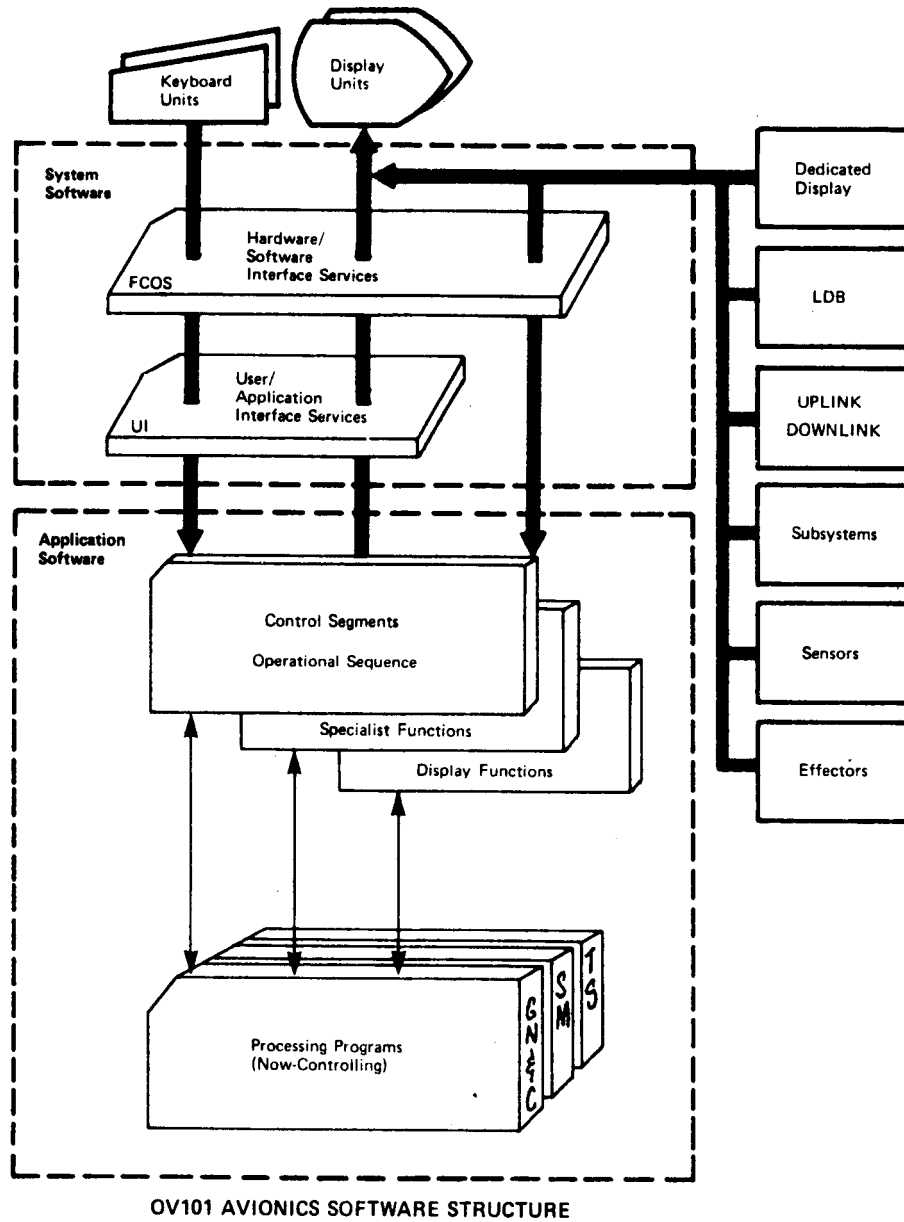


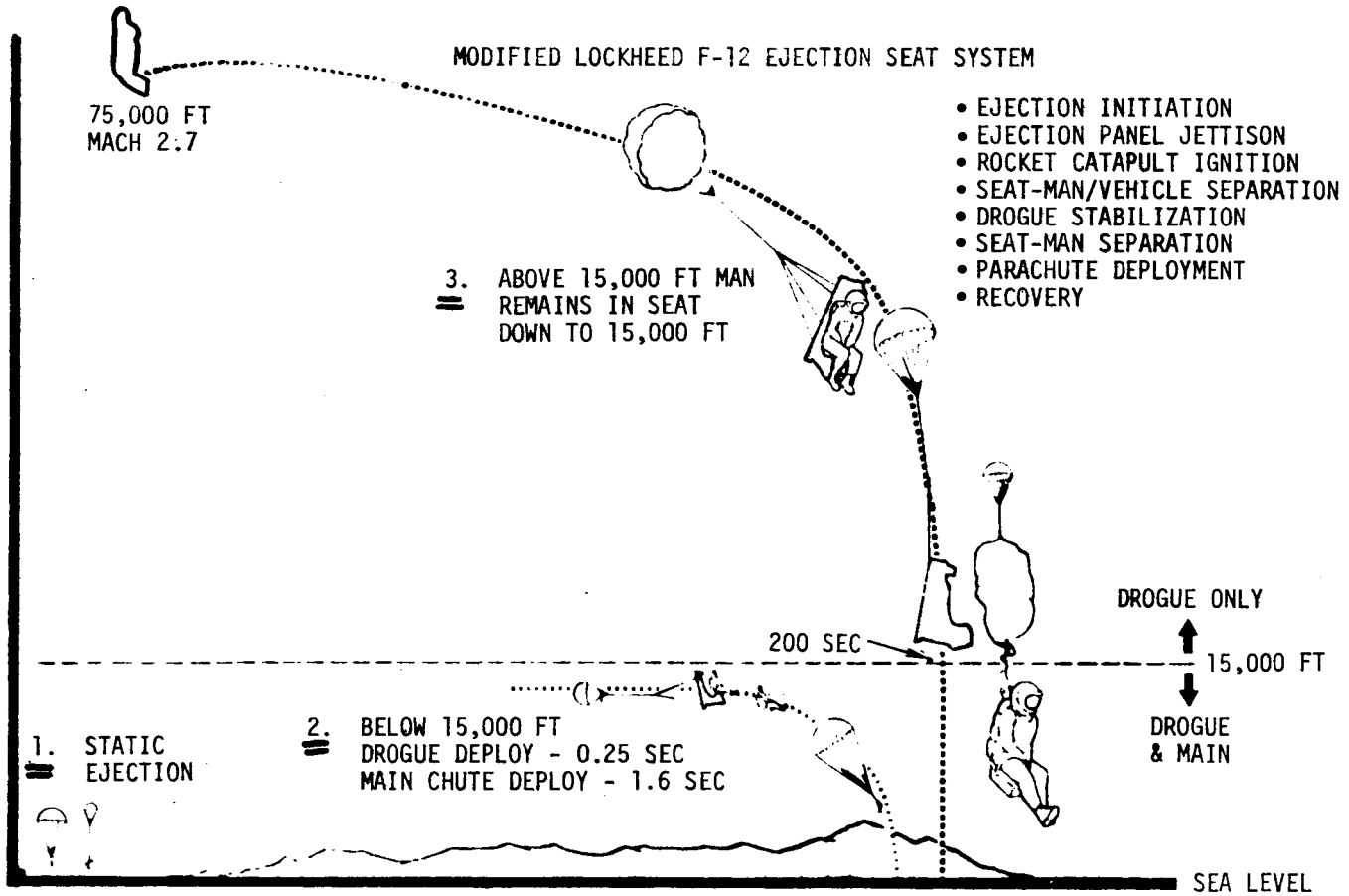
FIGURE III-7 SOFTWARE STRUCTURE





# CREW STATION AND EQUIPMENT - EJECTION SEAT EMERGENCY ESCAPE SYSTEM

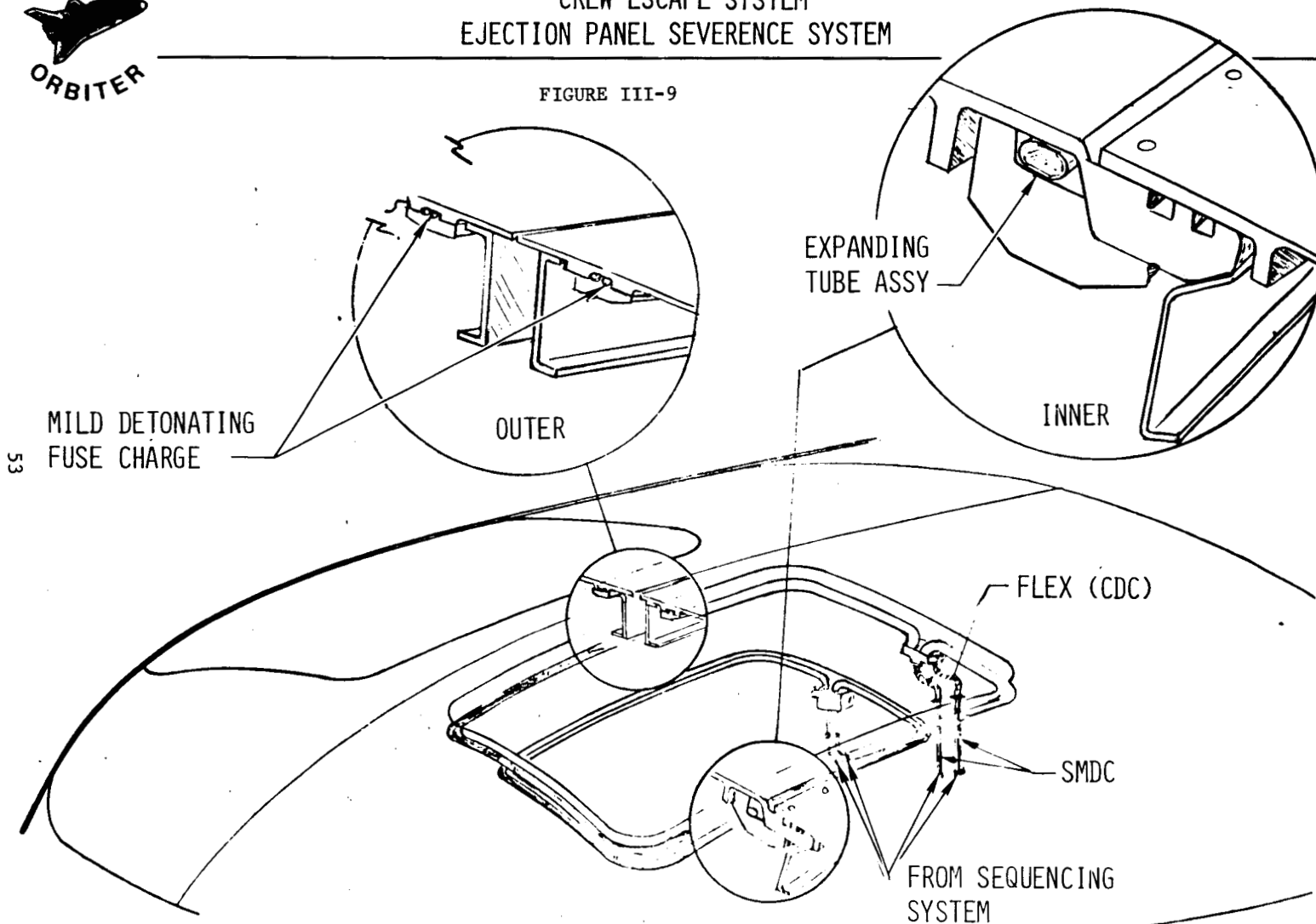
FIGURE III-8





# CREW STATION AND EQUIPMENT CREW ESCAPE SYSTEM EJECTION PANEL SEVERANCE SYSTEM

FIGURE III-9

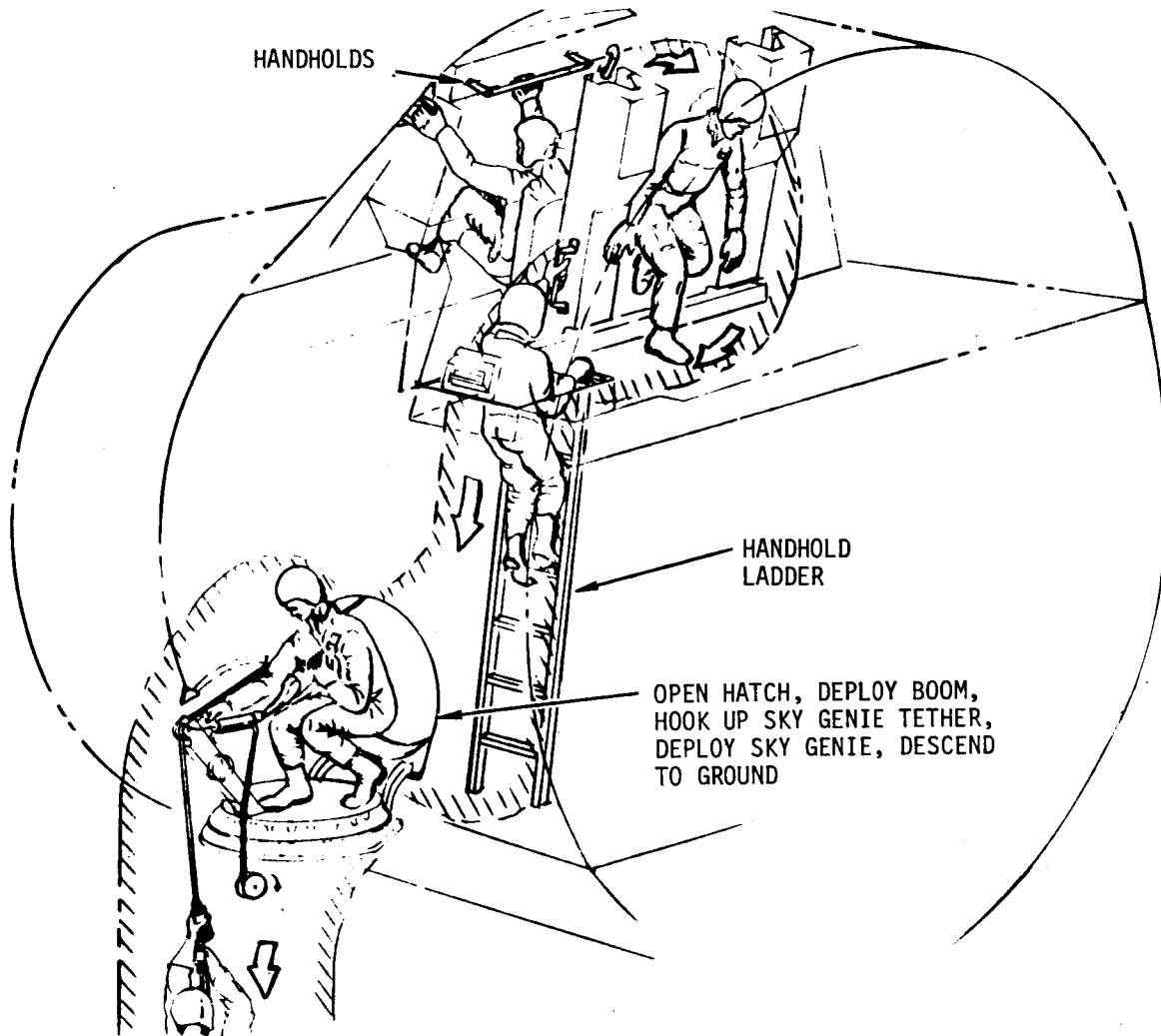




# PRIMARY EMERGENCY GROUND EGRESS

FIGURE III-10

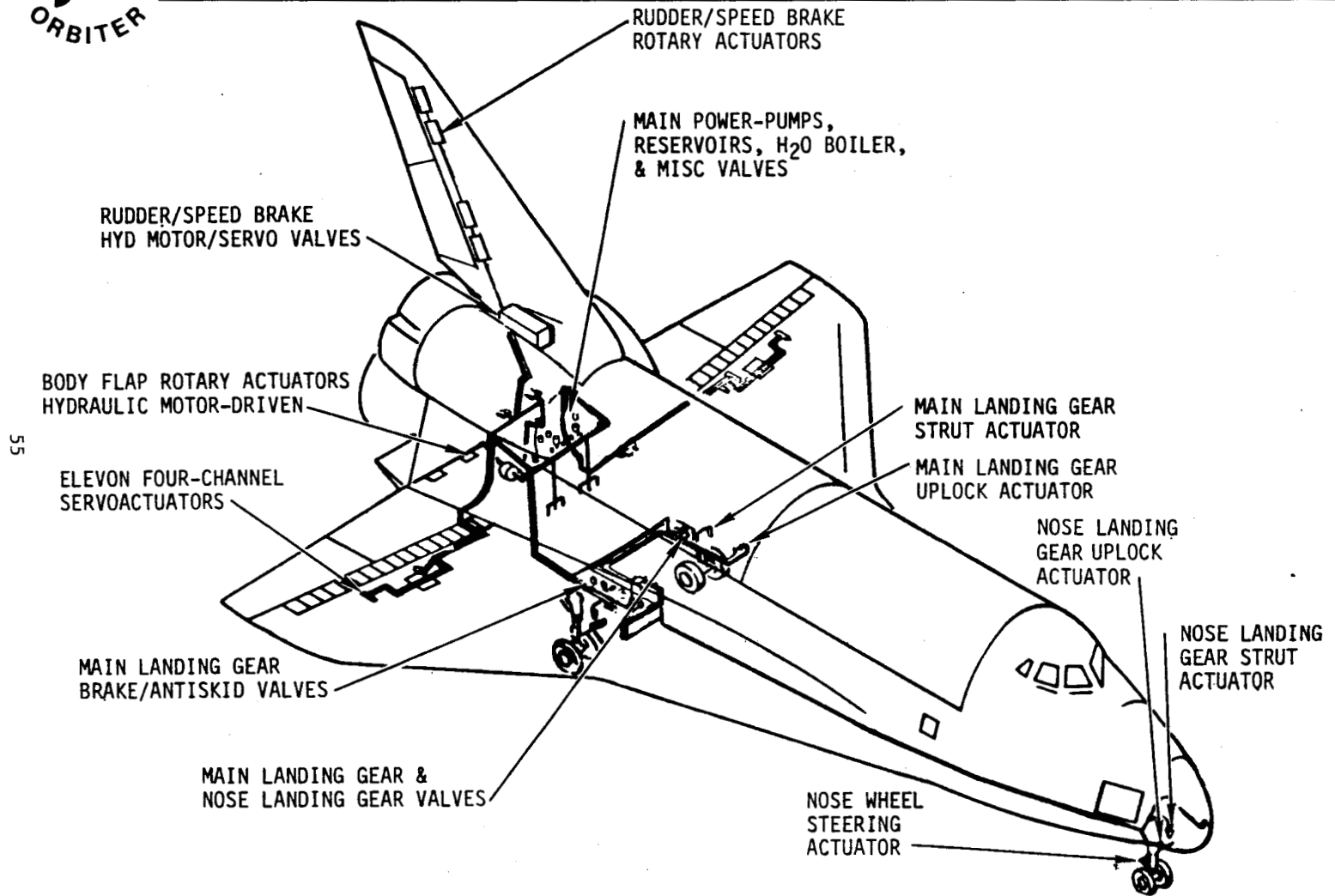
54

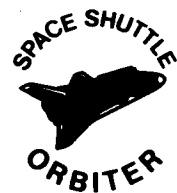




# DCR OV 101 ALT HYDRAULIC SUBSYSTEM

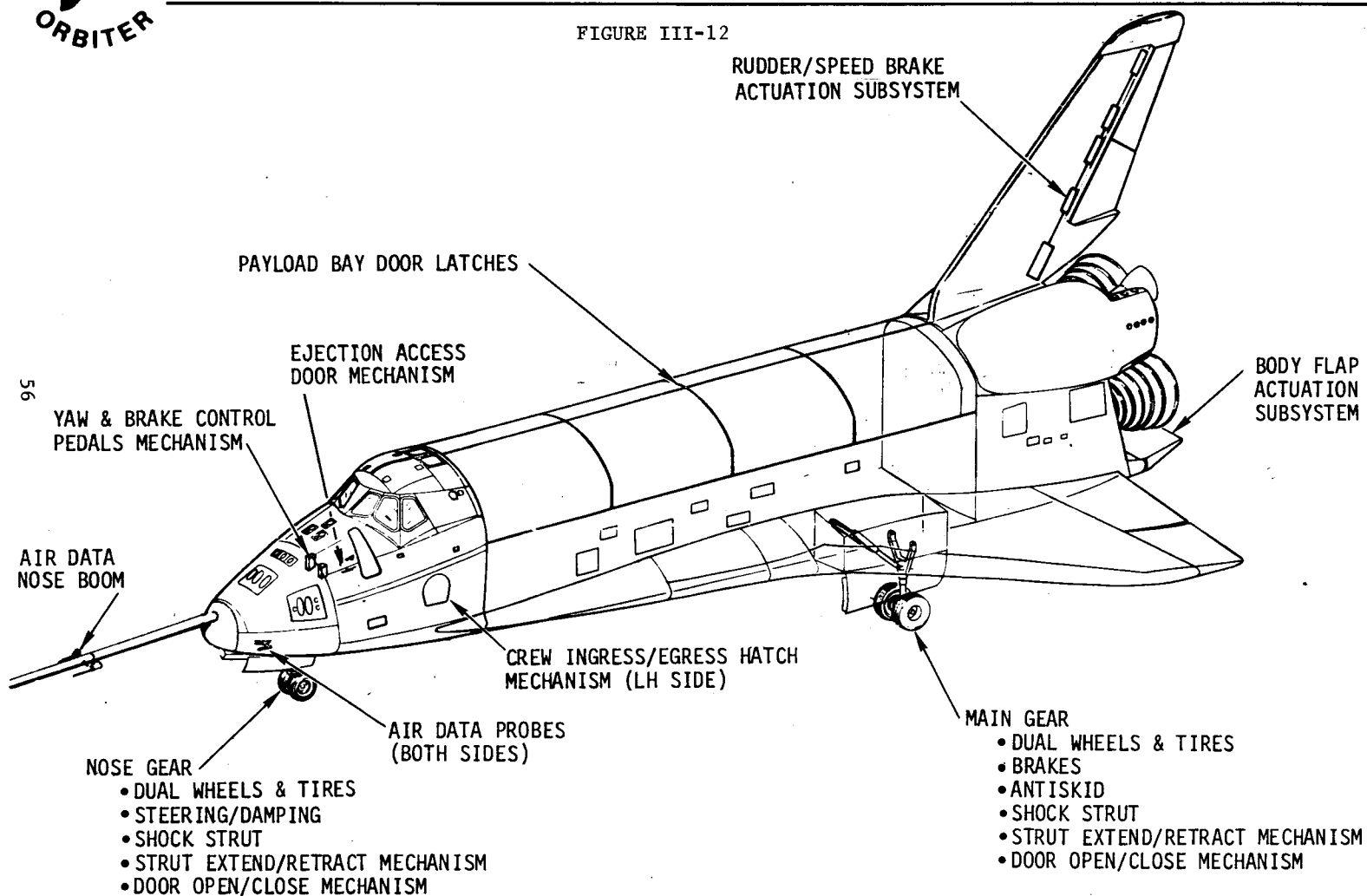
FIGURE III-11





# DCR OV 101 ALT MECHANICAL/ACTUATION SYSTEMS

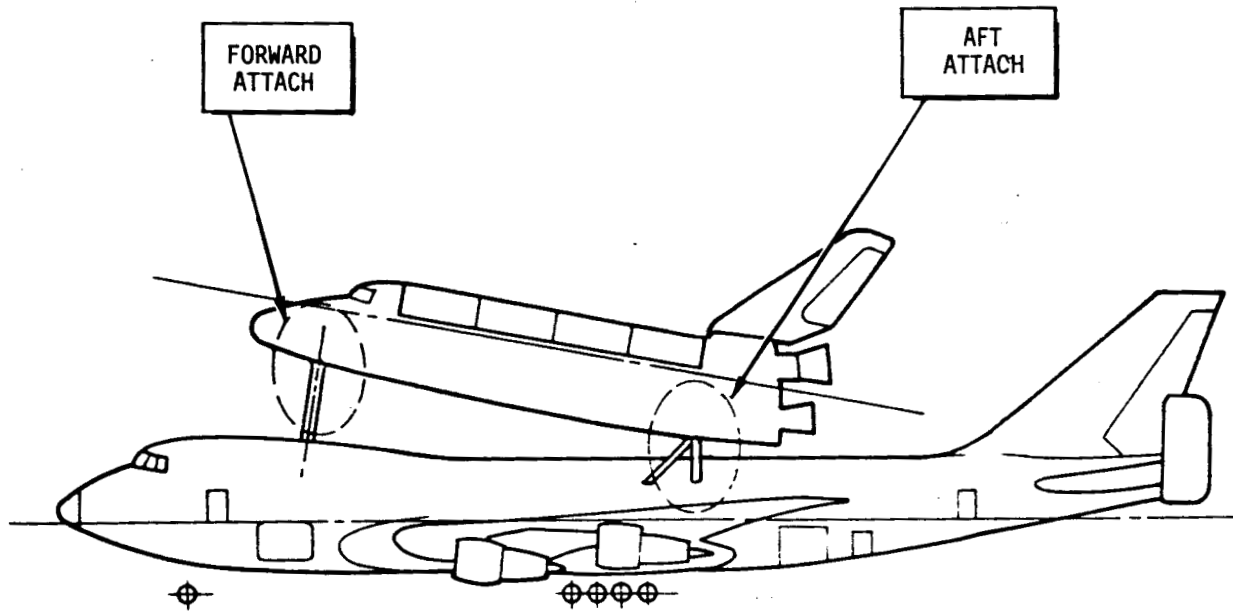
FIGURE III-12





DCR OV 101 ALT  
MECHANICAL SEPARATION SYSTEM

FIGURE III-13



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#### IV. SHUTTLE CARRIER AIRCRAFT, 747

##### A. Introduction

The basic 747 Model 123 aircraft was qualified in 1970 by FAA certification. Rockwell, the prime contractor, procured the services of the 747 manufacturer, The Boeing Company, to modify the vehicle to meet Shuttle requirements as an ALT carrier aircraft and as a ferry vehicle. Flight tests initiated on December 2, 1976 are currently being completed. Delivery to the DFRC site was made on January 14, 1977 in preparation for the first captive flight of the Orbiter set for February 18, 1977.

##### B. Observations

###### 1. ALT requirements/General and Specific.

The key technical requirements are in six areas: orbiter weights, stability and control, handling qualities, structures, environment and modification criteria. In addition, there are specifications for such things as the separation clearances after orbiter release, communications, and interfaces with ground facilities for mating purposes. Table IV-I provides a brief overview of the requirements of principal interest. The separation requirements are depicted in Figure IV-1 and the communications in Figure IV-2.

###### 2. Airplane Modifications

The modifications required to meet the ALT and Ferry requirements fall into two categories: (1) permanent modifications and (2) removable modifications. These modifications are shown in Figures IV-3 and IV-4. Permanent modifications are those made to the basic structure



and subsystems that remain with the airplane. These modifications certifiable by the FAA and are of a nature that the airplane configuration could be type-certificated for commercial use if required. The airplane presently is designed as a "Public Aircraft" and does not require FAA certification. Removable modifications have been made to the structure and subsystems in what is commonly called "kit" form. Design definition and verification of these modifications were obtained through a comprehensive analytical and test program which is described later on.

### 3. Design Verification

This work was accomplished through (a) utilization of the extensive commercial airplane data base available, (b) analysis wherever possible, and (c) the extensive use of wind-tunnel testing to support analyses. For those permanently installed modifications, FAA criteria and participation were used. Because the program is basing its needs on flight-proven concepts and qualified hardware components there was no developmental hardware, no qualification tests, and the final verification was accomplished at the system-level.

Qualification tests on orbiter interfacing hardware and government furnished equipment (GFE) were performed where required based on the use of common aircraft and shuttle orbiter designs and qualified hardware.

The wind tunnel testing was accomplished in the following phases: (1) Configuration Development Tests to define or refine the external geometry of the modifications, (2) Design Verification tests to verify that the design of the modifications and the mated

SCA/Orbiter configurations will be satisfactory for the performance of the ALT missions, and (3) Design Data tests to provide data required for detail design analysis of flight characteristics, performance, control capability, airloads, and flutter boundaries. The tests were planned to obtain data for the SCA alone, and for the mated configuration for ALT flights. Air launch aerodynamics data were obtained from a combination of SCA-alone data and proximity effects data. A total of 3470 occupancy-hours of wind tunnel testing was completed using models ranging from 0.03-scale to 0.046-scale for high and low speed work respectively.

Aerodynamic characteristics were developed for those 747 and the mated configurations pertinent to the ALT program. These characteristics formed the basis of the performance analysis, determination of flying qualities which included detailed pilot simulation studies, and evaluation of failure cases. Analyses were conducted to determine recommendations for the optimum launch sequence.

Stability and control analyses were also conducted using the basic aerodynamic characteristics. Primary and automatic flight control system detail design requirements were defined. Flying qualities were determined both analytically and by piloted simulation. Manual and autopilot performances under normal and failure conditions were verified by 1200 hours of simulation usage.

Flutter analyses were accomplished to verify that the 747 final design is essentially flutter free up to  $1.2 V_D$  which is equivalent to 1.44 times the dynamic pressure.  $V_D$  is the Design Maximum Velocity, indicated airspeed in knots. Wind tunnel tests indicate a minimum

margin of about 2.0  $V_D$ . The mated flutter analysis work should be concluded in January 1977 and the verification work on coupled modes should be finished prior to the first mated flight in February.

The 747 structural design loads were developed based on the FAA FAR 25 requirements "Airworthiness Standards, Transport Category," except as modified to allow safe and efficient operation of the basic airplane during orbiter ALT flights.

Systems tests consisted mainly of the vehicle/system functional checkout and acceptance tests, major ground tests, and flight tests. Vehicle/system functional checkout and acceptance tests verified form and fit for all removable structure as well as subsystem end-to-end operability and performance. The major ground tests performed included a ground vibration test or modal survey and an electromagnetic compatibility test. Flight tests currently in progress will complete the verification testing prior to mating with the orbiter for ALT and will demonstrate airworthiness of the 747. Principal test objectives include checks on flutter, stability and control in both the manual and the automatic flight control modes, performance, loads and buffet .

#### 4. Major Areas of Concern

To assure safety of flight and successful ALT missions the following items are to be followed in detail.

The buffet effect of the orbiter (tailcone-off) on the aft sections of the 747 may limit the crew capability because of excessive 747 cockpit vibration. Tailcone-on flight (the greatest number) do not present a concern due to buffet. The 747 crew must have absolute control over the aerodynamic controls and displays at the time of separation of the orbiter

from the 747 to assure proper and safe operation. Current calculations, based on available data, indicate that the 747 structure fatigue life is about 50 hours of mated flight (Tailcone-off) particularly in aft sections of the 747. Flying qualities are expected to be somewhat degraded due to the mated conditions.

To meet these concerns a number of steps are being taken, including:

- a. Instrumentation is installed to monitor loads and stresses.
- b. Critical structure is inspectable and relatively short flights are to be followed by inspections.
- c. Incremental flight test program allows gradual expansion of the flight envelope and permits a greater understanding of the adequacy of the structures after each flight.
- d. Current tailcone-off ALT flight plans call for less than 10 hours of flight time, depending upon the impact of initial tests and actual flights.
- e. Full-scale buffet can be evaluated at lift-off and the 747/orbiter landed immediately on the dry lake bed if buffet is excessive.

##### 5. Special Areas of Certification

This deals with the details of the separation panel, communication interface unit, S-band transceiver/antennas and the load measurement system as well as the government furnished equipment. The government furnished equipment is discussed briefly here, while those interfaces with the orbiter are discussed under the orbiter section of this report. GFE (government furnished equipment) includes the 747 crew bailout or escape system, L-Band telemetry equipment, C-band beacon, UHF radio and the separation camera.

The crew escape system relates directly to the 747 crew safety during the ALT program. The design concept was discussed and accepted in the Panel's previous Annual Report and only the pertinent areas are mentioned here along with the verification results to date.

The basic system must provide depressurization of the 747 crew areas and evacuation route within 5 seconds to preclude any adverse impact on crew movement or on the escape-chute system. At the same time this is happening an opening is cut in the lower fuselage and an aerodynamic spoiler is extended. The escape system uses standard, developed, Air Force hardware. All pyrotechnic components have been through military qualification testing. The verification method is as shown in Table IV-II and the certification plan as shown in Table IV-III.

TABLE IV-I

OVERVIEW OF REQUIREMENTS (747 Aircraft)

Orbiter Weights	performance requirement      150,000 lb to 170,000 lb launch altitude baseline      152,000 lb structural design                192,000 lb
Structures	commercial airplane design loads criteria per FAR #25 - minimal deviations only for maneuver load factor for ALT of 2.0 - ultimate crash load factors of forward            6.0 aft                 1.5 side                1.5 down               3.75 up                  1.5 - fatigue life based on Orbiter tailcone on mated flights. Fatigue to allow 55 ALT Flights and 265 ferry flights. - fail-safe design except 747 nose gear and orbiter support structure
Handling Qualities	When Orbiter is mated, the carrier aircraft is: - safe operation with all stability augmentation failed - controllable during take-off and landing in 15 kt x-wind - controllable with one orbiter rudder hardover - controllable with critical 747 engine failed.

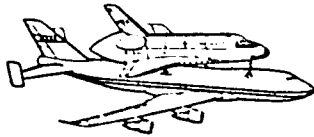


TABLE IV-II

CERTIFICATION INDEX  
for the 747 Escape System

ITEM	COMPONENT TYPE			NO. OF TESTS	ENVIRONMENT			
	STRUCTURAL	EXPLOSIVE FUNCTIONAL	NON-EXPLOSIVE FUNCTIONAL		TEMPERATURE	VIBRATION	SHOCK	LOAD
INITIATION ASSEMBLY		X		—	S	S	S	S
SAFETY COVER			X	—	A	A	A	A
SAFETY HANDLE		X		—	S	S	S	S
TIME DELAY (3.00)		X		—	S	S	S	S
TIME DELAY (0.300)		X		—	S	S	S	S
WINDOW BURSTER ASSEMBLY		X		15	T	A	A	A
EGRESS PORT CUTTER		X		6	T	A	A	A
RIB CUTTING S/A		X		19	T	A	A	A
STRINGER CUTTING S/A		X		19	T	A	A	A
EXPLOSIVE VALVE		X		11	S	S	S	A/T
ACCUMULATOR			X	11	S	S	S	A/T
BOX, TAMPER PROOF			X	—	A	A	A	A
SPOILER ASSEMBLY	X		X	11	T	T/B	T/B	T/B
LINEAR ACTUATOR			X	4 x 11	T	T	T	T
ESCAPE TUBE INSTL			X	—	—	B/D	B/D	B/D
747 STRUCTURE	X			—	—	D/B	D/B	D/B
GUIDE RAILS			X	—	—	D	D	D

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CERT CODE: T = TEST  
S = SIMILAR  
A = ANALYSIS  
B = ANALYSIS  
D = ANALYSIS

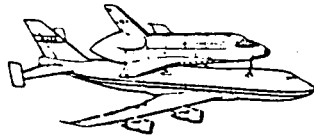
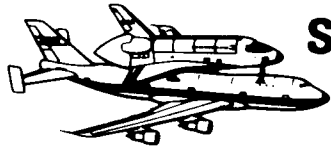


TABLE IV-III  
 VERIFICATION METHOD  
 for the 747 Escape System

	MIL QUAL TEST	ANALYSIS	TEST
• PYROTECHNIC COMPONENTS	T/McS *		T/McS
• SPOILER/THRUSTER ASSEMBLY		T/McS	T/McS
• WINDOW BURSTERS		T/McS	T/McS
• ESCAPE HATCH CUTTER		T/McS	T/McS
• AIRCRAFT FLOOR BEAM MODS		DFRC	
• ESCAPE TUBE INSTALLATION		DFRC	
• GUIDE RAILS		DFRC	
• DEPRESSURIZATION CYCLE		JSC/BOEING	
• AIRCRAFT STRUCTURAL INTEGRITY		BOEING	

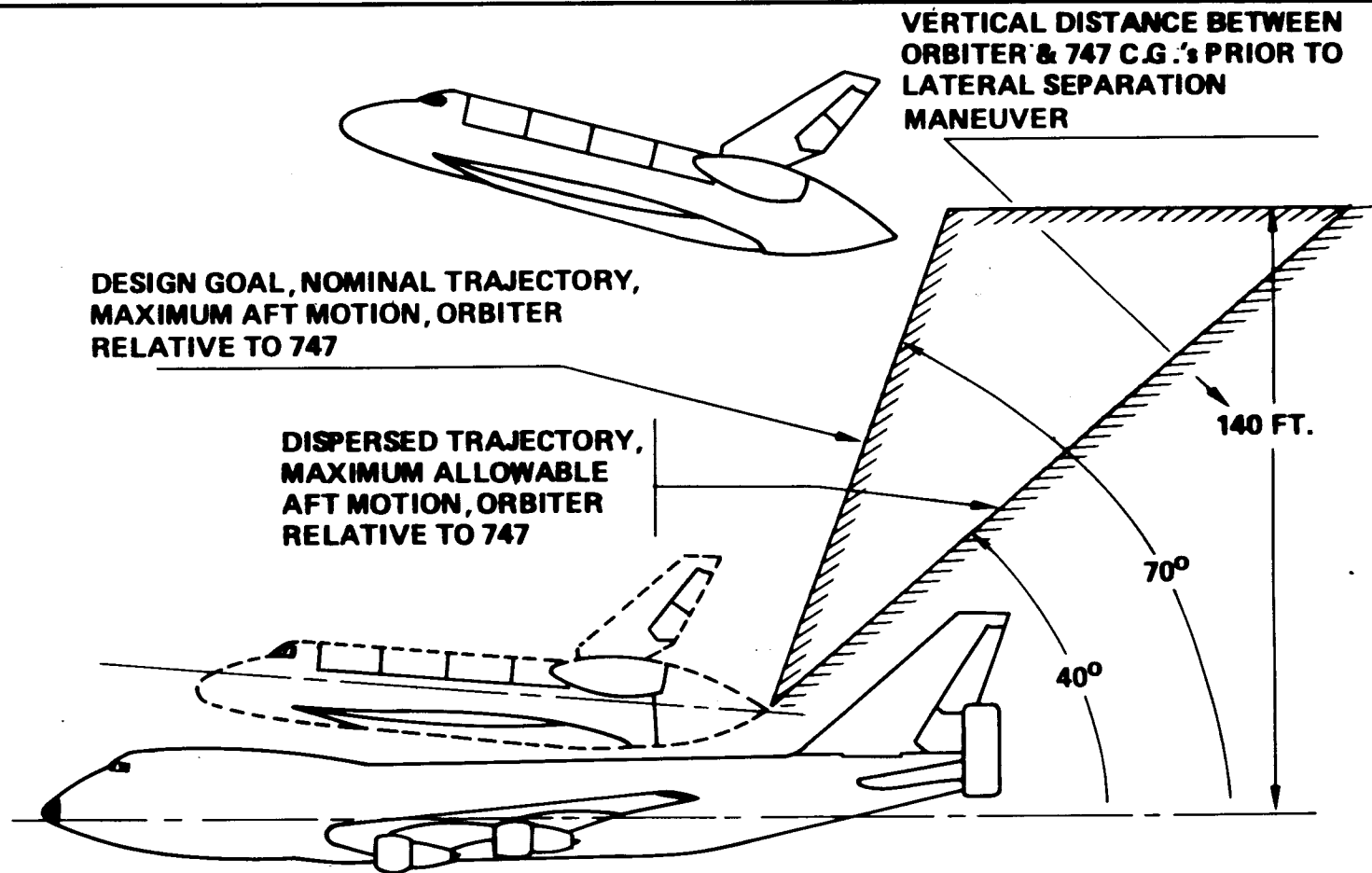
\* Teledyne McCormack Self Company





# SEPARATION CLEARANCE DESIGN REQUIREMENTS AND GOAL

FIGURE IV-1



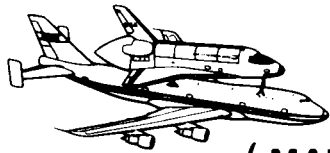
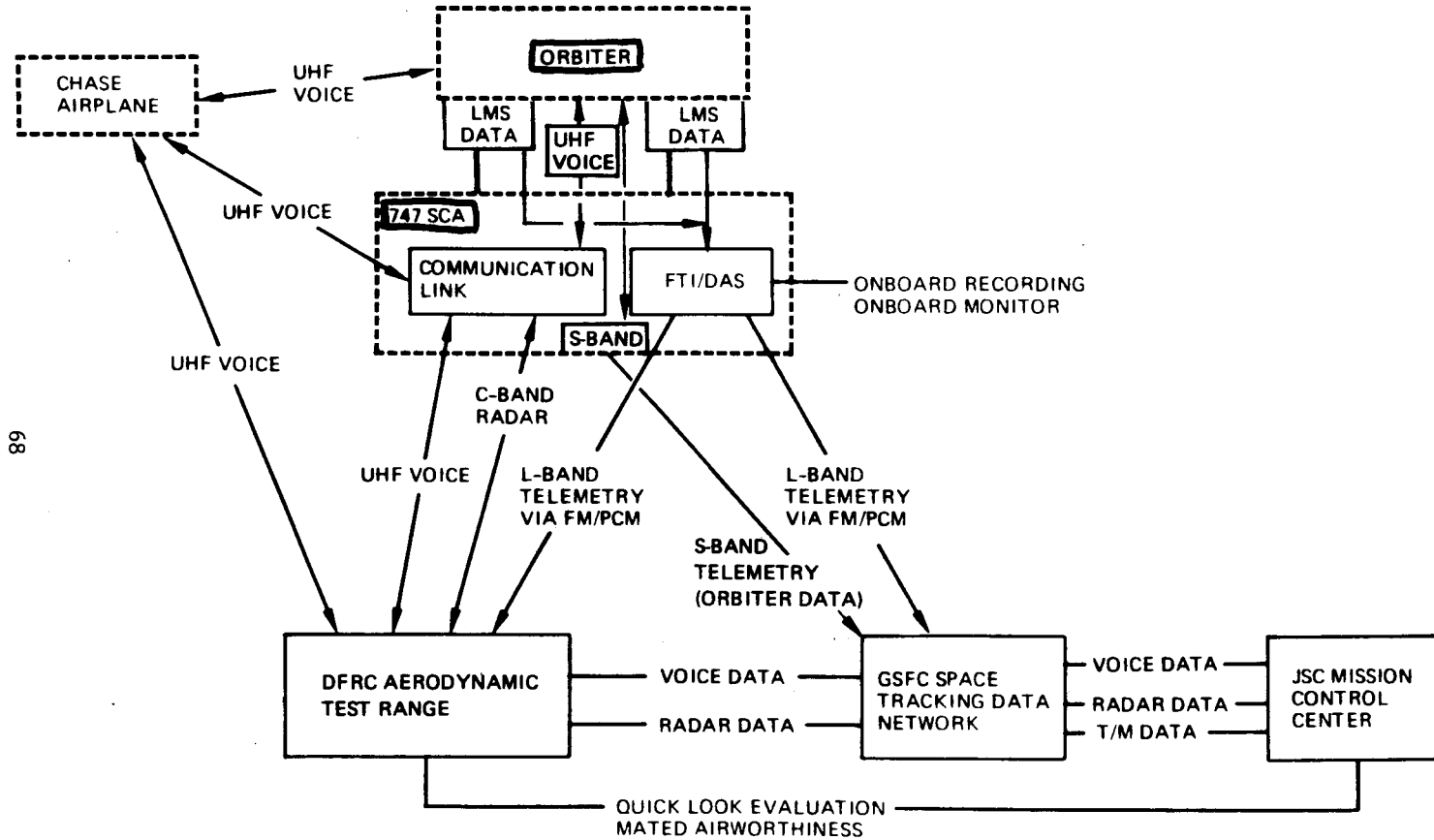


FIGURE IV-2A

# AIR-TO-AIR & GROUND COMMUNICATIONS INTERFACES

( MATED 747 SCA TESTING – POWERED/MANNED ORBITER )



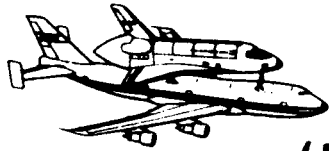
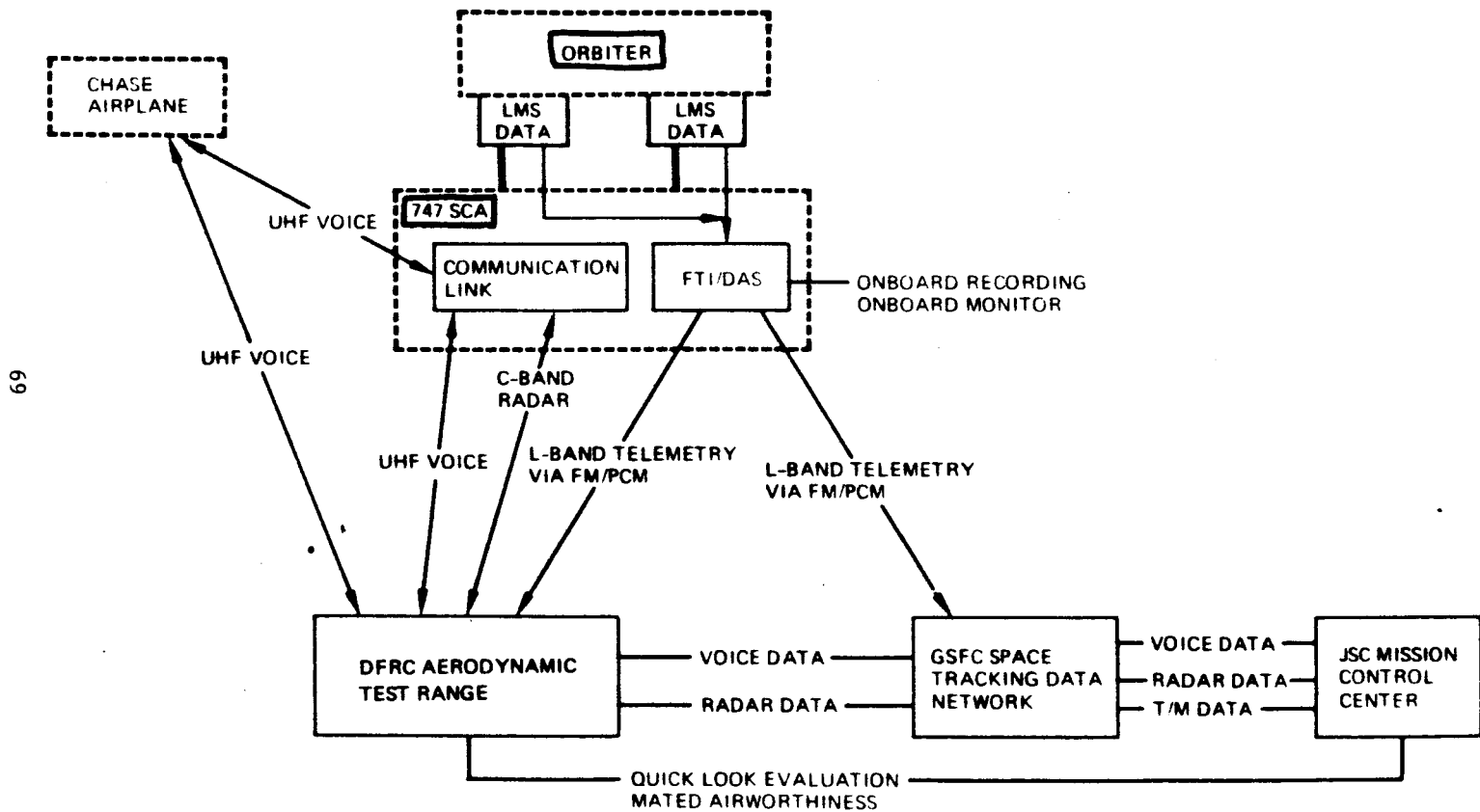


FIGURE IV-2B

# AIR-TO-AIR & GROUND COMMUNICATIONS INTERFACES (MATED 747 SCA TESTING – UNPOWERED ORBITER)



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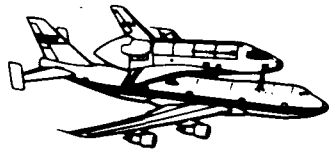
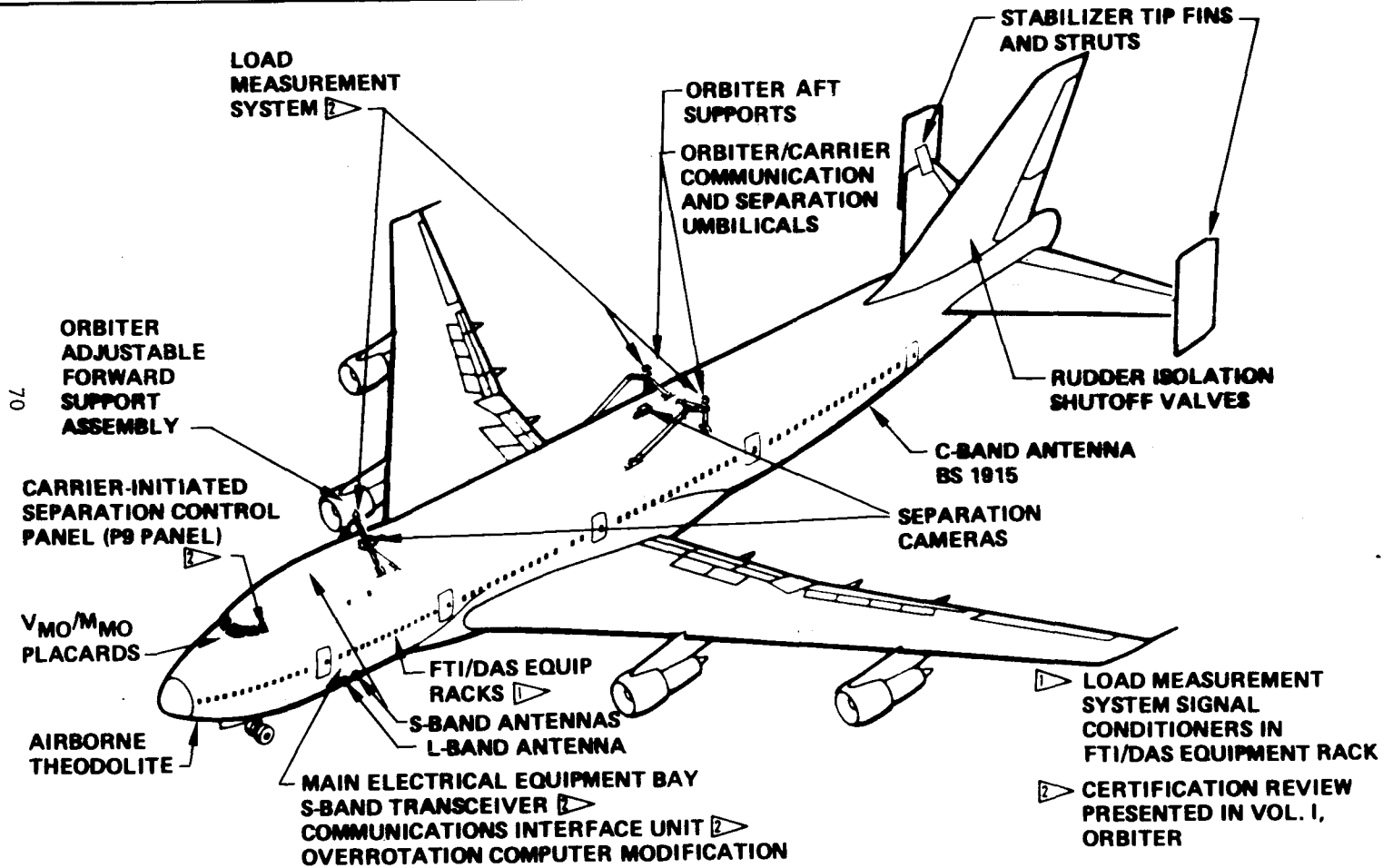


FIGURE IV-3

# REMOVABLE AIRPLANE MODIFICATIONS



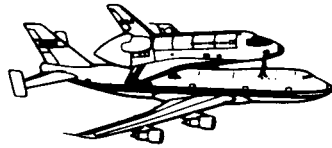


FIGURE IV-4

## PERMANENT AIRPLANE MODIFICATIONS

### AIRPLANE SYSTEMS REVISIONS

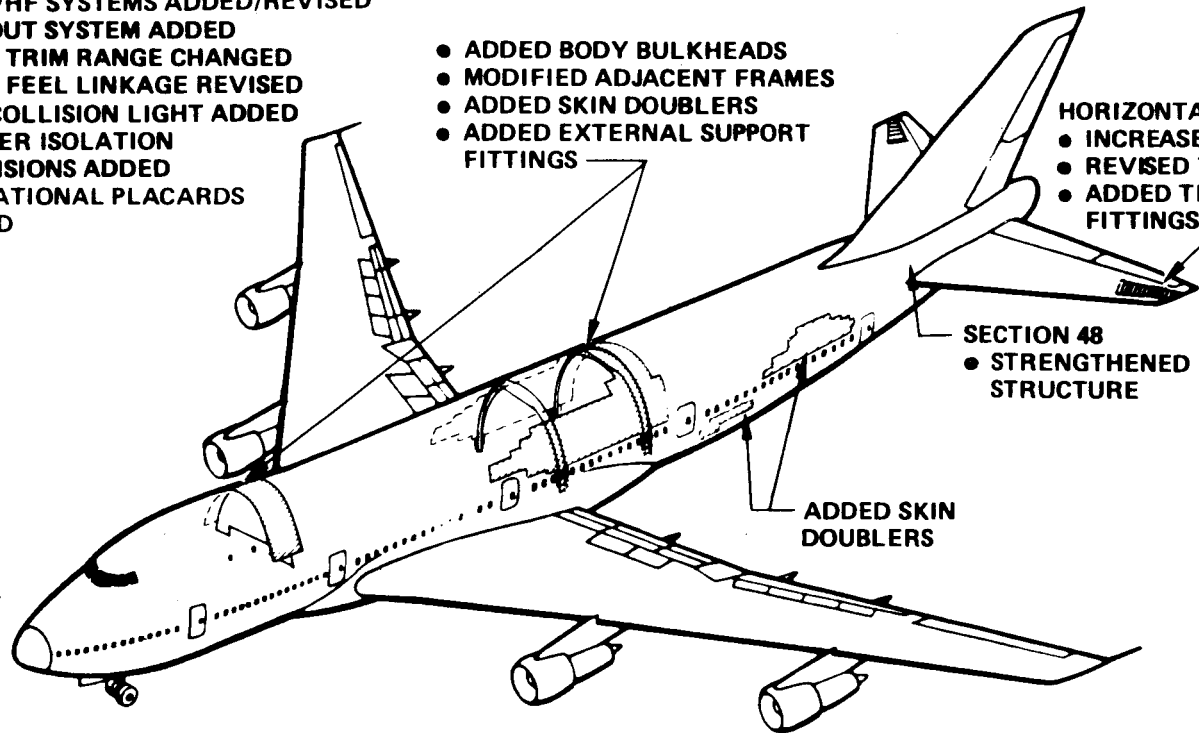
- ENGINES UPGRADED TO JT9D-7AH
- ENVIRONMENTAL CONTROL MODS
- CIRCUIT BREAKERS & SWITCHES ADDED
- SIDESLIP SYSTEM ADDED
- UHF/VHF SYSTEMS ADDED/REVISED
- BAILOUT SYSTEM ADDED
- PITCH TRIM RANGE CHANGED
- PITCH FEEL LINKAGE REVISED
- ANTICOLLISION LIGHT ADDED
- RUDDER ISOLATION PROVISIONS ADDED
- OPERATIONAL PLACARDS ADDED

- ADDED BODY BULKHEADS
- MODIFIED ADJACENT FRAMES
- ADDED SKIN DOUBLERS
- ADDED EXTERNAL SUPPORT FITTINGS

- HORIZONTAL STABILIZER
  - INCREASED SKIN GAGE
  - REVISED TIP RIBS
  - ADDED TIP FIN ATTACH FITTINGS

- SECTION 48
  - STRENGTHENED INTERNAL STRUCTURE

- ADDED SKIN DOUBLERS



## V. ALT OPERATIONS

### A. Introduction

Much of this area has been covered in other sections of this report. ALT planning, procedural and implementing documents have been discussed in Section II. This section covers only those activities conducted at the Houston Mission Control Center and at DFRC which support the ALT missions. This area comes under discussion again in Section IX, "Configuration Management." Thus, this section will be very brief.

### B. Observations

The ALT functional organization is shown schematically in Figure V-1.

#### 1. ALT Scheduling and Status Monitoring

This area as required for ALT is to be performed under a manual system. Schedules will be maintained for three levels, as well as any supplemental level deemed necessary.

The first is the ALT program schedule which encompasses the entire ALT program with sufficient detail to show each flight, each ground turnaround, each major ground test period, and each NASA controlled and ALT planning milestone.

The ALT Planning Milestones that control ALT scheduling and status monitoring system is defined in APD No. 121, dated October 19, 1976. These milestones start with the 747 on-dock at DFRC on 1/14/77 and go through completion of free-flights with tailcone off on 1/13/78. These dozens of milestones actually cover from 11/1/76 through 3/17/78.

The integrated ALT work schedule then plans for a 14 working day duration (72 hours/11 days) including all ALT milestones within those 14 working days, and all element interaction and external interface milestones derived from Element Work Schedules. This integrated schedule is to be published each working day. The third level of scheduling provided the Element Work Schedule which support the Integrated Schedule. Finally, a recovery schedule is established when necessary because of difficulties in meeting the next ALT Planning Milestone in the Integrated ALT Work Schedule or the ALT Program Schedule does not provide accurate schedule information.

## 2. ALT Management

The management structure includes the Manager DFRC ALT operations, Active Orbiter Flight Director, and the Orbiter Ground Operations Manager.

The documents that deal directly with the day-to-day operations both at JSC and at DFRC in support of the ALT mission include:

- MI-108 Customer and Contractor C/O Support functions
- 112 Operational Support and Documentation System
- 113 ALT Ground Operations Scheduling Activities (ISSUED)
- 118 ALT Control Room Operations
- 120 ALT Support Coordination (ISSUED)
- 304 Performing Flight Readiness Review

Only about one-sixth of these have been issued at the time of this writing.

### 3. Mission Rules

As in all missions, a set of mission rules are established which specify what is to be done (the decisions are pre-selected) for a specific set of events which are off-nominal. These have been thoroughly analyzed and tested both on paper and in simulations to assure known results. These mission rules are provided for each phase of the flight, i.e., mated inert taxi tests, mated prior to take-off, mated takeoff, after takeoff, inflight, and so on to final position after landing. Typical of such rules for that period of flight immediately after takeoff would include:

- If the landing gear doors are found to be open or gear will not retract the decision is to abort the mission.

- If there is a single blown tire on the 747 an inspection is to be made by the proper chase plane to ascertain the exact condition and if no other damage is discernable either by chase or by displays onboard then the mission may continue as a nominal mission.

Such rules are developed for each critical area. For instance the hydraulic systems may have mission rules which establish five basic decisions which can be effected depending upon how many hydraulic systems are lost on the 747. These five decisions are: emergency jettison of the orbiter 101; abandonment of the 747; abort the mission and return to the base; continue the flight in a reduced environment (minimize stresses); or continue the flight as scheduled. Thus with the loss of one, two or



three 747 hydraulic system the decision would be to abort the mission and return to the base, while with the loss of all four systems the decision would be to abandon the 747.

#### 4. Contingencies Operations

The thoroughness of the planning for ALT flights is demonstrated by the contingency operations plans whose objectives are manifold to assure that everything that can be done will be done. The objectives in chronological order if you will are: preserve life/minimize injuries; preserve vehicles and property; secure the contingency landing site; secure all possible information relating to the incident; and assure administrative actions are taken as required including the appointment of an appropriate review board for investigations.

There are two categories to deal with: (1) abnormal test vehicle condition (OV-101, 747, or both) which has produced or is resulting in substantial damage to the test vehicles and/or injury to personnel, (2) Accident or incident involving damage to facilities or equipment other than the test vehicles. These are covered in the ALT Contingency Plan and by appropriate NASA Agency documents, particularly NHB 1700.1 and NMI 8631.1B.

#### 5. Other Areas of Operations

The post flight data reduction analysis and reporting system includes the DFRC "quick-look" program, The Boeing Company program which is to be utilized only through the captive inert flights, all of which is to provide summary reports to the ALT manager and his people within 24 hours.

Such reports will contain such things as the objectives accomplished, the crews comments, engineering comments, and a thorough problem assessment.

Emergency jettison of the inert orbiter, if it were ever to be necessary, has been examined to assure that the limits of such actions are known. Wiring and controls are provided so that the 747 crew can initiate the jettison of the orbiter if such a contingency should occur. Analyses and simulations have been conducted to assess the procedures, jettison capability, and the best orbiter elevon fixed position. NASA/DFRC pilots, as well as others, have participated in the "man-in-the-loop" simulations. As a result of these activities the following results are known so far:

(1) Successful emergency jettison is very sensitive to the position of the orbiter's elevon, and that increased negative or up elevon improves clearance for inert flights. Based on the best available data at this time it appears that nominal separation requires at least a zero-degree elevon to preclude collision. Thus for the ALT inert flights the -1 degree up-elevon was selected to assure a safe emergency jettison for nominal conditions and a 50% of uncertainty range.

(2) The airspeed range over which a successful emergency jettison can be performed range from 200 KnotsCAS to the 747's  $V_D/M_D$  limit speed. Additionally, 747 pushover is required at lower airspeeds to provide positive relative normal acceleration.

(3) The jettison altitude is not significantly constrained, except

that an altitude loss of 2000 to 3000 feet may occur prior to 747 recovery after the release. The jettison time required is about 6 seconds.

(4) The steps to be taken upon the declaration of an emergency situation requiring orbiter jettison go something like this:

Left Seat Pilot

"Chop" the throttles

Deploy the speedbrakes

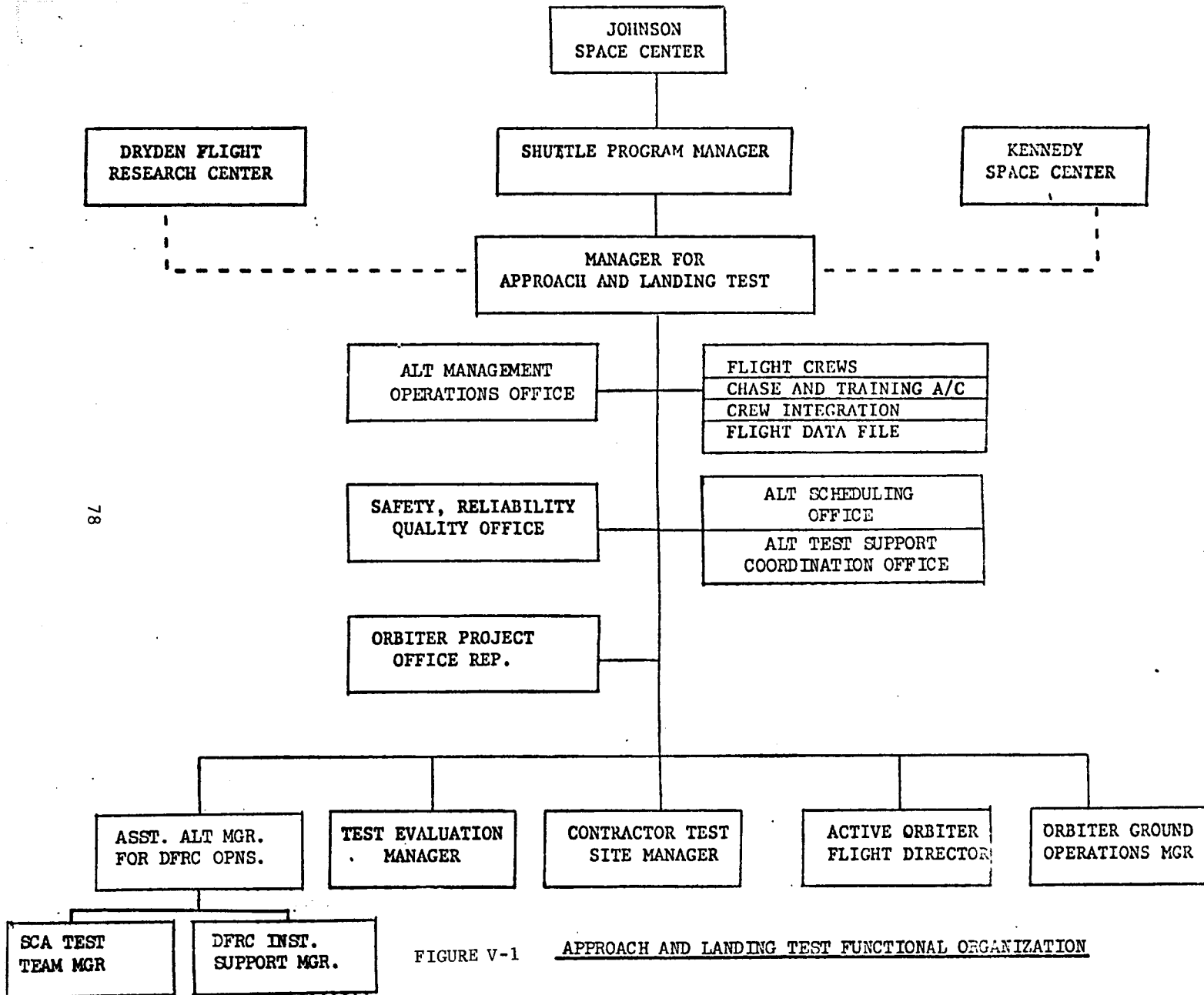
Perform a pushover @ 0.3g

Maintain the pushover for the proper time (6 seconds)

Right Seat Pilot

Arm the jettison system on panel P9

As the 747 engines approach idle initiate jettison through Panel P9



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FIGURE V-1

APPROACH AND LANDING TEST FUNCTIONAL ORGANIZATION

## VI. GROUND FACILITIES

### A. Introduction

The Shuttle Master Verification Plan states that Ground Support Equipment (GSE) must undergo formal certification by test or analysis where the expected environmental conditions, operational constraints, or the significance of a hardware failure indicate it is necessary to assure an appropriate level of confidence in the GSE beyond that provided by acceptance testing. The responsible GSE design group identified the ground support equipment and the appropriate test/analysis plan, procedures and implementation initiated. They identified for Orbiter 101 five models (sets) of quick disconnect filter assemblies for the APU, NH<sub>3</sub> servicing, ground cooling, freon servicing and waste disposal, and PRSD/FCP. All of these have been certified.

### B. Observations

#### 1. Key Orbiter GSE Management Documentation

There are a number of directives and implementation documents which guide the development and qualification of the ground support equipment. They key items are listed in Table VI-I.

A key to providing GSE and facilities on-time and in adequate configuration to meet the ALT/OFT/Operational needs is strict Configuration Management (see Section IX).

#### 2. Safety Requirements on GSE

From the viewpoint of safety of operation, ground equipment is considered in the same light as flight equipment. To achieve this a number of steps are taken:

a. A Safety Critical Item List (CIL) is established as described in NASA NHB 5300.4 (ID-1). The policy requires hazard analyses to identify a potential hazard and their resolution as well as the safety requirement verification which calls for test-to-safety margins.

b. Each end item is reviewed by NASA and Contractor through formal design reviews which utilize the RID system to assure that issues are identified and formally resolved.

c. A functional end item verification is performed at the completion of the end item fabrication. When that is completed an integrated schematic verification is also made.

d. Other steps in the certification process include the station set validation of the GSE-to-Vehicle interface, the update of configuration acceptance readiness reviews, and the Flight Readiness Review.

The current plan for GSE to support the ALT program calls for use of Station Set 16 and transfer of much of the GSE used with Orbiter 101 at Palmdale ("Caravan GSE").

### 3. Facilities

The team reviewed the Approach and Landing Complex and flight operations support facilities at DFRC and JSC.

#### a. DFRC

The basic items supplied to DFRC by KSC for use in the ALT include facilities, communications systems and the mate/demate device, plus certain government furnished equipment. In addition KSC supplied

the requirements for fixed facilities at DFRC as to the tow-way, shuttle hanger, mate/demate device foundation, facility AC power, emergency power, fire protection and hazardous storage areas, hoists, microwave tower and other items. The ALT complex facilities were accepted from the contractor on August 16, 1976 after acceptable completion of all testing. Open items still exist, but are to be closed during the January/February time period for support of the ALT missions as required.

The Mate/Demate Device, since it is unique to NASA experience, is probably of interest to the reader and should be described briefly.

- (1) It has a lifting capacity of 225,000 pounds.
- (2) Its structure is designed for maximum winds of 125 mph at the 30 foot level.
- (3) Lateral controls will hold Orbiter steady in a 12 knot wind.
- (4) There is positive lifting control by three 50-ton hydrosets.
- (5) There is a deluge system for spills of hazardous materials.

The communications arrangement for working at DFRC includes an operational intercommunications system, a radio frequency communications system, and a paging/area warning system. This covers the local area and also supplements the DFRC-to-Palmdale 2-wire system with an 11-channel, 4-wire system.

The 747 equipment for maintenance and flight support includes

standard 747 ground support equipment (GSE) and the Flight Monitor Room and Telemetry Processing Area at DFRC. It is in effect a mission control room for the 747 up to the interface with the Orbiter. It also supplies the direct interface communications between DFRC and JSC and its mission control center. The communications at DFRC include:

- (1) Air to ground.
- (2) Local ground data flow.
- (3) Tracking data system.
- (4) Telemetry monitor system.
- (5) Chase Plane/Trailer/Long Range Optics Television system.

While at DFRC the 747/Orbiter will undergo a Mated Ground Vibration Test (MGVT). The details of this test have not been reviewed by the Panel.

b. JSC

Flight Operations Support has specific areas of responsibility, as shown in Figure VI-1. The ALT Mission Control Center has been located on the third floor, Building #30 at JSC. The following functions are contemplated: telemetry processing, track processing, communications, television, with displays to cover all systems and follow all operations on a real-time basis with memory and data playback. The system capability is for an update rate of once per second and to process 1,330 parameters and record 125 events. It needs to be on time to support the February unmanned Orbiter mated flight and fully operational for the fully operational Orbiter in March.



c. Communications and Data System

The importance of this portion of the facilities to be applied to both the ALT and OFT programs cannot be overemphasized. In this area the orbiter is one of the key elements along with the ground segments of the communications and data system. The elements of the system are not all brought into operation at one time, rather they are phased into operation as they become required. Thus for the ALT program the requirements include the orbiter, DFRC, one STDN (Space Tracking and Data Network) site, GSFC and the Mission Control Center at JSC. The first three OFT flights as presently conceived do not require DFRC, but add the Launch and Landing requirements affecting KSC and MCC (mission Control Center) plus an additional ten (10) STDN sites. The remaining OFT 4-6 flights require the Tracking and Data Relay Satellite and its ground station added to that already used on OFT 1-3. The Orbiter itself adds capability in the same way, e.g., during ALT it uses modified S-band system, for OFT 1-3 it uses the S-Band PM and FM system, then going to the S-Band (PM and FM) plus Ku-Band system adding payload interface requirements as needed. The major development effort for the OFT MCC will start about the middle of FY 1978.

TABLE VI-I

Key Documents for GSE

I. Directives

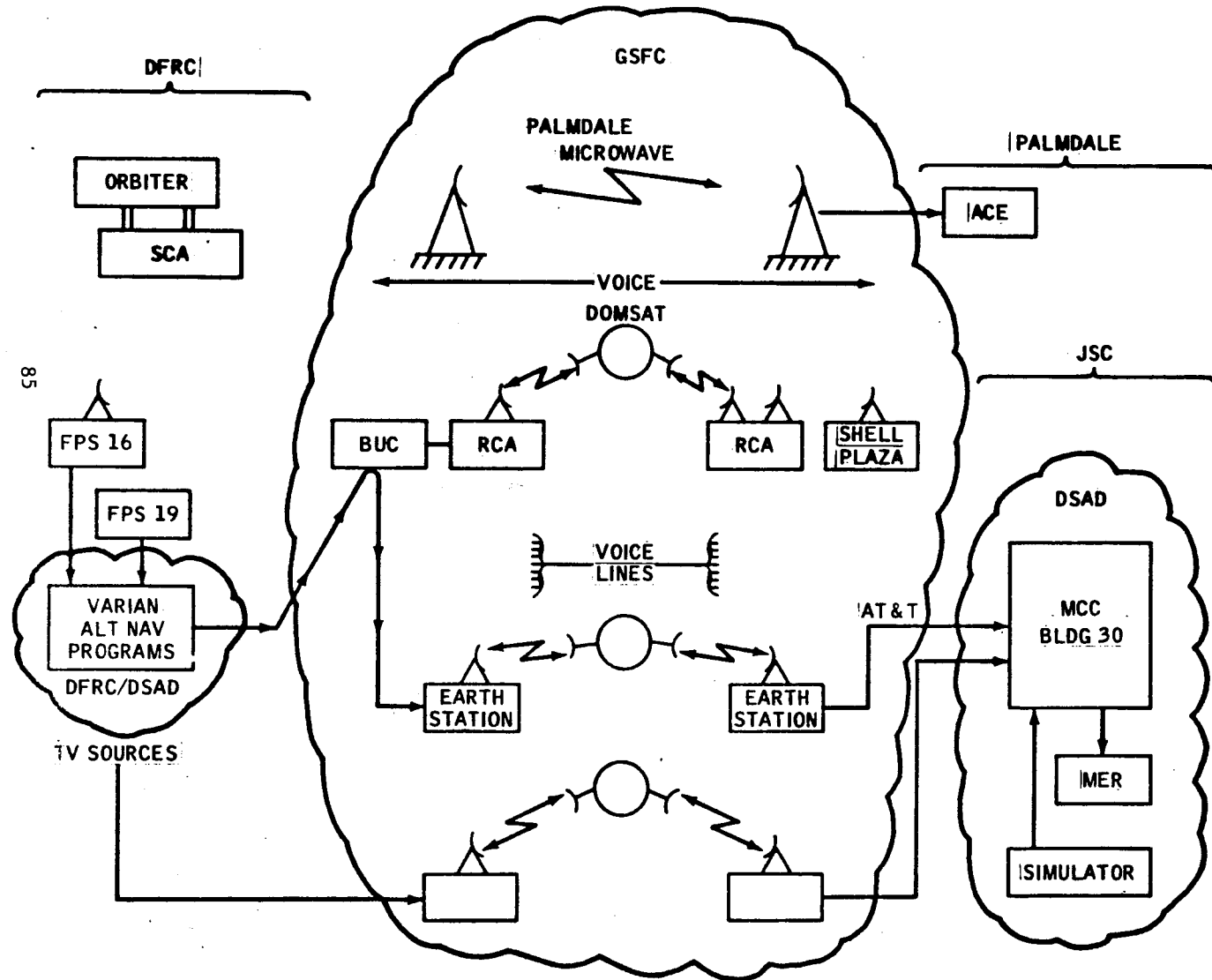
- A. Level II Specification, JSC 07700, Volume X "Flight and Ground Specification"
- B. Space Shuttle Program Directive #19, "Ground Systems Support Equipment Design and Control System."
- C. Space Shuttle Program Directive #71, "Ground Operations Panel"
- D. Space Shuttle Ground Support Equipment Integration Plan, JSC 08110

II. Implementation

- A. Orbiter GSE Management Plan
- B. GSE requirements definition document (RDD)
- C. Abbreviated item description sheet
- D. GSE utilization List (GUL)
- E. Station Set Specifications
- F. GSE Design Requirements, SW-E-0002

# FLIGHT OPERATIONS SUPPORT AREAS OF RESPONSIBILITY

FIGURE VI-1



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## VII. TRAINING THE GROUND AND FLIGHT CREWS

### A. Introduction

The Panel reviewed the experience, training and competence of personnel. As in reviewing past programs, the Panel has focused on skill retention and morale among the ground and manufacturing personnel as well as the degree of training received by the flight crews in the unique aspects of mission operations.

A review of training must consider that tight schedules historically seem to generate more human errors resulting in equipment failures and mission anomalies than one might expect from the design of the hardware and software themselves. Thus training must be designed with this in mind to minimize such problems.

### B. Observations

The observations for this segment of the report are reported in Volume I of the Panel's report. They deal mainly with the flight crew training at this time, and apply to the Approach and Landing Test Program only.

Flight crew and flight controller training was covered to some degree in the Panel's last annual report. The current status of development of the simulators and trainers are:

1. The orbiter aeroflight simulator (OAS) for the Approach and Landing Test has been in use since November 1976. It can be tied into the Mission Control Center for integrated simulations. The Shuttle

mission simulator (SMS) to be used for the Orbital Flight Test Program and operational missions is expected to be in use in April 1978. The OAS motion base crew station is to be updated upon completion of the Approach and Landing Test program and will become an integral part of the SMS. The SMS will be tied in with the Mission Control Center for integrated simulations. The Shuttle Mission Simulator moving base and fixed base crew stations will initially provide forward flight deck training only. The fixed base crew station will be upgraded later on to provide full flight deck training capability by at least the third manned mission.

2. The part task simulators include (a) crew procedures evaluation simulator, (b) shuttle procedures simulator, (c) spacelab support module simulator, (d) the interim upper stage simulator, and (e) the single systems trainer which has only been conceptually defined at this time. The spacelab and upper stage units are not expected to be in use until the 1979-80 timeframe. The other two, "a" and "b", are now in use.

A directive has recently been issued (JSC SSPD #75) to ensure the establishment and effective formal configuration control of the 1-G trainers, neutral buoyancy trainers, training devices, and related trainer facilities. This will keep the configuration up-to-date and responsive to the most current requirements.

An area that will be exercised to assure the highest possible level of capability is that of post-test data reduction and analysis.

This is bound to be a problem in both ground test and checkout as well as in post-flight operations because the amount of material to be processed is so large. Procedures and how they are to be implemented as well as dry runs should help to keep this problem in hand.

The ALT ground team training has been going on concurrently with the work being performed at DFRC in readying the ground and flight hardware for the ALT flight. The ALT ground training plan was developed by KSC, since this area comes under their cognizance, and was issued as document K-SM-12.5.01. Personnel requiring specific training in certain skills have been recertified through a series of intensive courses which are 100% complete. Special areas such as those handling toxic fuels and requiring emergency egress procedures on the ground have been the subject of training and are 100% complete. To assure that the ALT turnaround schedules can be met the crews have been trained in each of the steps involved. There is of course no substitute for the "real thing" which will enhance the skills which the ground crews already have obtained.

The Shuttle Carrier Aircraft (747) Test Team (SCATT) is a mix of DFRC, Rockwell, Boeing and JSC personnel. They have participated in the 747 test program planning, they were involved in the windtunnel and post modification testing and are the Flight Control Room Monitors at DFRC. The SCATT members also participated in the mated ground vibration test program, the taxi tests and any other area that dealt with the flight of the 747. Through a series of detailed reviews

these skilled technicians and engineers covered such areas as: flight test requirements, real-time monitoring, the DFRC control room setup, 747 and orbiter operational limits, flight crew and training requirements, and the mated inert flight plans and contingency procedures.

The flight crew training has been detailed and intense over the past two years. The pilots and flight engineers have gone through the American Airlines 747 ground training schools and simulators, FAA 747-type ratings, current American Airlines refresher courses at the ground school and the flight engineers school and simulators. An example of the flying experience brought to the ALT program:

<u>PILOTS</u>	<u>Total Hours</u>	<u>747 Hours</u>	<u>747 Landings</u>
	12,800	114	90
	6,100	51	73
	9,450	55	61
	9,575	4	5
	<u>14,450</u>	<u>38</u>	<u>47</u>
total	52,375	262	276

<u>FLIGHT ENGINEERS</u>		
	1,025	115
	2,625	105
	3,250	8
	3,000	8

The "chase" pilots have also been heavily involved in training for the ALT flights. The Chase procedures have been established and briefly they are that Chase #2 and #3 are to take off before the mated 747/orbiter, while Chase #4 will takeoff after. Two additional planes, Chase #2A and #3A will relieve the #2 and #3 planes at a pre-determined point in the ALT mission. The Chase pilot training includes attendance at the Orbiter ground school at JSC, the 747 ground school at DFRC, having the chase pilots involved in all crew briefings given for the 747 and orbiter crews. A schematic of chase-plane positioning is shown in Figure VII-1



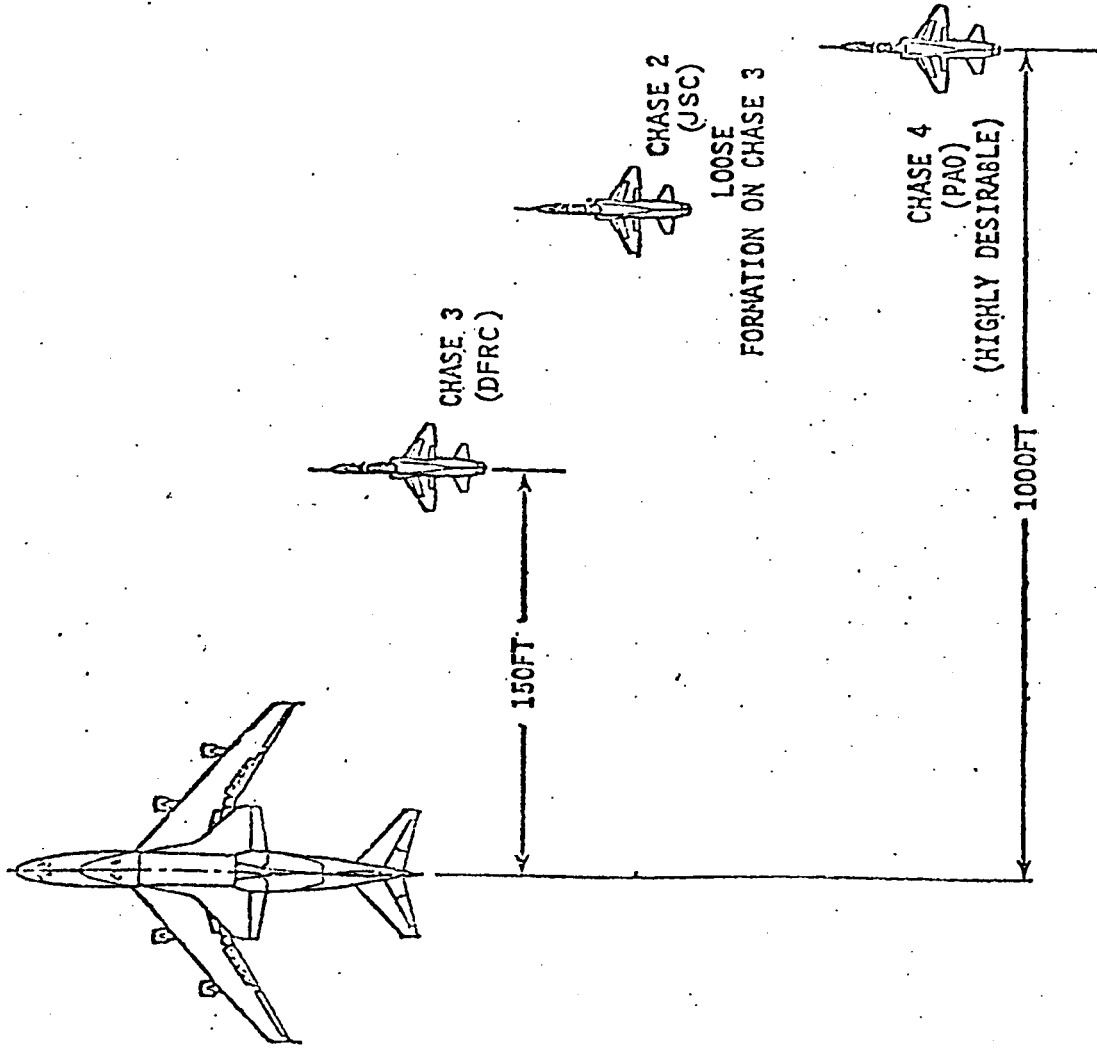


FIGURE VIII-1 CHASE POSITIONING - CAPTIVE INERT FLIGHTS

## VIII. SAFETY, RELIABILITY AND QUALITY ASSESSMENT

### A. Introduction

These areas have been under constant scrutiny by the Panel as a whole as well as by a number of Panel Task Teams. Rather than plow through ground covered in varying degrees by other sections of this report, this section focuses on the mission safety assessment system as applied to the ALT project, and the system which screens or evaluates hazards and safety concerns as a part of the every day program operation.

This task team organized its review to answer the following questions:

1. Is there a reasonable basis of confidence, based on data presented, that the ALT mission safety assessment has been thorough and adequate, and supports the decision to fly?
2. What are the major points that should be brought to the attention of the Shuttle Management and the NASA Administrator, and what will provide the Administrator with the best visibility into the risk assessments made to date?
3. Has the review system really done the job at each level of the ALT program, from contractor to NASA Headquarters, and is the aggregate risk really understood (including the subjective summation of apparently non-major type risks)?
4. To what degree are the steps followed in reaching ALT safety assessment being applied to the many elements that make up the OFT first mission?

Background data was gathered from the following documents:

1. ALT (Approach and Landing Tests) Project Safety Assessment, JSC 10888, latest issue.
2. Technical Assessments examining ALT safety hazards.
3. Space Shuttle Program Safety, Reliability and Quality Assurance Plan-Level II, JSC 10681.
4. Space Shuttle Program System Level Open Problem List, JSC 09925.
5. Orbiter Open Problem List/Technical Issues, JSC 09079.
6. ALT Critical Design Review RID list.
7. Selected PMIR Action Items relating to S, R&QA activities.

The team then reviewed the adequacy of the data base for these reports as well as management use of these reports to assure knowledgeable risk management.

Given the magnitude of the work necessary to adequately examine and evaluate the S, R&QA systems a sampling method had to be employed. Members of the team participated in the S, R&QA Major Safety Concerns Screening Board meetings, and Orbiter Configuration Reviews. Discussions were held with NASA and contractor personnel and many of the questions and answers are reported in other sections of this chapter.

#### B. Observations

1. Orbiter Project-Problem Reporting and Corrective Action.

Discussions with the Quality Engineering Branch at JSC went into details of the Problem Reporting and Corrective Action System

(PRACAS) covering the following areas:

- a. Background, purpose, requirements for reporting.
- b. Relationships and data flow.
- c. Reports and problem resolution.

Problem reporting and corrective action systems have been established by all three NASA Centers, JSC/KSC/MSFC, and as far as can be determined at all the element contractors as well. Their mode of operation may differ but their purpose and end products are all similar. Therefore, at this time the Orbiter system was considered as the sample system. The way the system works for an element is shown in Figure VIII-1 on the Orbiter program. Those problems of a "systems or integration" nature are handled as shown in Figure VIII-2. The Orbiter contractor reporting requirements are shown in Table VIII-I.

It is important that this system provide prompt visibility of problem so their impact can be assessed and management can take appropriate action. Therefore, it is worth noting that 80% of the problem notifications occur within the 24 hour standard and the remaining 20% are reported within a few days of occurrence.

System level problems for major end items and major test articles, as well as "commonality" items are reported to JSC. These for the most part have been restricted to Criticality I and II types of problems. Criticality I and II refer to those which if they occurred during actual operations would cause loss of life, loss of mission or both. The relationship between MSFC and JSC regarding problem reporting is such that MSFC reports only Level II, systems-type problems to JSC and

maintains its own Level III problems. Two documents issued as a result of these efforts are the "Orbiter Open Problem List/Technical Issues Only," JSC 09079 prepared by the Quality Assurance Division, and "Space Shuttle Program System Level Open Problem List with S, R&QA Remarks," JSC 90025, also prepared by the Quality Assurance Division. A sample page from the first document is shown in Figure VIII-3 and one sample from the second document is shown in Figure VIII-4a/4b. This effort is supported by an information flow system using a JSC CYBER computer system with terminals at the NASA resident offices and operational sites, MSFC, KSC, RI/SD and DFRC by the end of 1977.

data base is at JSC as the focal point for this work. The sections of these reports which provide the needed visibility to various levels of management are kept in the Management Information Centers at NASA Centers and their prime contractors. The major problem reports and their resolution are discussed at periodic reviews as appropriate.

The system is described in further detail in the following documents:

(a) NHB 5300.4(1D-1) sets forth the requirements for contractors to provide a closed-loop system for the reporting of all problems and the establishment of corrective action, (b) Volume V, JSC 07700, Level II requirements define problem reporting and corrective action information requirements for all elements of the program, (c) JSCM 5324A and JSC 09296 describes the JSC on-site system, and (d) NASA/RI contract NAS 9-14000 Information Requirements Descriptions defines the Orbiter project implementation.

## 2. Materials Analysis Tracking and Control (MATCO)

Given the Panel's background, the Panel emphasizes the importance of controlling the materials used in and around space vehicles. The team, therefore, reviewed the MATCO system for identifying, assessing and controlling materials in their application in Shuttle.

MATCO is one of the building blocks for safety and reliability analyses and assessments since it takes all of the materials information noted below and documents it for quick identification, tracking, retrieval and control. MATCO also provides "Acceptable Materials Lists" or the "directory" in order to assist design personnel.

- Flammability, toxicity, vacuum thermal stability, hazardous fluid compatibility, age-life, stress corrosion, and fracture control.

There have been some problems in obtaining all the materials data from all the elements of the program and inserting them into the MATCO format. The current status of the MATCO program is that Rockwell International/SD met all MATCO requirements for the ALT Orbiter 101 in January 1977. MSFC has been granted a MATCO delay until 1980; however, a JSC audit of the MSFC position conducted in June 1976, indicated that MSFC is in fact reviewing all drawings and related documents to assure compliance with program materials requirements.

Further details on the system can be found in the following documents:

- a. Level II requirements are established in Volume V and

Volume X of the JSC 07700 series of documents. These requirements are specified in greater detail in JSC-SE-R-0006B document, "NASA JSC Requirements for Materials and Processes" and the Information Requirement 2EN-13, "Worksheets, Standard and Accountability Control, Tracking Information and Data on Material."

b. Level III requirements are established through Rockwell International Document SD72-SH-0090B, Information Requirement Document RA-366T2, "Space Shuttle MATCO Information and Data System."

c. Level IV requirements for the Orbiter are established in RI/SD document SD-72-SH-0172, "Space Shuttle Orbiter Materials Control and Verification Plan."

3. Approach and Landing Test (ALT) Project Safety Assessment.

This assessment is published in the JSC 10888 document. It provides management an assessment of the Shuttle Carrier Aircraft crew escape system and aircraft modifications, Orbiter, GFE, Flight and Ground Operations. The systematic approach that is used is portrayed in the fault-tree schematics shown in Figure VIII-5a, b, c, d, e, and f. Orbiter systems that are not in operation during ALT are not addressed and analysis of the 747 is limited to modifications made for ALT. GSE is analyzed for single failure points that could cause damage to the ALT hardware. The safety concerns selected for inclusion stem from JSC Safety Division activities, including the SR&QA Major Safety Concerns "Screening" Board. They are chosen on the basis of criticality, credibility and significance for aggregate risk. Those risks that fall in the category of "accepted risk" are of most interest.

Other categories of major interest are the impact of newly defined safety concerns on those already considered "closed," and the qualitative evaluation of the aggregate risk.

The safety assessment shows there are three accepted risks considered major concerns:

- a. Smoke sensor provision in the orbiter crew cabin for ALT.
- b. Single elevon hydraulic actuator.
- c. Bird impact with the orbiter windshield.

The remainder of known accepted risks are as follows:

- a. The crew cannot escape from Shuttle Carrier Aircraft in-flight if it is not in a stable mode.
- b. There is a materials incompatibility of the 747 with the ammonia which is used as a coolant.
- c. The vertical stabilizer is vulnerable to damage from the orbiter ejection panels released during captive flight.
- d. The lack of "rip-stop" construction in landing gear switching valves introduces some hazards.
- e. A failure in the pressure transducer tube would release the hot turbine gases.
- f. There is a possibility for tank rupture in the APU hydrazine system, gaseous oxygen and hydrogen tanks and ammonia boiler system/ammonia tanks.
- g. There is no relief capability for a buildup of the fuel cell coolant pressure.
- h. There is a lack of redundancy in the severance system for the inner hatch.



i. The redundant pyrotechnic wiring in fact uses common cables/connectors and thus is not redundant at those points.

j. There may be situations where there is not sufficient time to engage backup flight control system.

k. The "nosewheel steering fail" light may give erroneous signals.

The program has carefully considered each of these and the program feels it has an adequate rationale for accepting each one. This rationale is outlined in the report, (JSC 10888 document).

The Project Safety Assessment also summarizes the results of sneak circuit analyses. Sneak circuit analyses proved valuable on previous programs. The work on the Orbiter for ALT is being done by Boeing for the system contractor and their supporting elements. As noted in the Safety Report, sneak circuits occur when current flows through unexpected paths, at unexpected times thereby causing ambiguous or false displays or unintentional operating conditions. Since these conditions could damage equipment, inhibit an operation, cause inadvertant operation, or present erroneous data, the systematic search and identification of them means management can take the appropriate action.

#### 4. ALT Project Safety Plan

This document, JSC 11031, "Approach and Landing Test Project Safety Plan" defines the safety organization, establishes safety policy and establishes safety responsibilities. JSC provides overall ALT safety management, monitors the implementation of safety policy, regulations, and plans, and provides safety group for the SCA/Orbiter

flight operations and orbiter flight operations. The ALT Manager ensures that safety policy and plans are implemented. KSC then provides safety management for orbiter ground operations and DFRC provides safety management for SCA ground and flight operations and serves as focal point for safety coordination with Edwards Air Force Base. The Rockwell Space Division complies with contractual safety requirements and supports JSC, KSC, and DFRC in conduct of safety tasks.

5. ALT Major Review RID Status.

To test the effectiveness of the RID system in handling safety concerns, the Panel asked about the number of Review Item Discrepancies (RID) from the ALT Critical Design Review still open after nine months. The response showed that only 19 of 44 RID's from the CDR board were still open as of October 28, 1976. All RID's which impact the first captive inactive flight have been closed. Six RID's which are open at the time of this report are not a constraint to that flight.

6. Task Team Questions and JSC Responses

The team also raised the following technical questions or concerns for consideration by the JSC Safety, Reliability and Quality Assurance Office. The questions and answers are provided below.

Q. Is there any identifiable concern with the Microwave Scanning Beam Landing System (MSBLS) that could affect the ALT program with mated or free flight? For example, accuracy, reliability of operation, and integration into a combined autoland with possible manual takeover?

A. The MSBLS provides data for glide slope, bearing, and slant range. MSBLS data is provided to the guidance and control to facili-