

MDC E0558

Phase B System Study Extension

FINAL REPORT

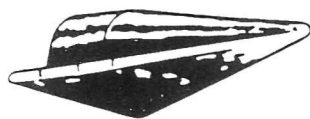
Part IV

**COST AND
SCHEDULING DATA**

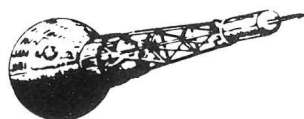
HIGH VALUE

**SPACE
SHUTTLE**

LOW COST



JRA



(NASA-CR-143910) SPACE SHUTTLE PHASE B
SYSTEM STUDY EXTENSION. PART 4: COST AND
SCHEDULING DATA Final Report, 1 Nov. 1971 -
15 Mar. 1972 (McDonnell-Douglas Corp.)
221 p

N75-76036

Unclass

00/98 17879

MCDONNELL DOUGLAS

TRW
SYSTEMS GROUP



SPACE SHUTTLE PHASE B SYSTEM STUDY EXTENSION FINAL REPORT

15 MARCH 1972

MDC E0558

Part III DEVELOPMENT REQUIREMENTS

Submitted Under NASA
Modification 24
Supplemental Agreement
to Contract NAS 8-26016
CDRL Item MA-04

MCDONNELL DOUGLAS

TRW



TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
	Foreword	iii
	Introduction	iv
1	Facilities Summary	1-1
2	Support Equipment	2-1
3	Manufacturing & Final Assembly	3-1
4	Logistics Support, Maintenance & Maintainability	4-1
5	Development Test & Verification	5-1
6	Ground & Flight Operation	6-1
7	Product Assurance	7-1

List of Pages

Title Page

ii iii iv

1-1 through 1-3
 2-1 through 2-9
 3-1 through 3-11
 4-1 through 4-15
 5-1 through 5-114
 6-1 through 6-37
 7-1 through 7-13

FOREWORD

The Space Shuttle Phase B Extension Study was conducted under Modification 24, Supplemental Agreement to Contract NAS 8-26016 by a team headed by the McDonnell Douglas Corporation. The period of performance for the study was 1 November 1971 through 15 March 1972. Members of the study team included the McDonnell Douglas Corporation, the Martin Marietta Corporation, TRW Incorporated, Pan American World Airways Incorporated, and Sperry and Norden as subcontractors.

This document constitutes Part III of the final documentation for the study which consists of the following:

CDRL Item MA-04 Final Report

- Part I Executive Summary
- Part II Technical Report
 - Volume I System and Orbiter
 - Volume II System and Booster
 - Volume III MMC Activity
- Part III Development Requirements
- Part IV Cost and Scheduling Data

CDRL Item SE-03

- Part V Design Data Book
 - Volume I Program and System Baseline
 - Volume II Drawings
 - Volume III Orbiter Aero Design Data Book
 - Volume IV Booster Aero Design Data Book (CDRL Item SE-01)

CDRL Item SE-04

- Part VI Final Mass Properties Report

INTRODUCTION

This volume presents the development requirements documentation associated with the Space Shuttle configurations which were developed during the Phase B Extension Study.

For convenience, this data is presented in the form of viewgraph style charts, with accompanying text where required. The data places emphasis upon the changes required to the various development efforts from the program as it existed at the end of the Phase B Study. Where the level of effort has justified it, some subjects are treated in greater detail than others.

FACILITIES SUMMARY

MDC E0558
PART III
15 MARCH 1972

1-1



FACILITIES SUMMARY

PHASE B EXTENSION VS PHASE B - DELTAS

The impact on facilities for the Phase B extension study is reflected in the attached facility matrix. The Phase B Extension baseline calls for a Tank End-Loaded series burn Pressure Fed Recoverable Booster, a smaller Orbiter due to external expendable Hydrogen and Oxygen fuel tank which replaces the Orbiter internal fuel tank proposed during Phase B. This concept eliminates the requirement for the construction of a new final assembly and maintenance building that was proposed for KSC. The Phase B Extension proposes that the Orbiter be assembled in MDC facilities, the HO tank at the NASA, Michoud, Louisiana, facility, the Pressure Fed Booster tank assembled at the NASA, Seal Beach, California, facility, and final assembly; i.e., attach Booster tank to thrust structure, in the VAB at KSC.

FACILITIES SUMMARY
PHASE B EXTENSION VS PHASE B - DELTAS

ITEM	BOOSTER(1)		ORBITER		HO TANK	
	PHASE B	EXTENSION	PHASE B	EXTENSION	PHASE B	EXTENSION
MODIFY VERTICAL WELD CELL NO. 1	\$ 265,000					
MODIFY HYDROSTATIC TEST & CLEANING STATION	60,000	(2) \$ 3,800,000				\$ 1,900,000
NEW PNEUMOSTATIC TEST FACILITY	339,000					
NEW INSULATION FACILITY	635,000					4,000,000
NEW SODIUM DICHROMATE FACILITY	212,000					INCL IN ITEM 2
NEW ANODIZE FACILITY			\$1,920,000	\$ 4,000,000		
NEW VERTICAL WELD CELL			530,000			
NEW ORBITER TEST FACILITY			800,000			
NEW BOOSTER TEST FACILITY	3,150,000					
MAINTENANCE/ASSEMBLY FACILITY	59,491,000					
CARGO OPERATIONS FACILITY			100,000	100,000		
LANDING & DESAFEING FACILITY	23,250,000	21,783,000				
LAUNCH COMPLEX	11,575,000					
MOBILE LAUNCHERS	46,500,000					
MOBILE SERVICE STRUCTURES	5,000,000					
X-RAY FACILITY						300,000
ADDITIONAL ENVIRONMENTALLY CONTROLLED AREA						6,000,000
TANK STORAGE FACILITY						790,000
BOOSTER TANK ASSEMBLY		9,900,000				
BOOSTER THRUST STRUCTURE		6,750,000				
MARAGING & CLEANING		4,100,000				
RECOVER SLIP W/350 TON GANTRY @ BARGE TERMINAL		1,900,000				
TOW ROADS AND PAVING		530,000				
TEST AND FLUSH AREA - BOOSTER		2,784,000				
VAB MODS		7,044,000				
LAUNCH PAD MODS		5,000,000				
MOBILE LAUNCHER MODS (3)		16,200,000				
ORBITER PROPULSION SYSTEM INTEGRATION			325,000	6,500,000		
BOOSTER PROPULSION SYSTEM INTEGRATION	5,400,000	5,400,000				
TOTALS	\$155,913,000	\$85,191,000	\$3,675,000	\$10,600,000	--	\$12,990,000

NOTES: (1) IF A FACILITY IS REQUIRED FOR BOTH ORBITER & BOOSTER, THE REQUIREMENT IS SHOWN IN BOOSTER COLUMN.
(2) ONE AT KSC; ONE AT MANUFACTURING SITE.

SUPPORT EQUIPMENT

PROPULSION AND FLUID SYSTEMS

The following summarizes the major GSE changes required by the Phase B Extension configurations:

- o Booster propellant requirements changed from a LOX/LH₂ flyback booster to a LOX/RP₁ series and parallel pressure fed booster. GSE requirements changed accordingly omitting requirements for LH₂ servicing and checkout and adding RP₁ GSE requirements.
- o Cryogenic and RP₁ servicing GSE will not be required if twin solid rocket booster is elected.
- o The main propulsion GSE requirements for the orbiter is the same except the vehicle propellant tanks changed from internal to external H/O tanks.
- o ACPS changed from LOX/LH₂ to an N₂H₄ system. The ACPS is now modular in design. This concept requires new components, systems, servicing and deservicing GSE.
- o APU changed from a LOX/LH to an N₂H₄ system. The APU is modular in design and requires new components systems, servicing and deservicing GSE. APU for the booster is a solid propellant hot gas turbine. New GSE will be required to support this system.
- o OMS changed from a LOX/LH₂ to a hypergolic NTO/A50 system. The OMS will also be a modular configuration. New GSE to support this design is component, systems, hypergolic servicing and deservicing GSE.
- o ECLS on Phase "B" received its cryogenic O₂ from main tankage. ECLS now shares LO₂ tankage with fuel cell.
- o Portable LO₂/LH₂ servicing dewars are required to service ECLS and fuel cell requirements.
- o Coolant, hydraulic, ABES GSE requirements basically the same for Phase B as for Phase B extension.

PROPULSION AND FLUID SYSTEMS

ORBITER								
	MAIN PROP	ACPS	APU	OMS	ECLS	COOL-ANT	HYD.	ABES
PHASE B	LOX LH ₂	LOX LH ₂	LOX LH ₂	LOX LH ₂	O ₂ N ₂	FREON 21 REQ WATER	HYD FLUID	JP ₄
PHASE B EXTENSION	LOX LH ₂	N ₂ H ₄	N ₂ H ₄	NTO A50	O ₂ N ₂	FREON 21 REQ WATER	HYD FLUID	JP ₄

BOOSTER										
	MAIN PROP	ACPS	APU	ECLS	COOL-ANT	HYD	ABES	PRESSURANT	DRAG BRAKE	ENGINE COVER
PHASE B	LOX LH ₂	LOX LH ₂	LOX LH ₂	O ₂ N ₂	FREON 21 REQ WATER	HYD FLUID	JP ₄	He GROUND OPS LO ₂ /LH ₂ DURING FLIGHT	NONE	NONE
SERIES (SRAO)	LOX RP ₁	NONE	SOLID APU	NONE	PASSIVE	HYD FLUID	NONE	HYDRAZINE FOR RP ₁ . He FOR LOX	He	HYDRAU- LIC
TWIN SRM	SRM	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
TWIN PRESS.FED BOOSTER PARALLEL BURN (TRA0)	LOX RP ₁	NONE	NONE	NONE	PASSIVE	NONE	NONE	HYDRAZINE FOR RP ₁ . He FOR LOX	He	PNEU- MATIC

SHUTTLE ELECTRICAL GSE

The Shuttle Electrical GSE Philosophy remains as follows:

- o Use automation where practicable as a general operating concept.
- o Use common designs among usage areas and between orbiter and booster.
- o Share equipment where scheduling permits.
- o Use GFE when the result will be lower total program costs.

The monitor, display, and control (MDAC) system, consisting of the MDAC unit and related equipment, now has a computer for orbiter testing and another one for booster testing. This facilitates software programming for parallel and unrelated orbiter and booster checkout. In addition, the MDAC system now has several subsystem test engineer consoles which are required for detailed subsystem evaluation because of less vehicle checkout autonomy. The consoles are identical and therefore undedicated.

Interfaces between the MDAC system and the vehicles and other GSE are still digital except that two one-way data links are now used in place of a two-way data bus in all instances. This takes advantage of on-board technology. In addition to the launch site areas previously supported by the MDAC systems, two external tank maintenance areas are now included.

Carry-on or roll-up test sets have been eliminated except for the air data sensor hangar test set which must be used in close proximity to the vehicle. The RF test sets are rack mounted and interface with the vehicles through GSE coaxial cables and antennas.

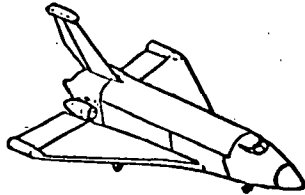
Because the APU, OMS, and ACPS modules will be removed after an orbiter flight, interface simulators for the modules are now required in case subsystems interfacing with those modules must be tested.

The orbiter now requires only AC ground power for ground operations. The SRAO and solid boosters require DC ground power. The SRAO booster requires less GSE than the Phase B flyback booster, and the solid booster requires still less.

SHUTTLE ELECTRICAL GSE

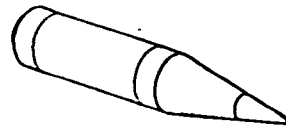
VEHICLE MAINTENANCE

ORBITER



- o AC POWER SUPPLY
- o STAR TRACKER & HORIZON
SENSOR TEST SETS
- o SIMULATORS
 - o BOOSTER
 - o EXTERNAL TANK
 - o ACPS, OMS, APU
 - o PAYLOAD
- o S-BAND COMM STATION
- o UHF COMM STATION
- o ILS & TACAN TEST SET
- o AIR DATA SENSOR HANGAR TEST
SET
- o MONITOR, DISPLAY, AND
CONTROL SYSTEM

EXTERNAL TANK



- o DC POWER SUPPLY
- o ORBITER SIMULATOR
- o BATTERY CHARGER
- o RANGE SAFETY COMM STATION
- o MONITOR, DISPLAY, AND
CONTROL SYSTEM

SRAO BOOSTER



- o DC POWER SUPPLY
- o ORBITER SIMULATOR
- o S-BAND COMM STATION
- o VHF COMM STATION
- o BEACON COMM STATION
- o RADAR COMM STATION
- o BATTERY CHARGER
- o RANGE SAFETY COMM STATION
- o MONITOR, DISPLAY AND
CONTROL SYSTEM

ON LINE ELECTRICAL GSE FOR ORBITER

The Monitor, Display, and Control (MDAC) System is used for ground checkout of the Orbiter and/or Booster by interfacing with the vehicle(s) and with remotely controllable GSE such as ground cooling units and power supplies. Included in the MDAC System is the MDAC Unit, Subsystem Test Engineer Consoles, NASA Test Conductor Console, computers and peripheral devices, and ground based remote multiplexer and command decoder units. Peripheral devices include line printers, a CRT hard copy device, and magnetic tape and disc units.

Primary operational mode is automatic using a computer to control step sequencing, data gathering, and analysis, and command/stimuli generation. Manual override capability exists. A higher order test language is used for software development, and the software contains self-test diagnostics.

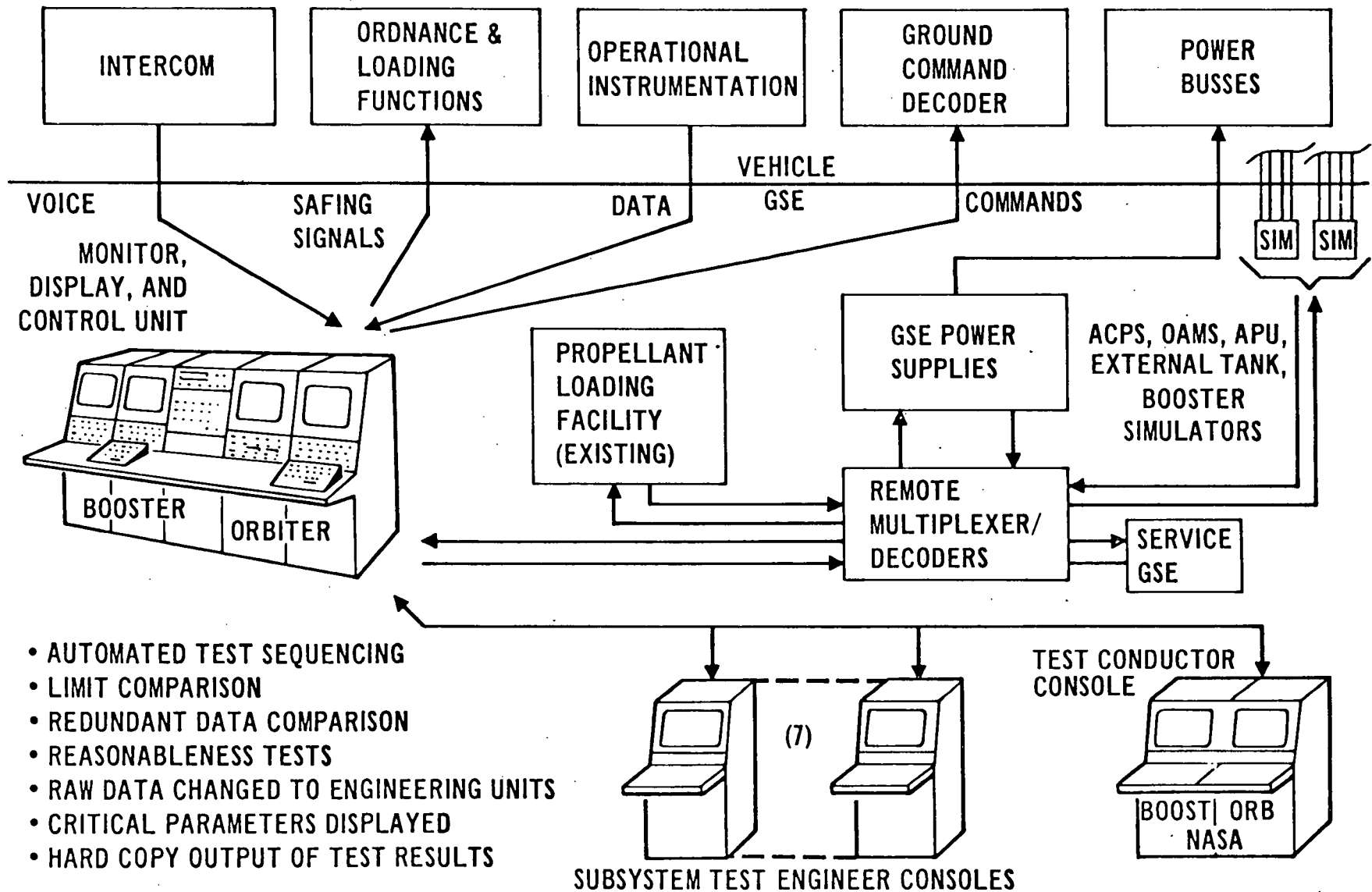
The central control point for ground operations is the MDAC Unit which contains CRT displays, keyboards, and programmable switches. For testing the mated vehicles a full MDAC Unit (5 racks) is used. Using a modular concept, a "one-half" MDAC Unit (3 racks) is used for single vehicle checkout.

The Subsystem Test Engineer Consoles are used by subsystem experts for overall subsystem evaluation. The consoles, which contain CRT displays and programmable switches, are not dedicated to particular subsystems (any page of data can be displayed on any CRT).

The MDAC System is designed with sufficient flexibility to serve common usages including: Orbiter and Booster factory on-line testing; development and flight testing (MDAC System can interface with the development flight or the operational instrumentation system); launch site horizontal maintenance, pre-launch, launch, and safing area operations; and control of selected bench test equipment.

To reduce development costs, onboard technology is used for the ground based remote multiplexer and command decoders.

ON LINE ELECTRICAL GSE FOR ORBITER



LAUNCH SITE LRU MAINTENANCE CONCEPT

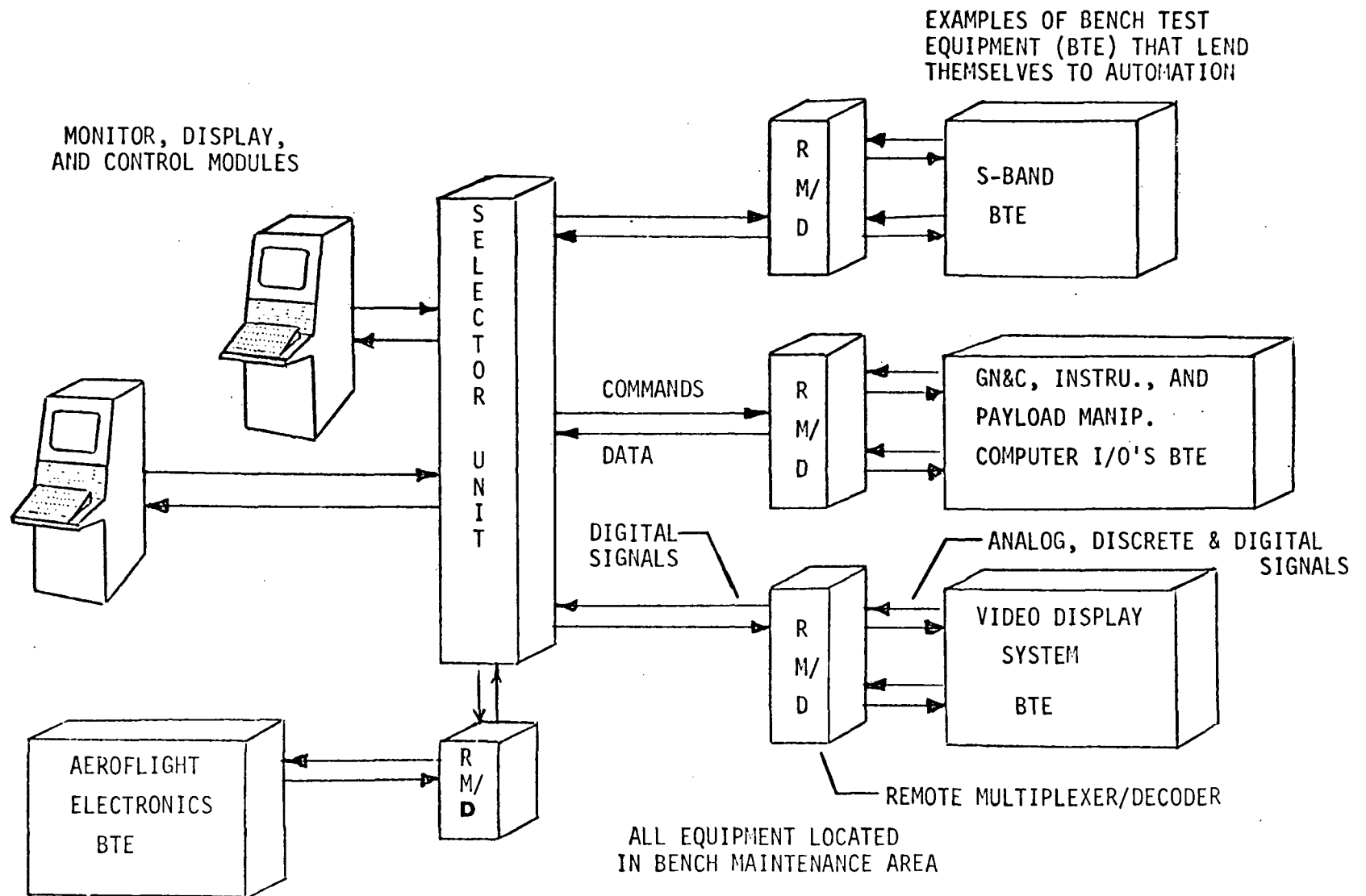
The launch site LRU maintenance philosophy is based on typical airline maintenance concepts of having capability to perform acceptance test and troubleshooting to the repairable or replaceable assembly. A set of bench test equipment (BTE) is located in a launch site maintenance area to perform the required testing for all subsystems.

Under the Monitor, Display, and Control (MDAC) System modular concept, MDAC modules are used for control of selected BTE's which lend themselves to automation. A MDAC module is a one-rack control station containing a CET and keyboard and operates in conjunction with a computer and peripheral devices. The module utilizes the same types of hardware and software as the full MDAC Unit.

Examples of equipment to be controlled in this manner include BTE's for the S-band system, computer I/O's, video display system, and aeroflight electronics system. A MDAC module, which is located near the BTE's, can be switched to any BTE for checkout flexibility. The total number of MDAC modules required depends on the quantity of BTE's that can be automated and the scheduling and complexity of LRU testing.

This control concept allows a smaller number of standardized control systems to replace unique control systems in each BTE.

LAUNCH SITE LRU MAINTENANCE CONCEPT



MANUFACTURING & FINAL ASSEMBLY

MDC E0558
PART III
15 MARCH 1972

3-1



ORBITER MANUFACTURING TECHNOLOGY

The impact of the changes in required Orbiter manufacturing technology as a result of the use of concepts selected in the Phase B extension study is reflected in the accompanying chart. Many areas of manufacturing technology which previously required further development, now fall within present state-of-the-art technology capabilities. It should also be noted that as before, the status indicated has a direct relationship with the identified areas of manufacturing problems concerning the production of the vehicle.

It is significant that the number of manufacturing problems previously identified in the Phase B System Study Final Report has been greatly reduced during the extension study. Those manufacturing problem areas remaining concern production of the Orbiter thermal protection system and the expendable tank. As in the Phase B study, manufacturing problems related to the thermal protection system are based on the use of materials which necessitate the transition of R & D methods and processes to production methods and processes. This remains true even though the baseline materials have changed. External tank problems concern the handling of large sheet stock and thin milled skins, insulation requirements that are not conducive to low cost high production rates, protection of insulation after machining, and the removal of the high volume of foam dust and chips during the LH₂ tank insulation foam machining operations. The identified problem areas will require further analyses. A considerable number of problems may be eliminated as the design progresses toward more in-depth definition.

ORBITER MANUFACTURING TECHNOLOGY COMPARISON

MANUFACTURING FUNCTION/ACTIVITY	PHASE "B" BASELINE ORBITER MAJOR ASSEMBLIES										EXTENSION STUDY BASELINE ORBITER MAJOR ASSEMBLIES									
	FINAL ASSEMBLY	MAIN PROPULSION TANK	CREW STATION	MAIN FUSELAGE	WINGS AND CONTROL SURFACES	CARGO DOORS	SECONDARY TANKS	AIRBREATHING ENGINE PODS	THERMAL PROTECTION SYSTEM		MAIN PROPULSION TANK	FINAL ASSEMBLY	FORWARD FUSELAGE	CENTER FUSELAGE	AFT FUSELAGE	WINGS AND CONTROL SURFACES	CARGO DOORS	ACPS AND OMS PODS	AIRBREATHING ENGINE PODS	THERMAL PROTECTION SYSTEM
TOOLING	D	D	P	D	D	P	P	P	D		P	P	P	P	P	P	P	P	P	D
FABRICATION	N	D	P	P	D	P	P	P	D		D	P	P	P	P	P	P	P	P	D
ASSEMBLY	P	D	P	P	D	D	P	P	D		P	P	P	P	P	P	P	P	P	D
PROCESSING	N	D	N	N	N	N	D	N	D		D	P	P	P	P	P	P	P	P	D
QUALITY CONTROL	P	D	P	P	P	P	D	P	D		P	P	P	P	P	P	P	P	P	D
HANDLING	D	D	P	D	P	P	P	P	D		D	P	P	P	P	P	P	P	P	D

LEGEND: P = PRESENT MANUFACTURING TECHNOLOGY APPLICABLE
 D = FURTHER DEVELOPMENT OF MANUFACTURING TECHNOLOGY REQUIRED
 N = NOT APPLICABLE

ORBITER CONCEPT DIFFERENCES WHICH IMPACT THE MANUFACTURING APPROACH

This chart identifies six items which have major impact on the manufacturing approach and shows how the Phase B approach design concept differs from that developed during the extension.

The reduction in size of the Orbiter results (in most cases) in reduced detail piece part, subassembly, and assembly sizes. These reduced size parts are more compatible with proven commercial and military type aircraft manufacturing technologies, existing manufacturing machine tool capabilities and capacities, current state-of-the-art manufacturing tooling and handling techniques, a greater range of possible fabrication and assembly locations, and available standard raw material stock sizes.

The external main propulsion tank allows a simpler vehicle design for construction, simpler design for construction of the tank itself, manufacturing breakdown of vehicle fuselage into more conventional aircraft "sectional" approach, reduced manufacturing schedule span time for construction of vehicle structure, and results in smaller vehicle structure which is more compatible with existing manufacturing facilities.

The all-aluminum vehicle structure eliminates hot forming and sizing operations required for titanium piece parts; requires less complex, more economical, fabrication tooling than titanium and boron aluminum; eliminates manufacturing methods specifically associated with boron aluminum; results in more economical cleaning and processing operations; and utilizes more economical raw stock.

The separable OMS, ACPS, and ABPS pods makes possible single location manufacturing and acceptance test; reduces quantity and interchange of interface coordination tooling; promotes manufacturing replaceability and interchangeability; and reduces manufacturing schedule span time by allowing more work to be performed in parallel.

The ablative/RSI Thermal Protection System (TPS) tiles and TPS bonded directly to the vehicle structure reduces the number of different TPS panel materials from (5) metallics plus carbon/carbon, to (2) ablatives plus HCF, but introduces some new areas of concern associated with the ablative/PSI panels system. It also increases potential scrap or repair and replacement rates and changes the panel removal and replacement approach from mechanical method to bond removal and rebonding. In addition, it introduces the requirement to maintain TPS moldline control while applying panels of varying thicknesses to a fixed structure moldline.

ORBITER CONCEPT DIFFERENCES WHICH IMPACT THE MANUFACTURING APPROACH

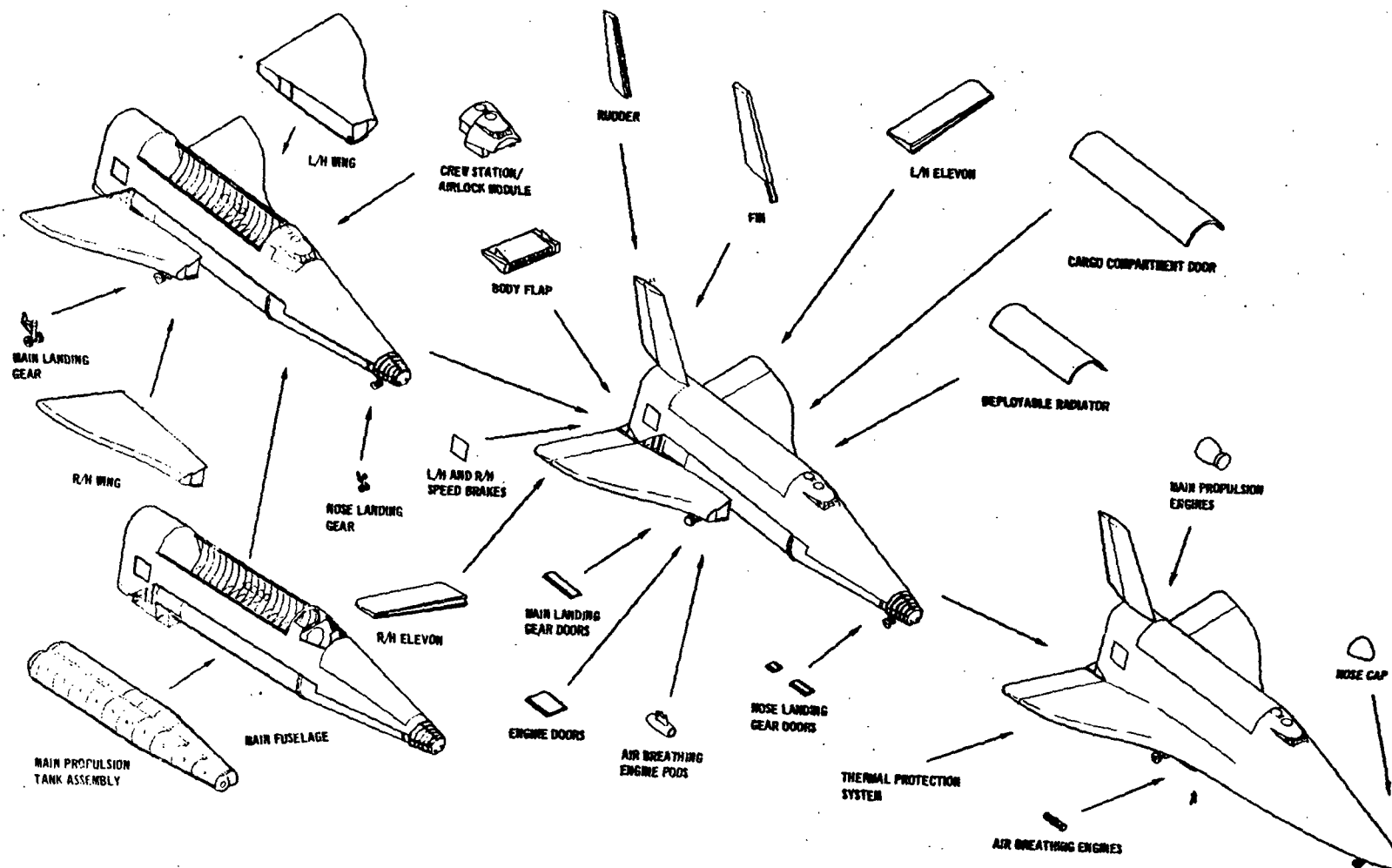
DESIGN ITEM	PHASE "B" BASELINE DESIGN	PHASE "B" EXTENSION STUDY BASELINE DESIGN
VEHICLE SIZE	174.7' LG. X 63.7' H. X 107.5' SPAN	123' LG. X 45.1' H. X 79.6' SPAN
MAIN PROPULSION TANK	INTERNAL (STRUCTURALLY INTEGRAL)	EXTERNAL (EXPENDABLE)
VEHICLE STRUCTURE	TITANIUM/BORON ALUMINUM	ALL ALUMINUM
ORBITAL MANEUVERING, ATTITUDE CONTROL, AND AIR BREATHING PROPULSION SYSTEMS	STRUCTURALLY INTEGRAL	SEPARABLE (SELF CONTAINED) PODS
THERMAL PROTECTION PANELS/TILES	METALLIC PANELS	ABLATIVE/RSI TILES
TPS INSTALLATION	MECHANICALLY SUSPENDED	BONDED DIRECTLY TO THE VEHICLE STRUCTURE

MANUFACTURING BREAKDOWN - PHASE B BASELINE CONCEPT

This Phase B Orbiter manufacturing breakdown chart is provided for comparison with the following chart to illustrate the advantages of the Phase B Extension Study baseline design over the Phase B baseline design for division of the manufacturing effort.

This Phase B baseline chart indicates that with the exception of the aft fuselage subassemblies and the crew station/airlock module, the manufacture of the Orbiter fuselage is essentially limited to one major assembly operation. Also, assembly completion of the main propulsion tank is necessary prior to the start of fuselage assembly. These factors cause limited dispersion of related manufacturing tasks, require numerous operations to be performed in series, and cause increased overall manufacturing schedule span time.

ORBITER MANUFACTURING BREAKDOWN PHASE B BASELINE CONCEPT

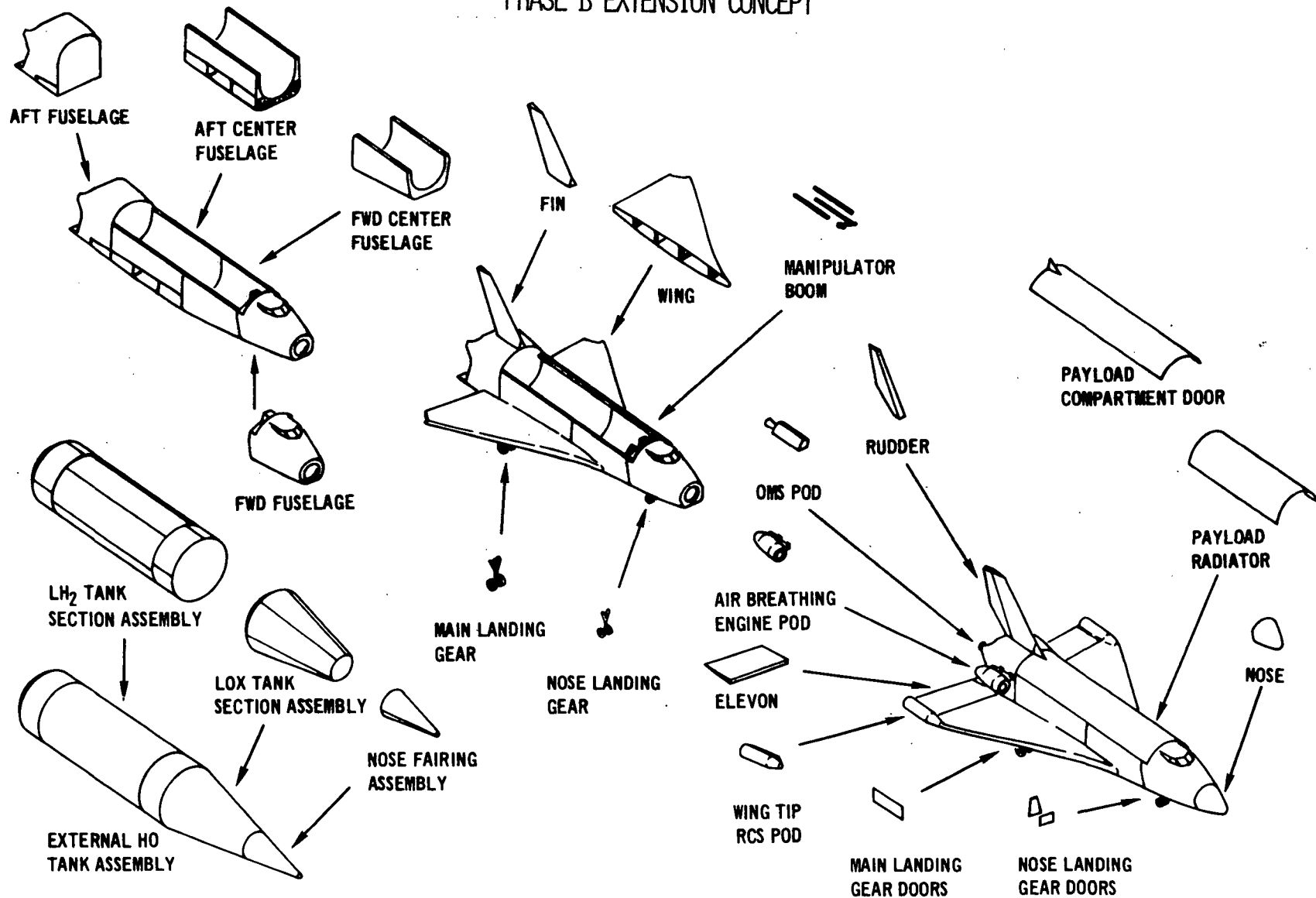


MANUFACTURING BREAKDOWN - PHASE B EXTENSION STUDY BASELINE CONCEPT

An examination of the manufacturing breakdown chart for the Phase B Extension Study baseline shows the advantages of the more conventional aircraft type fuselage design and the separate external main propulsion tank. These features allow the fuselage to be subdivided into four major sectional assemblies which may be manufactured at more widely dispersed locations. Also, the assembly buildup of these sections may be performed in parallel. Operations required for manufacture of the main propulsion tank are completely separate from those required for the fuselage. This eliminates the previously required tank/fuselage series operations, and allows a subsequent reduction in the overall Orbiter manufacturing schedule span time.

Another advantage of the Phase B Extension Study baseline design, shown on this chart, is the separable self contained modules for the Orbital Maneuvering, Attitude Control, and Airbreathing Propulsion systems. These add to the advantages of wider dispersion of tasks, more parallel operations, and shorter overall manufacturing schedule span time.

ORBITER MANUFACTURING BREAKDOWN PHASE B EXTENSION CONCEPT

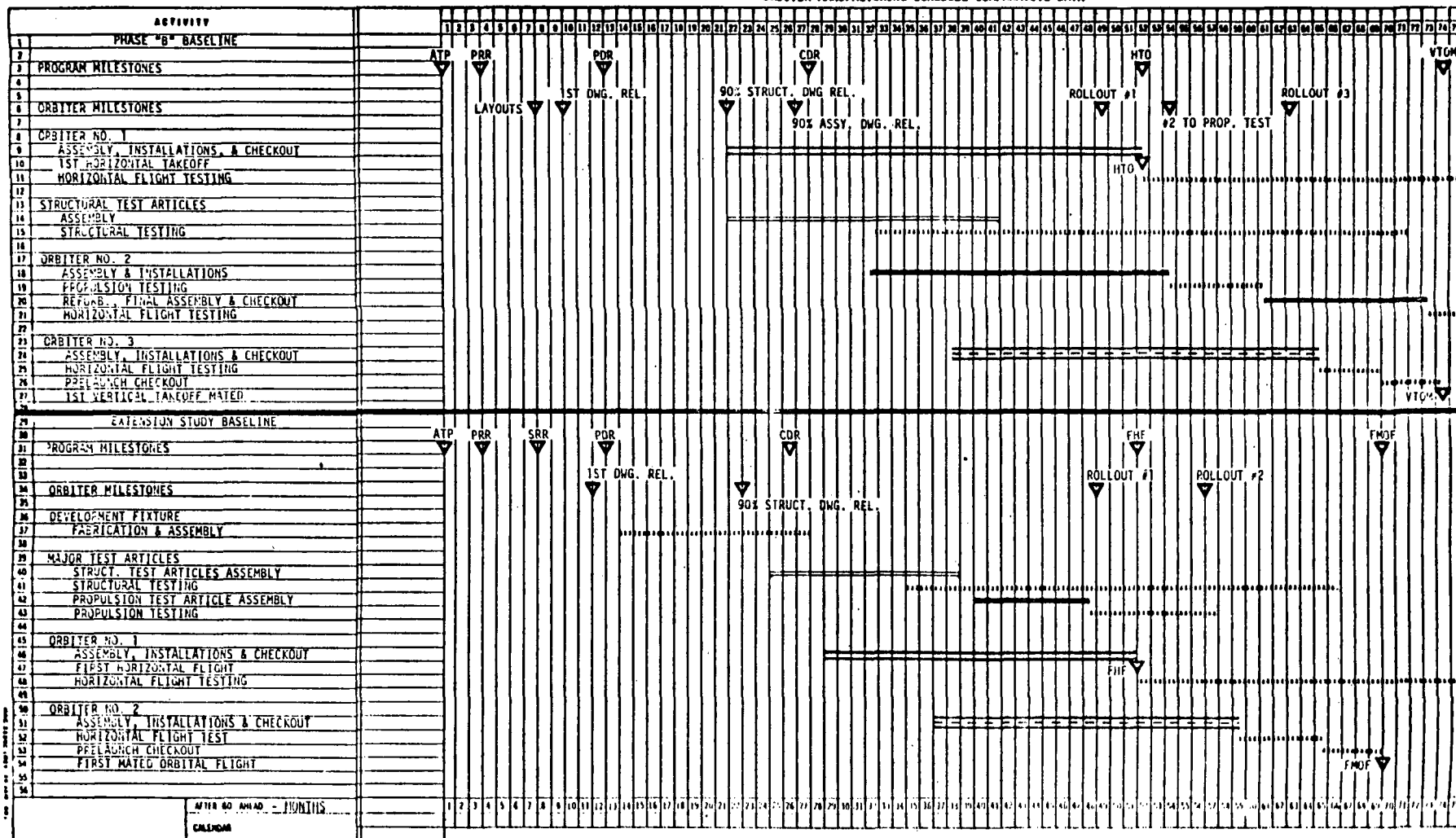


MANUFACTURING SCHEDULE DATA

The manufacturing schedule chart presents comparative data of relative manufacturing schedule span times based on the Phase B baseline versus the Phase B Extension Study baseline designs and manufacturing breakdowns. These schedule span times are shown in relation to key Space Shuttle Program and Orbiter milestones.

This chart makes appraent that the relative schedule span times both for Orbiter vehicles and major test articles have been considerably reduced for the Phase B Extension vehicles. This is a direct result of the previously discussed changes in design of the Orbiter to a more conventional aircraft type structure, removal of the internal main propulsion tank, in addition to the subsequent allowable manufacturing breakdown of the vehicle into more sectional and modular major subassemblies which may be produced as parallel lines of manufacturing effort.

ORBITER MANUFACTURING SCHEDULE COMPARATIVE DATA



LOGISTICS SUPPORT, MAINTENANCE & MAINTAINABILITY

MDC E0558
PART III
15 MARCH 1972

4-1



TURNAROUND MAINTENANCE CYCLE MANHOURS

A logistics and maintenance analysis was completed during the Phase B extension study defining the impact the extension Orbiter and Booster design changes would have on the maintenance turnaround cycle. Subsequent charts compare extension vehicles logistics and maintenance data with Phase B vehicle's analyses.

The following are characteristics of the vehicle design used:

EXTENSION ORBITER

- o Three HiPc Engines
- o Modular pods for ACPS, OMS and APU systems
- o Payload manipulator system
- o Two air breathing engines pod mounted
- o HCF and ablator TPS

EXTENSION BOOSTER

- o Unmanned
- o Six pressure fed engines, series burn with TVC
- o No ACPS, OMS or ABES
- o Retro rocket and range safety systems
- o Water recovery system: engine nozzle closure, drag brake, tow line

TURNAROUND MAINTENANCE CYCLE MANHOURS

SYSTEM	ORBITER		BOOSTER	
	PHASE B	EXTENSION	PHASE B	EXTENSION
AIRFRAME	1333	3221	1388	1078
PROPULSION	7621	1299	1921	359
AVIONICS	247	134	122	31
ECLS	330	178	9	5
POWER SUPPLY	948	469	1171	15
RANGE SAFETY	-	-	-	6
TOTALS	10479	5301	4611	1494

TURNAROUND MAINTENANCE REDUCTION RATIONALE

The turnaround maintenance cycle manhours summary chart (previous chart) comparing Phase B with Extension vehicles shows significant manhour reductions. This chart provides an explanation of these hours reductions by vehicle and subsystem.

TURNAROUND MAINTENANCE REDUCTION RATIONALE

SYSTEM	ORBITER	BOOSTER
AIRFRAME	EXTENSION VEHICLE TPS DESIGN REQUIRES 1650 ADDITIONAL SHOP REPAIR HOURS	ELIMINATION OF TPS ON EXTENSION VEHICLE REDUCES ON VEHICLE SUPPORT
PROPULSION	EXTENSION VEHICLE REDUNDANCY CHANGE, 3 VS 4 MAIN ENGINES, OMS ENGINE CHANGE, MODULAR ACPS AND APU PODS WITH HYDRAZINE PROPELLANT REDUCES OFF VEHICLE SUPPORT	APU DESIGN CHANGE AND ELIMINATION OF ACPS AND ABES REDUCES EXTENSION VEHICLE SUPPORT
AVIONICS	EQUIPMENT AND SYSTEM REDUNDANCY CHANGE REDUCES EXTENSION VEHICLE SUPPORT	UNMANNED EXTENSION BOOSTER SUBSYSTEM CHANGES REQUIRE LESS SUPPORT
ECLS	EQUIPMENT COOLING CHANGE FROM COLD PLATE TO FORCED AIR REDUCES EXTENSION VEHICLE SUPPORT	NO SIGNIFICANT CHANGE
POWER SUPPLY	EXTENSION ORBITER HAS 2 LESS FUEL CELLS THAN PHASE B DESIGN	EXTENSION BOOSTER DESIGN CHANGE FROM FUEL CELLS TO BATTERY POWER VIRTUALLY ELIMINATES SUPPORT
RANGE SAFETY	NOT INSTALLED ON ORBITER	NEW SYSTEM ADDED TO UNMANNED BOOSTER

ORBITER TURNAROUND MAINTENANCE MANHOURS

The Orbiter Maintenance Manhours identified during the analysis were those expended during inspection, replacement, repair, adjustment, calibration and servicing performed after the Orbiter landing to assure the vehicle is in a serviceable condition for satisfactory completion of pre-launch/launch operations and subsequent flight. Maintenance includes the test/checkout time necessary to verify that all prescribed tasks have been adequately performed; however, it does not include the subsystem and system checkout accomplished as part of pre-launch operations.

ORBITER TURNAROUND MAINTENANCE MANHOURS

SYSTEM	SCHEDULED		UNSCHEDULED		SHOP REPAIR	
	PHASE B	EXTENSION	PHASE B	EXTENSION	PHASE B	EXTENSION
AIRFRAME	632	653	508	828	193	1740
PROPULSION	179	174	263	158	7179	967
AVIONICS	72	35	84	41	91	58
ECLS	71	13	34	20	225	145
POWER SUPPLY	56	-	32	55	860	414
	1010	875	921	1102	8548	3324

BOOSTER TURNAROUND MAINTENANCE MANHOURS

The Booster Maintenance Manhours are expended on the same type of maintenance tasks as previously described for the Orbiter. However, the unmanned booster water recovery, retrieval and tow back systems require tasks not associated with the flyback vehicles.

Additional refurbishment tasks which have been included in the extension booster maintenance manhours are fresh water flush; retro-rocket, drag brake, range safety, engine nozzle closure, and engine base heat shield refurbishment.

BOOSTER TURNAROUND MAINTENANCE MANHOURS

SYSTEM	SCHEDULED		UNSCHEDULED		SHOP REPAIR	
	PHASE B	EXTENSION	PHASE B	EXTENSION	PHASE B	EXTENSION
AIRFRAME	452	356	634	288	302	434
PROPULSION	127	73	70	35	1724	251
AVIONICS	72	22	6	2	44	7
ECLS	7	-	-	1	2	4
POWER SUPPLY	31	-	1	6	1139	9
RANGE SAFETY	-	5	-	-	-	1
	689	456	711	332	3211	706

SHOP REPAIR MATERIAL COSTS

Shop repair times for LRU's removed during unscheduled and/or scheduled maintenance were determined and are included in the vehicles turnaround manhour allocation. Material costs for these shop repairs have been accumulated by shops and are shown on this chart. The extension orbiter TPS design change from metallic to HCF and ablator panels generates a significant additional number of shop repair hours and additional material cost.

SHOP REPAIR MATERIAL COSTS
(DOLLARS)

SHOP	ORBITER		BOOSTER	
	PHASE B	EXTENSION	PHASE B	EXTENSION
WHEEL & TIRE	174	599	294	-
BRAKE	1254	1254	2508	-
MECHANICAL ACCESSORY	3481	2407	9260	2510
HYDRAULIC	1716	1480	6404	108
PNEUMATIC	1452	704	527	285
SHEET METAL	360	399	245	2617
TPS SHOP	-	711790	-	400
ELECTRICAL	27163	15101	1626	966
RADIO	1030	208	21	250
ELECTRONICS	48415	8651	4411	44875
INSTRUMENTS	3780	2994	1987	389
ENGINE (ABES)	4192	2836	2304	-
ENGINE (ROCKET)	60801	126247	264033	34191
PROPELLANT	52299	11847	40400	1098
PARACHUTE	875	-	-	-
PYRO	1249	14284	31500	813
TOTALS	\$208,241	\$900,801	\$365,520	\$88,502

CANDIDATE REPAIR FACILITY CAPABILITIES

A study was accomplished to determine what organizations were capable of repairing the LRU's removed from the shuttle vehicles. Using proposed design characteristics a review of airline and DOD facility capabilities was accomplished and results shown on Airline and Air Force Repair Capability chart. Geographic location and transportation requirements were not evaluated during the study. See legend for facility alpha code used in matrix.

AIRLINES

(AAL)	American Airlines, Tulsa Facility
(UAL)	United Air Lines, San Francisco Facility
(EAL)	Eastern Air Lines, Miami Facility
(NWA)	Northwestern Airlines, Minneapolis Facility
(PAA)	Pan American Airlines, New York Facility Pan American Airlines, Miami Facility

DOD

(OC)	Oklahoma City, Air Material Area
(OO)	Ogden Air Material Area
(SA)	San Antonio Air Material Area
(SM)	Sacramento Air Material Area
(WR)	Warner Robins Air Material Area
(AGMC)	Aerospace Guidance and Metrology Center

CANDIDATE REPAIR FACILITY CAPABILITIES

SPACE SHUTTLE SYSTEM	AIRLINE FACILITY					AIR FORCE FACILITY					
	AAL	EAL	NWA	PAA	UAL	OO	OC	SA	SM	WR	AGMC
HYDRAULIC											
BRAKE											
MAIN LANDING GEAR											
NOSE LANDING GEAR											
AIRBREATHING ENGINES	X	X	X	X	X	X	X	X	X	X	
HELIUM GAS PRESSURANT						X					
JP4 FUEL	X	X	X	X	X						
COMMUNICATION/NAV AIDS	X	X	X	X	X		X	X			
DISPLAYS & CONTROL	X	X	X	X	X	X	X		X	X	
DATA MANAGEMENT							X				
ELECTRICAL POWER	X	X	X	X	X			X			
GUIDANCE & NAVIGATION							X				X
FLIGHT CONTROLS ELECTRONICS				X					X		
CABIN AIR LOOP	X	X	X	X	X		X	X			
CABIN GAS SUPPLY & CONTROL	X	X	X	X	X		X	X			
CABIN COOLANT LOOP	X	X	X	X	X		X	X			
EQUIPMENT COOLANT LOOP	X	X	X	X			X	X			
PRODUCT WATER	X	X	X	X	X						
WASTE MANAGEMENT	X	X	X	X	X						
FIRE EXTINGUISHING	X	X	X	X	X						
DRAG CHUTE								X			
PAYLOAD ACCOMMODATION	X	X	X	X	X						
SEPARATION				X							
ROCKET PROPULSION									X		

REPAIR CAPABILITY EXCEPTIONS

The repair facilities analysis revealed some shuttle system LRU's will require additional considerations, i.e., dedicated hydraulic GSE and test facilities. These have been enumerated as repair capability exceptions.

Facilities capable of supporting all repair requirements exist. However, availability of work force and facility, projected capability and what contractor support will be required requires evaluation for assignment of repair responsibility.

REPAIR CAPABILITY EXCEPTIONS

AIRLINE AND DOD EXCEPTIONS	
SYSTEM	COMMENTS
HYDRAULIC BRAKE MAIN LANDING GEAR NOSE LANDING GEAR	COMMERCIAL AIRLINES USE SKYDROLL HYDRAULIC FLUID. AIR FORCE USES MIL-H-5606 HYDRAULIC FLUID. THE ORBITER HYDRAULIC SYSTEM USES MIL-H-83282 FLUID REQUIRING DEDICATED GSE AND TEST FACILITIES.
LIMITED AIRLINE REPAIR CAPABILITY	
COMMUNICATIONS INERTIAL NAVIGATION	VOICE CONTROL MASTER STATION AT PAA, MIAMI, FLORIDA, FACILITY. REPAIR CAPABILITIES AT PAA, MIAMI, FLORIDA, FACILITY.
NO AIRLINE REPAIR CAPABILITY	
COMMUNICATIONS DATA MANAGEMENT ELECTRICAL GUIDANCE & NAVIGATION EQUIPMENT COOLANT LOOP DRAG CHUTE HELIUM SYSTEM	S BAND; RANGING SET, TRANSCEIVER AND ANTENNA, VHF OR UHF ANTENNA. DATA BUS, MASS MEMORY ELECTRONICS, MASS MEMORY, CONTROL COMPUTER AND SYSTEM CONTROL UNIT. FUEL CELLS. OPTICAL TRACKER OPTICS, OPTICAL TRACKER ELECTRONICS, HORIZON SENSOR OPTICS AND HORIZON SENSOR ELECTRONICS. H ₂ SHUTOFF VALVE, CYROGENIC HEAT EXCHANGER AND CONTROLLER. PILOT CHUTE MORTAR ASSEMBLY AND DRAG CHUTE. He GAS PRESSURANT REGULATOR MODULE.

DEVELOPMENT TEST & VERIFICATION

MDC E0558
PART III
15 MARCH 1972

5-1

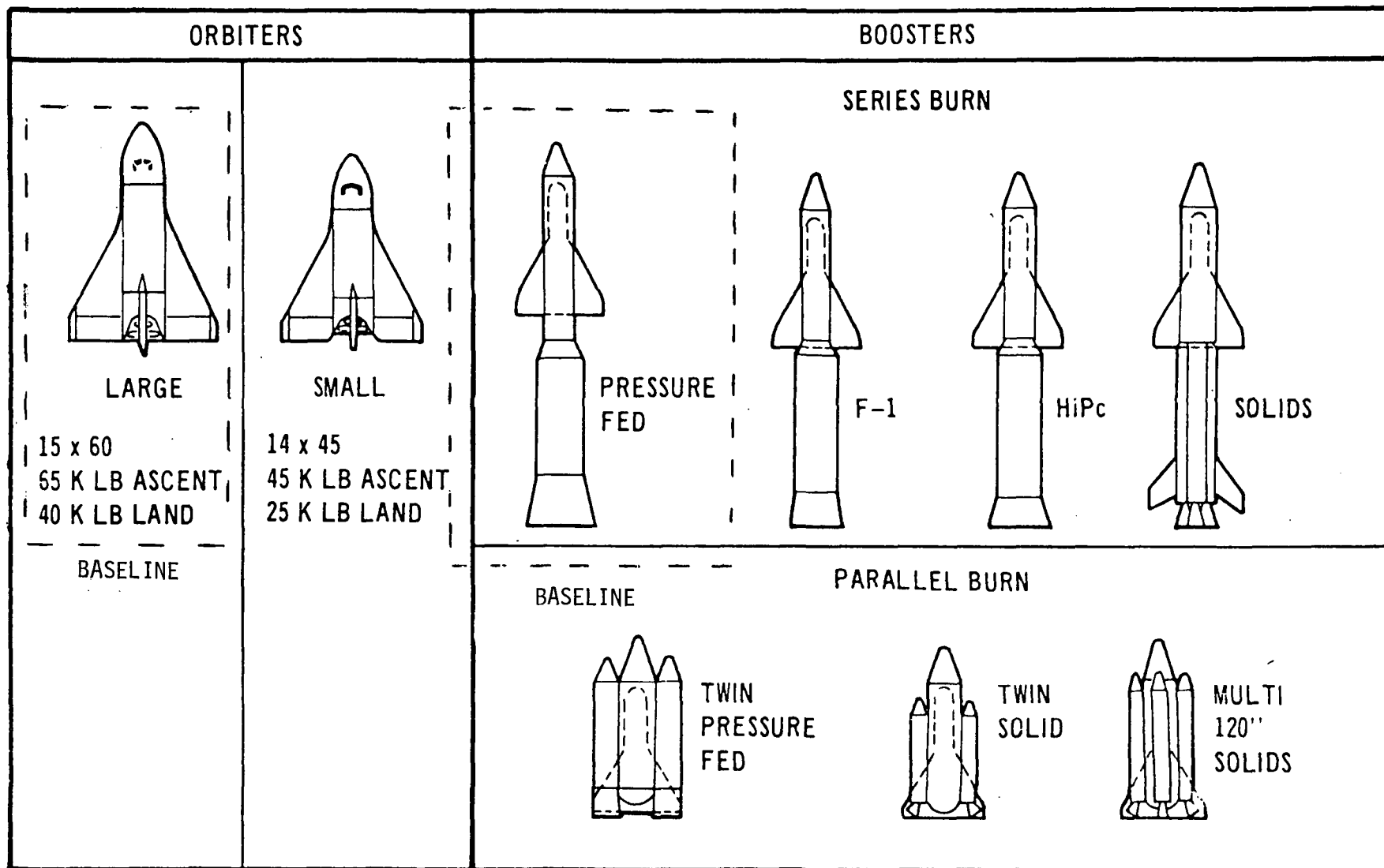


This section provides the test plan for the Series Burn, Pressure Fed, 15 x 60 ft. Payload Bay Orbiter Baseline. Differences in this plan from that for the Phase B, two-stage, fully reusable system are included. Significant areas of test planning for other Booster concepts are provided.

Sub-section organization is:

- o Ground Test
- o Acceptance Test
- o Launch Site Test
- o Flight Test

SHUTTLE SYSTEM CONCEPTS



CONFIGURATION CHANGES INFLUENCING TESTING PHASE B VS. PHASE B EXTENSION

DELTA ORBITER	068 ORBITER
o INTEGRAL MAIN PROPELLANT TANKAGE	o EXTERNAL HO TANK
o PIGGY BACK MATING	o BELLYMOUNTED TANK; TANK END LOADED BOOSTER MATING
o 2 - 550K LBTHRUST Hi P _c ENGINES	o 3 - 470K LBTHRUST Hi P _c ENGINES
o CENTRAL HYDROGEN/OXYGEN STORAGE SUPPLYING APU, ACPS, OMS	o MODULAR STORABLE B1-PROPELLANT OMS; MODULAR STORABLE MONOPROPELLANT ACPS; N ₂ H ₄ APU
o METALLIC TPS WITH CARBON/CARBON NOSE CAP	o RSI TPS WITH ABLATIVE LEADING EDGES
o TITANIUM/BORON - ALUMINUM WITH INTEGRAL, COMMON BULKHEAD, ALUMINUM TANK.	o ALUMINUM BASIC STRUCTURE; CONVENTIONAL AIRCRAFT
o 4 ABEs DEPLOYED FROM WING - ORBITAL MISSION; 5TH ABE MOUNTED ON VEHICLE BOTTOM VERTICAL C _L - FERRY MISSION.	o 2 ABEs - ORBITAL MISSION; 4 ABEs - FERRY MISSION; FIXED POSITION - AFT FUS.
o DOCKING FRAME DEPLOYED FROM PAYLOAD BAY	o NOSE DOCKING
o SINGLE PIVOT PAYLOAD DEPLOYMENT	o MANIPULATOR BOOM
o CENTRALIZED COMPUTER/DATA BUS/AREA MULTIPLEXING CONCEPT OF AVIONICS ORGANIZATION.	o DEDICATED SUBSYSTEMS/MINIMAL INTERFACE CONCEPT OF AVIONICS ORGANIZATION.
o ORBITER SIZE APPROXIMATES DC-10	o ORBITER SIZE APPROXIMATES DC-9

G R O U N D

T E S T

- o ORBITER/SYSTEM LEVEL
- o BOOSTERS
 - o SRAO - PRESSURE FED
 - o TRAO - SOLIDS
 - o OTHERS

MAJOR GROUND TEST DIFFERENCES - PHASE B VS PHASE B EXTENSION SYSTEM LEVEL (WITH SRAO-PRESSURE FED) / ORBITER

AREA OF TESTING	PHASE B DELTA ORBITER	PHASE B EXTENSION HO ORBITER
o WIND TUNNEL OCCUPANCY HOURS		
ORBITER ALONE	27,430	29,000
MATED & PROXIMITY	12,140	6,000
TOTAL	<u>39,570</u>	<u>35,000</u>
o MATED GROUND VIBRATION DYNAMIC RESPONSE	o TEST IN HORIZONTAL POSITION USING FLIGHT VEHICLES	o BOOSTER-ORBITER TEST NOT A REQUIREMENT; ORBITER-HO TANK TEST IN VERTICAL POSITION USING ORBITER STRUCTURAL TEST ARTICLES.
o MAIN PROPULSION INTEGRATION DYNAMIC RESPONSE	o TEST AT LAUNCH FACILITY USING ORBITER FLIGHT STRUCTURE PRIOR TO COMPLETION OF FINAL ASSY.	o DEDICATED 'BOILERPLATE' TEST ARTICLE IN STATIC TEST STAND.
o MAIN PROPELLANT TANK STRUCTURAL VERIFICATION	o INTEGRAL TANK TESTED IN SECTIONS INTEGRAL WITH RES- PECTIVE FUSELAGE TEST SECTION	o EXTERNAL TANK TESTED SEPARATELY; DEDICATED TEST HARDWARE
	o SPECIAL TEST FOR TANK EXTERNAL PURGE	o NO EXTERNAL PURGE REQUIRED
	SAFE LIFE TESTS	o NO SAFE LIFE TEST (TANK NOT REFLOWN)
o PRIMARY STRUCTURE VERIFICATION	o SECTIONALIZED TEST ARTICLES	o STRUCTURAL TEST ARTICLE SUPPLE- MENTED WITH SELECTED TEST SECTIONS THAT ARE ALSO USED FOR OTHER TEST REQUIREMENTS.

MAJOR GROUND TEST DIFFERENCES-PHASE B VS PHASE B EXTENSION SYSTEM LEVEL (WITH SRAO-PRESSURE FED)/ORBITER

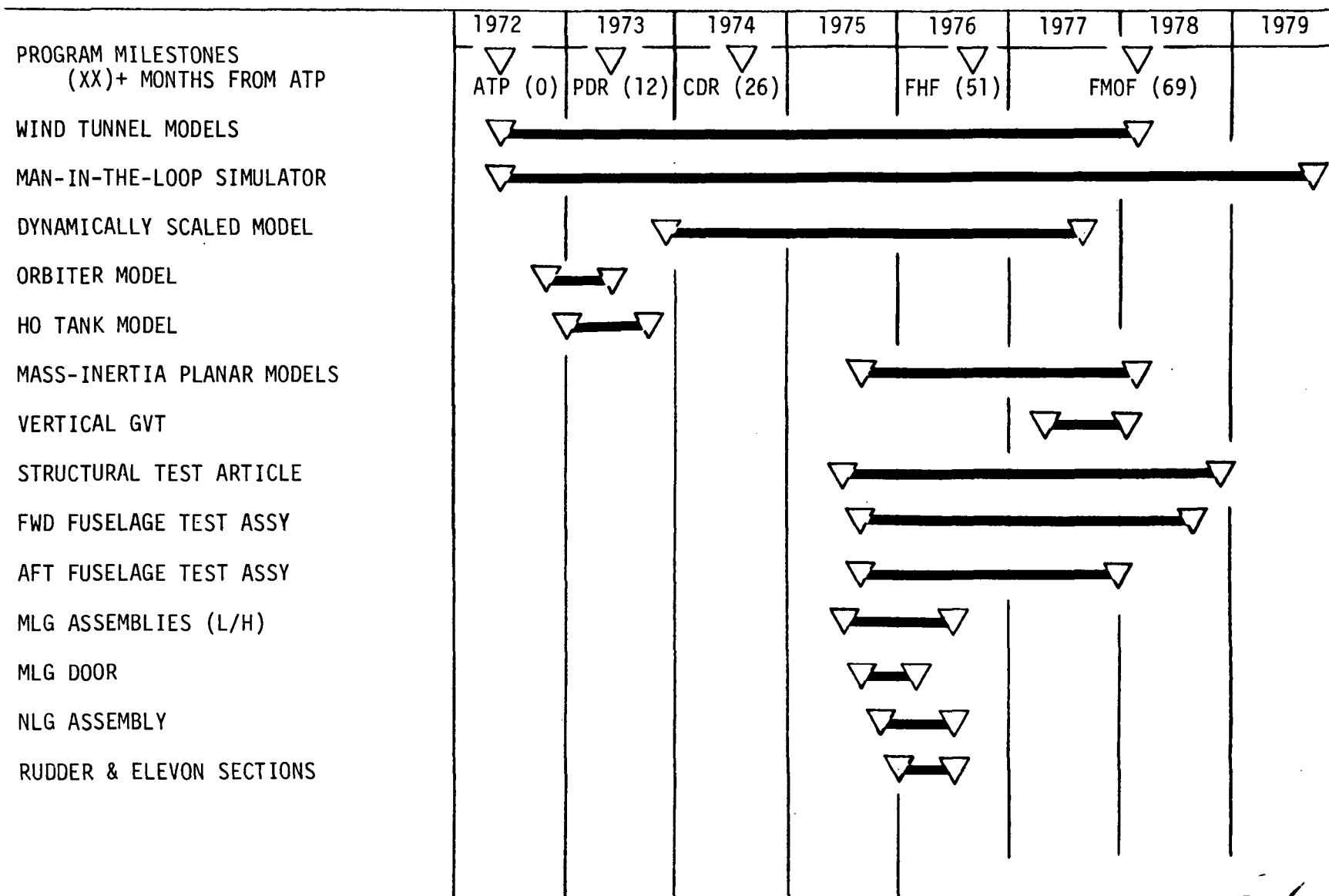
AREA OF TESTING	PHASE B DELTA ORBITER	PHASE B EXTENSION HO ORBITER
o PRIMARY STRUCTURE (CONT'd) VERIFICATION	o SPECIAL TESTS FOR COMPOSITES AND HOT STRUCTURES DESIGNS	o NO SPECIAL TESTS FOR CONVEN- TIONAL PRIMARY STRUCTURE DESIGN
o ACPS AND OMS INTEGRATION	o FLIGHT CONFIGURATION INTEGRATED TEST UNIT	o FLIGHT CONFIGURED SEPARATE TEST UNITS
o AVIONICS HARDWARE AND SOFTWARE INTEGRATION	o AVIONIC SYSTEM TEST UNIT/ SOFTWARE VALIDATION COMPLEX EMBODYING CENTRALIZED COMPUTER/ DATA BUS/AREA MULTIPLEXING FLIGHT SYSTEM ORGANIZATIONAL CONCEPT.	o AVIONIC SYSTEM TEST UNIT/SOFT- WARE VALIDATION COMPLEX EMBODY- ING HARDWIRED SAFETY OF FLIGHT ITEMS/DEDICATED SUBSYSTEMS/ MINIMAL INTERFACES FLIGHT SYSTEM ORGANIZATIONAL CONCEPT.
o THERMAL CONTROL VERIFICATION	o HEAT BALANCE TESTING EMPLOYING PRIMARY STRUCTURE TEST SECTIONS	o HEAT BALANCE TESTING EMPLOYING STRUCTURAL TEST SECTIONS AND PORTIONS OF STRUCTURAL TEST ARTICLE (NO DUPLICATE TESTING)
o THERMAL PROTECTION VERIFICATION	o ADDRESSED VERIFICATION OF MULTIPLE THERMAL PROTECTION DESIGNS & MATERIALS	o ADDRESSES VERIFICATION OF RSI AND ABLATIVE TPS.

SYSTEM LEVEL/ORBITER
GROUND TEST

System Level/Orbiter Ground Testing is scheduled by major test article configuration and correlates to the test article - test - location information on the succeeding pages.

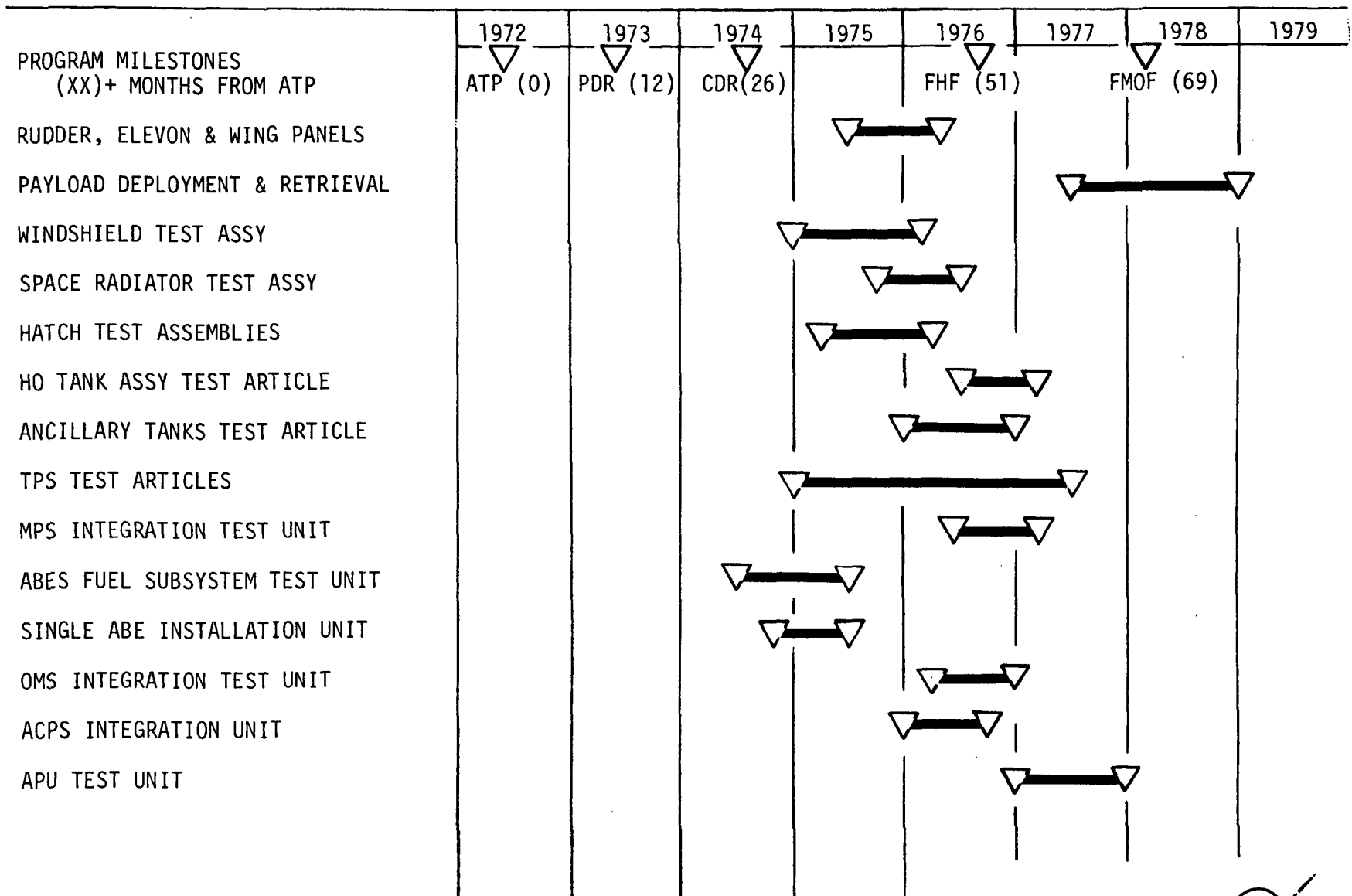
SYSTEM LEVEL * / ORBITER GROUND TEST

* SRAO - PRESSURE FED



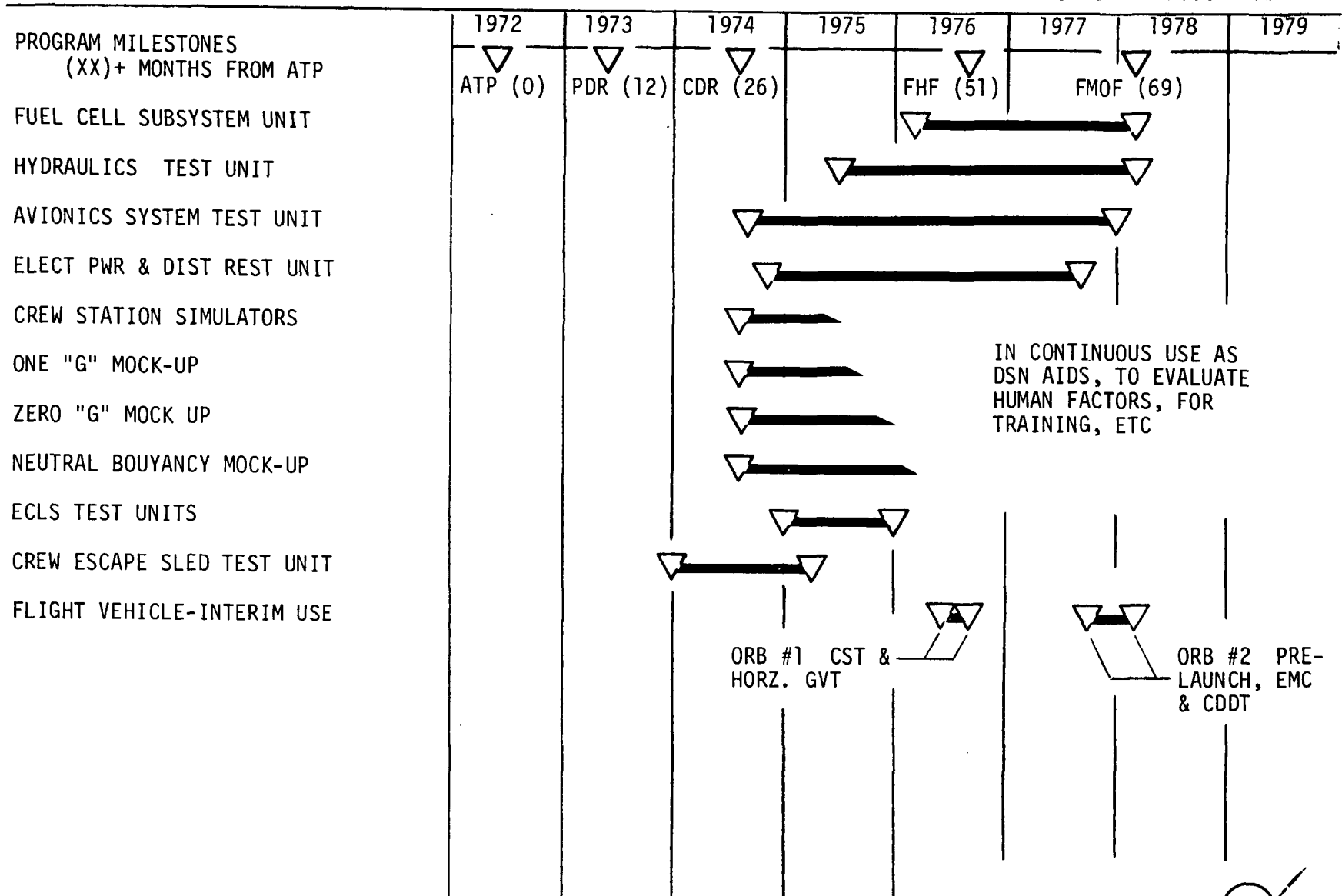
SYSTEM LEVEL * / ORBITER GROUND TEST

* SRAO - PRESSURE FED



SYSTEM LEVEL * / ORBITER GROUND TEST

* SRAO - PRESSURE FED



SYSTEM LEVEL* ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
WIND TUNNEL MODELS ORBITER MODELS BOOSTER MODELS	AERO, THERMO, LOADS, STRUCTURAL DYNAMICS, PROPULSION (29000 HRS) ORBITER ORBITER/HO TANK (6000 HRS) SYSTEM LEV	GOVERNMENT & CORPORATE WIND TUNNELS
MAN-IN-THE-LOOP FLIGHT SIMULATOR	EVALUATE HANDLING QUALITIES, PILOT INTERFACES, FLIGHT PROCEDURES	MDC
DYNAMICALLY SCALED STRUCTURAL ARRANGE- MENT (i.e., MODELS OF ORBITER, HO TANK, BOOSTER) (~ 25%)	MODE SHAPES, FREQUEN- CIES, INTER-BODY MODAL COUPLING	MDC
ORBITER-HO TANK SEPARATION SYSTEM TEST UNIT	DYNAMIC SEPARATIONS, INTERCONNECTS FUNCTIONAL	MDC
HO TANK-BOOSTER SEPARATION SYSTEM TEST UNIT	DYNAMIC SEPARATIONS, INTERCONNECTS FUNCTIONAL	MDC
VERTICAL GROUND VIBRATION DYNAMIC RESPONSE TEST ARTICLE (INCORP- ATING* ITEMS BELOW;- AND/OR DYNAMIC MASS- INERTIA SIMULATORS)	LOW LEVEL DYNAMIC RESPONSE/MODAL DAMPING OF ORBITER- HO TANK CONFIGURATION	NASA-KSC

* SRAO - PRESSURE FED

SYSTEM LEVEL ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
SCALE MODEL OF ORBITER (~ 10%)	ABE OPERATION (COLD JET) ACOUSTIC; LEVEL DETERMINATION	MDC
SCALE MODEL OF HO TA HO TANK (~ 25%)	FLUID-ELASTIC DATA FOR ANALYTICAL MODEL (LATERAL AND VERTICAL MOTION)	NASA-MSc
STRUCTURAL TEST ARTICLE* WINGS/FWD-CENTER-AFT FUSELAGE/ PAYLOAD BAY DOOR/VERTICAL TAIL/ L/H ELEVON/RUDDER/ NOSE CAP) (INITIALLY WITHOUT TPS BUT WITH CERTAIN TPS ADDED DURING TEST PROGRAM)	STRUCTURAL TESTS OF VERTICAL TAIL, RUDDER, ELEVON, LANDING GEAR BACK UP, MODAL RESPONSE- VERTICAL TAIL, ELEVON, RUDDER	MDC
	WINGS AND CARRY THROUGH STRUCTURE LOADS CONDITIONS FOR WING MAX. DOWN BENDING (ASCENT) AND FOR MAXIMUM UP-BENDING (AIRPLANE FLIGHT)	MDC
	THERMAL CONTROL - WING AND FIN FUSELAGE MAX. BENDING AND/OR COMPRESSION LOADS CONDITIONS THERMAL CONTROL- PAYLOAD ACCOMMODATIONS	NASA-MSc
		MDC
		NASA-LeRC

* SRAO - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
STRUCTURAL TEST ARTICLE* (CONT'D)	MATED ORBITER- HO TANK VERT. GVT PAYLOAD DOOR AND RADIATOR FUNCTIONAL	NASA-KSC MDC /NASA-KSC
FORWARD FUSELAGE TEST ASSEMBLY WITH NOSE LANDING GEAR AND DOORS	ECLS FUNCTIONALITY ACOUSTICS HEAT BALANCE FWD TANK TIE, CABIN PRESSURE SAFE LIFE VISOR & NOSE CAP FUNCTIONAL DOCKING FUNCTIONAL	MDC NASA-MSC NASA-MSC MDC NASA-MSC/MDC MDC
	NLG & DOOR FUNCTIONAL THERMAL RESPONSE	MDC MDC
AFT FUSELAGE TEST ASSEMBLY WITH L/H FERRY & ORBIT ABE POD STRUCTURAL ASSEMBLIES	MODAL DYNAMICS AND ACOUSTICS STRUCTURE SAFE LIFE (THRUST STRUCTURE, TANK TIE) HEAT BALANCE ABE POD STRENGTH	NASA-MSC MDC MDC MDC
L/H MAIN LANDING GEAR* ASSEMBLIES (INCL. ACTUATOR & MECHANISMS)(2 REQ'D)	MAX FWD ACTING LOAD (SPRING BACK); MAX AFT ACTING LOAD (BRAKED ROLL); MAX. SIDE LOAD (TURNING); THERMAL CONTROL	MDC NASA-MSC NASA-MSC
MLG DOOR ASSEMBLY (1 REQD) (INCL. ACTUATOR AND MECH- ANISM AND TPS) INSTALLED IN L/H MLG WHEEL WELL FIXTURE		

SYSTEM LEVEL*/ ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
MAIN LANDING GEAR & DOOR (CONT'D)	METERING PIN CALIBRATION; RESERVE LANDING ENERGY OVERLOAD CAPABILITY	VENDOR
	FUNCTIONAL AIRPLANE FLIGHT LOAD CONDITION (DOORS OPEN); ASCENT BURST PRESSURE TEST (DOORS CLOSED); ASCENT & ENTRY ACOUSTIC, THERMAL & PRESSURE LOADS RESPONSE	MDC
NOSE LANDING GEAR ASSEMBLY (1 REQD) (INCL. ACTUATOR AND MECHANISM)	METERING PIN CALIBRATION; RESERVE LANDING ENERGY OVER-LOAD CAPABILITY	VENDOR
	SHIMMY STEERING FUNCTIONAL	USAF-AFFDL MDC
RUDDER PANEL	VIBRO-ACOUSTICS SAFE LIFE	MDC
ELEVON PANEL	VIBRO-ACOUSTICS SAFE LIFE	MDC
WING PANEL	VIBRO-ACOUSTICS SAFE LIFE	MDC
RUDDER ACTUATION RIB SECTION	STRUCT. LIFE CYCLE	MDC
ELEVON ACTUATION RIB SECTION	STRUCT LIFE CYCLE	MDC
PAYLOAD DEPLOYMENT/ RETRIEVAL MECHANISM TEST UNIT	PAYLOAD MANIPULATION	MDC

* SRAO - PRESSURE FED

MDC E0558
PART III
15 MARCH 1972

5-15

MCDONNELL DOUGLAS

TRW



CORPORATION

SYSTEM LEVEL*/ ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
SPACE RADIATOR TEST ASSEMBLY*	HEAT BALANCE DEPLOYMENT	NASA-MSC/LeRC NASA-KSC
ANCILLARY TANKS STRUCTURAL TEST ARTICLES*	STATIC & DYNAMIC INTEGRITY	MDC/VENDOR(s)
HO TANK ASSEMBLY STRUCTURAL TEST ARTICLE* (INCL. AFT SKIRT & ORBITER ATTACH FITTINGS	MAX. COMPRESSION LOADS IN TANK AND SKIRT (2 CONDITIONS); MAX. LOADS IN TANK TO ORBITER ATTACH STRUCTURE (2 CON- DITIONS); MAX. ASCENT BURST PRESSURE LOADS. VERTICAL GVT (MATED WITH ORBITER TEST ARTICLE)	MFGR'G SITE NASA-KSC
THERMAL PROTECTION SYSTEM TEST ARTICLES		MDC, NASA, & USAF-AFFDL LABORATORIES
(2) 2' x4' SKIN STRINGER PANELS- MOLDLINE ABLATOR	MECHANICAL & THERMAL LDS.	

* SRAO - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
(8) 2'x4' SKIN STRINGER PANELS-MOLDLINE RSI	STRUCTURAL BUCKLING	MDC, NASA, & USAF-AFFDL LABORATORIES
(5) 2'x2' SKIN STRINGER PANELS- RSI TILES	THERMAL DEFORMATION	
(2) 2'x4' SKIN STRINGER PANELS-MOLDLINE RSI	MISSION SIMULATION MECHANICAL, ACOUSTIC, THERMAL LOADS	
(15)20"x20" SKIN STRINGER PANELS-ABLATOR JOINTS	TIME TEMPERATURE- PRESSURE PROFILES (VACUUM-PLASMA)	
(15)20"x20" SKIN STRINGER PANELS-RSI JOINTS	TIME TEMPERATURE- PRESSURE PROFILES (VACUUM-PLASMA)	
(5)20"x20" BASE HEAT SHIELD PANELS	ACOUSTIC, ELEVATED TEMPERATURE @ REDUCED PRESSURE (MISSION SIMULATION)	
(1) 4'x4' SECTION OF BASE HEAT SHIELD	ACOUSTIC, ELEVATED TEMPERATURE @ REDUCED PRESSURE (MISSION SIMULATION)	
(25)10"x10" SKIN STRINGER PANELS WITH RSI TILES	METEOROID IMPACT	
(2) DOOR SILL/SEAL SPECIMENS (LG DOOR & ELEVON HINGE)	MASS FLOW, TEMPERATURE AND PRESSURE	

MDC E0558
PART III
15 MARCH 1972

5-17

* SRAO - PRESSURE FED

MCDONNELL DOUGLAS

TRW



SYSTEM LEVEL* ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
(1) HOT GAS HINGE SEAL FOR ELEVON	MASS FLOW, TEMPERA- TURE AND PRESSURE	MDC, NASA, & USAF-AFFDL LABORATORIES
(1) SUBSCALE MODEL OF NOSE CAP ASSY	THERMAL LOADS	MDC, NASA, & USAF-AFFDL LABORATORIES
ABES FUEL SUBSYSTEM TEST UNIT (ORBITAL & FERRY CONFIGURATIONS	FUEL/DEFUEL, FUEL AVAILABILITY, FUEL PRESSURANT AND VENT FUNCTION/PERFORMANCE, GAGING FUNCTION AND ACCURACY	MDC
SINGLE ABE INSTALLA- TION TEST UNIT (EMPLOYING ONE ABE POD STRUCTURAL TEST ASSEMBLY)	AIRSTART, STEADY STATE & TRANSIENT PERFORM- ANCE, THERMAL CONTROL, ENGINE CONTROLS, DOORS DEPLOY, FIRE DETECTION & EXTINGUISHING	ENGINE MFG/MDC/ USAF-AEDC
MAIN PROPULSION INTEGRATION TEST UNIT (BOILERPLATE HO TANK, 3 HI P _c ENGINES)	SYSTEM AND GSE COMPATI- BILITY; FLUIDS LOADING/ UNLOADING; TANK SAFING; LEVEL & DEPLETION SEN- SORS PERFORMANCE; ULLAGE BACK PRESSURE; PRESSURIZATION RATES, DIFUSION, COLLAPSE FEED SYSTEM CHILL DOWN AND PRESTART; ELECT- RICAL/HYDRAULIC INTER- FACES; GIMBAL ENVELOPE & RESPONSE; ENGINE	NASA-MTF SIC STAND (MODIFIED) (MSFC, ALTERNATE)

* SRAO - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE

TEST

TEST LOCATION

CONT'D)
START AND
SHUTDOWN TRANSIENTS;
ENGINE MOUNT LOADING
PROFILE; PNEUMATIC
CONTROL AND PURGE;
DYNAMIC COUPLING
RESPONSE/CHARACTER-
ISTICS; STEADY
STATE OPERATION AT
RATED (AND REDUCED,
IF APPLICABLE)
THRUST; SYSTEM
RESPONSE FOR SINGLE
ENGINE(S) SHUTDOWN.

MTF SIC STAND
MODIFIED)
(MSFC,ALTERNATE)

ORBIT MANEUVERING
SYSTEM (OMS)
INTEGRATION TEST
UNIT*

FLUIDS SERVICING;
PRESSURIZATION AND
FEED FUNCTION AND
PERFORMANCE; SYSTEM
PERFORMANCE AND
INTERFACE COMPATI-
BILITY;ENDURANCE,
MAINTENANCE AND
CHECKOUT.
THERMAL CONTROL
STRUCTURAL INTEGRITY,
(VIBRATION, SHOCK,
AND MECHANICAL LOAD-
ING)

NASA-WSTF
(ALTERNATE: MDC-
SACTO IF ALTI-
TUDE SIMULATION
BECOMES NOT
REQUIRED)

& MDC
MDC

* SRAO - PRESSURE FED

SYSTEM LEVEL* ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
APU TEST UNIT	FLUIDS SERVICING; PRESSURIZATION & FEED FUNCTIONALITY AND PERFORMANCE, INTEGRA- TION SYSTEM OPERATION AND PERFORMANCE (ALTER- NATOR, HYDRAULIC PUMPS; CONTROLS AND SENSORS); MISSION DUTY CYCLE PERFORMANCE/ENDURANCE; MAINTAINABILITY AND CHECKOUT.	NASA-WSTF
FUEL CELL SUBSYSTEM INTEGRATION TEST UNIT	FLUIDS SERVICING; PRESSURIZATION AND REACTANT FEED FUNCTION- ALITY AND PERFORMANCE; INTERFACES COMPATI- BILITY; MISSION DUTY CYCLE PERFORMANCE AND ENDURANCE; MAINTAIN- ABILITY AND CHECK-OUT.	NASA-WSTF
ELECTRICAL POWER DISTRIBUTION AND CONTROL TEST UNIT (BREADBOARD FOR AC & DC POWER)	OPERATION, CONTROL, MONITOR AND DISPLAY EVALUATIONS; SIMULATED FAULT AND RECOVERY. POWER QUALITY, REGULA- TING AND SWITCHING; INTERFACE COMPATIBILITY (USING OTHER MAJOR TEST ARTICLES; e.g., AVIONICS SYSTEM TEST UNIT).	MDC

* SRAQ - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
CREW STATION SIMULATORS	OBTAIN CREW STATION DESIGN INFORMATION AND EVALUATION DATA TO ASSIST:	MDC, NASA-MSC NEUTRAL BOUYANCY FACILITY, GOVERNMENT ZERO 'G' AIRCRAFT
- o VEHICLE TRAINING SIMULATOR-VTS ** - o PART TASK	o ESTABLISHING A BASELINE CREW STATION	↓
ONE 'G' MOCK-UP	o DETERMINE FEASI- BILITY, COST, WEIGHT AND CREW ACCEPTANCE CRITERIA OF THE SELECTED ARRANGEMENT AND CONFIGURATION	
- o DEVELOPMENT AND TRAINING FIXTURE** (CREW STATION AND HABITABILITY AREA) - o PART TASK		
ZERO 'G' MOCK-UPS	o EVALUATE AND OPTI- MIZE RESULTING CREW STATION DESIGN AND OPERATIONAL PROCEDURES.	
- o CREW STATION AND HABITABILITY AREA** - o PART TASK		
NEUTRAL BOUYANCY MOCKUPS		
- o CREW STATION AND HABITABILITY AREA** - o PART TASK		

** - SPORADIC AND INTERIM
USE FOR TEST AND
EVALUATION PURPOSES
OF ITEMS THAT ARE
ACQUIRED FOR THE
PRIMARY USE IN
TRAINING FUNCTION.

* SRAO - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
AVIONICS SYSTEM TEST UNIT	SUBSYSTEMS INTEGRATION INCLUDING REDUNDANCY MANAGEMENT; VERIFY DESIGN PERFORMANCE GOALS; FUNCTIONAL EMI COMPATIBILITY; INTER- FACES VERIFICATION; PROCEDURES DEVELOPMENT (OPERATING, CHECKOUT AND SERVICING); VALIDATION OF FLIGHT SOFTWARE	MDC
HYDRAULICS AND FLIGHT CONTROLS TEST UNIT	INTEGRATION OF HYDRAU- LICS SUBSYSTEMS; INTEGRATION OF FLIGHT CONTROLS MECHANISMS; VERIFICATION OF DESIGN PERFORMANCE GOALS; FAILURE TOLERANCE; VERIFICATION OF INTER- FACES WITH NON- HYDRAULIC SUBSYSTEMS (e.g. FLIGHT CONTROL SYSTEM AVIONICS); PROCEDURES DEVELOPMENT.	MDC
ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (EC/LS) TEST UNITS	LEAKAGE; LINE AND DUCT PRESSURES AND VELOCITIES; ACOUSTIC LEVELS; HEAT TRANSFER RATES; CONTROL RESPONSE; SUBSYSTEM/ COMPONENT FUNCTIONAL COMPATIBILITY-SERVICE REQUIREMENTS AND	MDC

* SRAQ - PRESSURE FED

SYSTEM LEVEL*/ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE	TEST	TEST LOCATION
EC/LS - continued	PROCEDURES; LINE PRESSURE LEVELS AND DUCT PROOF PRESSURES; NORMAL OPERATION AND INPUTTED SUBSYSTEM AND COMPONENT FAILURE CONDITIONS. (COMPONENTS THEN AVAILABLE FOR USE IN FORWARD FUSELAGE TEST ASSEMBLY)	
CREW ESCAPE SYSTEM SLED TEST UNIT (SYSTEM FOR HORIZONTAL FLIGHT TEST OPERATIONS)	SLED TEST OPERATIONS FROM ZERO VELOCITY (STATIC EJECTION) TO DESIGN LIMIT CONDITION FOR MOST CRITICAL SYSTEM INSTALLATION AND HORIZONTAL FLIGHT TEST CONDITION.	USN-CHINA LAKE OR USAF-HAFB
WINDSHIELD TEST ASSY CONSISTING OF W/S FRAME, TRANSPARENCIES, SEALS VISOR	LEAKAGE, STRUCTURAL VERIFICATION, HEAT TRANSFER	MDC
HATCH TESTS - ONE EACH TYPE PRESSURE HATCH WITH SILL FRAME	LEAKAGE, FUNCTIONAL, STRUCTURAL ADEQUACY	MDC

* SRAO - PRESSURE FED

SYSTEM LEVEL ORBITER MAJOR TEST ARTICLES - GROUND TEST

TEST ARTICLE.

REACTION CONTROL
PROPULSION SYSTEM
(RES) INTEGRATION
TEST UNIT (L/H WING
POD ASSEMBLY)

TEST

FLUIDS SERVICING;
PRESSURIZATION AND
FEED FUNCTION AND
PERFORMANCE; SYSTEM
PERFORMANCE AND
INTERFACE COMPATI-
BILITY; ENDURANCE,
MAINTENANCE AND
CHECKOUT.
THERMAL CONTROL
STRUCTURAL INTEGRITY,
(VIBRATION, SHOCK,
AND MECHANICAL LOAD-
ING)

TEST LOCATION

NASA-MSTF

AND NASA-MSC
MDC
MDC

* SRAO - PRESSURE FED

WIND TUNNEL OCCUPANCY HOURS

COMPARISON AND RATIONALE

	<u>PHASE B-2 STAGE FULLY REUSABLE (REFERENCE)</u>	<u>SERIES BALLISTIC RECOVERABLE PRESSURE FED BOOSTER/ORBITER SYSTEM</u>	<u>PARALLEL BALLISTIC RECOVERABLE PRESSURE FED BOOSTER/ORBITER SYSTEM</u>	<u>PARALLEL SOLIDS BOOSTER/ORBITER SYSTEM</u>
ORBITER ALONE	27,430	29,000 ADDED EXTERNAL TANK REQUIRES TANK PLUS ORBITER AND TANK ALONG DELTAS	29,000	29,000
MATED AND PROXIMITY	12,140	6,000 SIMPLER MATING ARRANGEMENT WITH SERIES MATE (SIMPLIFIES SEPARATION AND PROXIMITY TESTS); BODY OF REVOLUTION; NO BOOSTER FLYBACK.	10,000 MATING ADDS COMPLEXITY TO SEPARATION AND PROXIMITY TESTING; NO FLYBACK, BODY OF REVOLUTION SIMPLER THAN REFERENCE.	8,000 BOOSTERS NOT RECOVERED; LESS INSTRUMENTATION DURING TEST (ON SRM'S); NO ITERATIVE TESTING GENERATED BY BOOSTER ALONE TESTS.

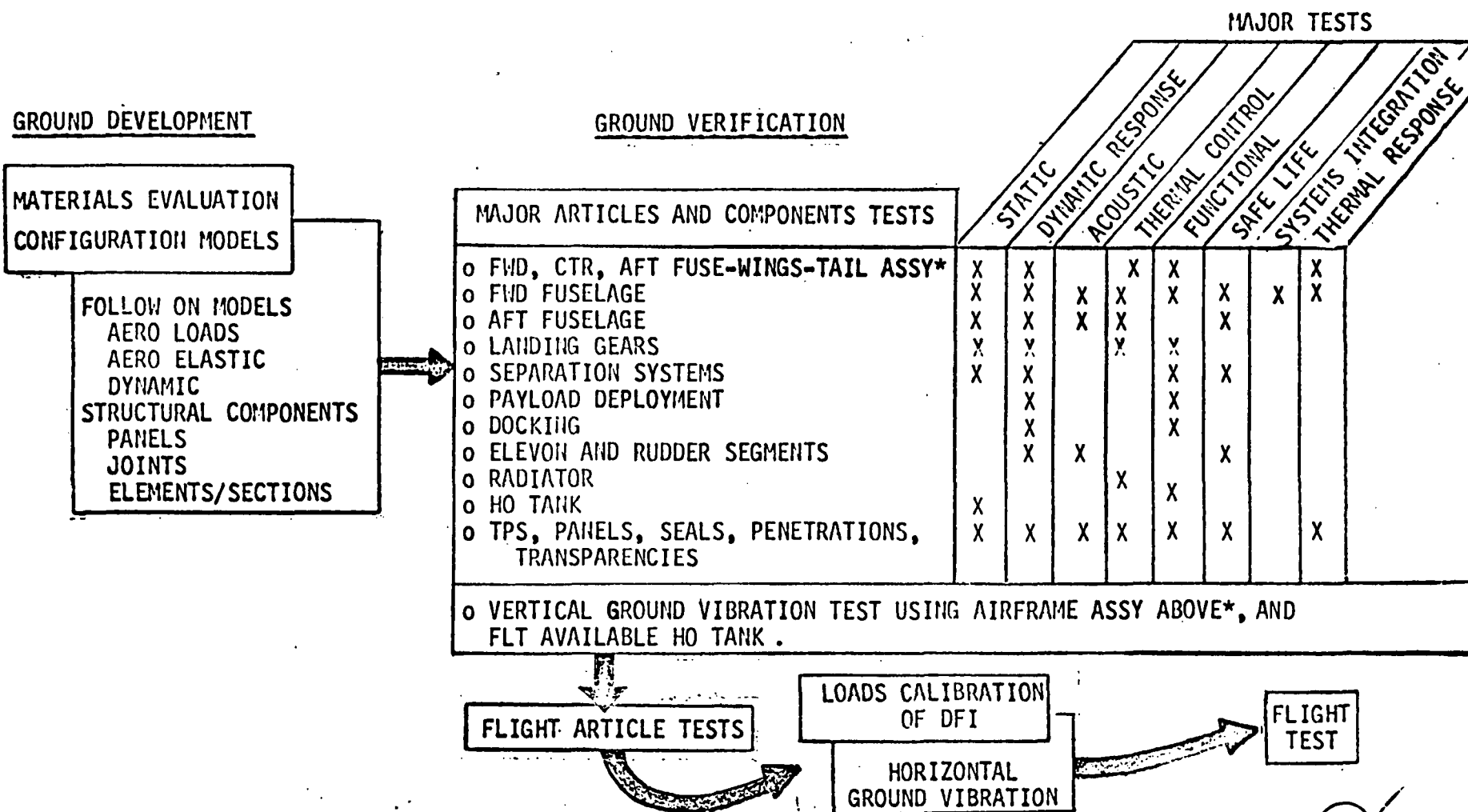
ORBITER SYSTEM

THERMAL - STRUCTURAL VERIFICATION TESTS

TESTING APPROACH AND MINIMUM PROGRAM MILESTONES:

- o PRIMARY STRUCTURE TO LIMIT LOADS PRIOR TO FIRST HORIZONTAL FLIGHT (FHF)
- o AERODYNAMIC CONTROL SURFACES SAFE LIFE VERIFICATION 50% COMPLETE PRIOR TO FHF
- o DFI AND OPERATIONAL INSTRUMENTATION CALIBRATIONS PRIOR TO FHF AND FMOF
- o LANDING GEAR AND FERRY ABES POD TO ULTIMATE LOADS PRIOR TO FHF
- o ORBITER HORIZONTAL GVT PRIOR TO FHF
- o MATED VEHICLE DYNAMICS VERIFICATION COMPLETED PRIOR TO FIRST MANNED ORBITAL FLIGHT (FMOF)
- o PRIMARY STRUCTURE TO ULTIMATE LOADS PRIOR TO FMOF
- o SEPARATION SYSTEMS FUNCTIONAL TESTS COMPLETE PRIOR TO FMOF
- o THERMAL PROTECTION SYSTEM QUALIFIABLE BY FHF, MISSION LIFE VERIFIED (ON GROUND) PRIOR TO FMOF, FLIGHT QUALIFIED WITH EARLY FLIGHTS
- o THERMAL CONTROL HEAT BALANCE TESTING 50% COMPLETE PRIOR TO FMOF
- o ACOUSTIC RESPONSE TESTS COMPLETE PRIOR TO FMOF
- o PAYLOAD MANIPULATOR FUNCTIONAL VERIFICATION PRIOR TO FMOF
- o DOCKING FUNCTIONAL VERIFICATION 25% COMPLETE PRIOR TO FMOF AND COMPLETED PRIOR TO THIRD MANNED ORBITAL FLIGHT

HO ORBITER/SYSTEM LEVEL THERMAL - STRUCTURAL TESTING APPROACH



ORBITER/SYSTEM LEVEL
DYNAMIC TEST REQUIREMENTS

Mating arrangement is the major consideration establishing differences in the requirements for test data to be used in dynamic mathematical modeling analysis.

O R B I T E R / S Y S T E M L E V E L D Y N A M I C T E S T R E Q U I R E M E N T S

REQUIREMENT	(REFERENCE) PHASE B 2 STAGE FULLY REUSABLE BOOSTER/ORBITER SYSTEM	SERIES BALLISTIC RECOVERABLE PRESSURE FED BOOSTER/ORBITER SYSTEM	PARALLEL BALLISTIC RECOVERABLE PRESSURE FED BOOSTER/ORBITER SYSTEM	PARALLEL SOLIDS BOOSTER/ORBITER SYSTEM
o WIND TUNNEL TESTING: STABILITY; FLUCTUATING PRESSURE ENVIRONMENTS; FLUTTER AND BUFFET	X	X	X	X
o DYNAMIC MODEL TESTS OF ORBITER, ORBITER-HO TANK, AND ORBITER-HO TANK- BOOSTER STRUCTURAL ARRANGEMENTS	X (EXCEPT NO HO TANK)	X	X	X
o FLUIDS-STRUCTURE INTERACTION USING SCALE MODELS OF HO TANK AND BOOSTER TANKS		X	X	HO TANK ONLY
o LOW LEVEL DYNAMIC RESPONSE AND/OR VIBRO-ACOUSTICS OF PERTINENT FULL SCALE ORBITER STRUCTURAL COMPONENTS (E.G., AERO CONTROL SURFACES, BODY STRUCTURE SECTIONS)	X	X	X	X
o HORIZONTAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER FLIGHT VEHICLE	X	X	X	X
o FULL SCALE VERTICAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER-HO TANK		X	X	X
o FULL SCALE VERTICAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER-HO TANK-BOOSTER		AMENABLE TO ANALYSIS - MAY REQUIRE TESTING	X	X
o FULL SCALE HORIZONTAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER-BOOSTER	X			

MAIN PROPULSION SYSTEM INTEGRATION TEST UNIT

ORBITER

o REQUIREMENTS:

- (1) THE ABILITY OF THE PNEUMATIC SYSTEM TO SUPPLY ADEQUATE PRESSURE AND FLOW AT ALL TIMES FOR VEHICLE SYSTEMS COMPONENT ACTUATION CONTROL AND PURGING AND FOR ENGINE CONTROL AND PURGING (INCLUDING REDUNDANCY MODE CAPABILITY) SHALL BE DEMONSTRATED.
- (2) GROUND CONTROLLED TANK PRESSURIZATION (DURING MAINTENANCE, CHECKOUT, PROPELLANT LOADING, PRESSURIZATION AND PURGING) AND FLIGHT CONTROLLED PRESSURIZATION (BOOST FLIGHT, COAST, REENTRY, CRUISE AND LANDING) SHALL BE DEMONSTRATED TO BE WITHIN COMPONENT AND SYSTEM SPECIFICATIONS. THIS SHALL INCLUDE REDUNDANCY VERIFICATION.
- (3) PROPELLANT SYSTEM FILL RATES, LEVEL CONTROL, ANTI-VORTEX EFFECTIVENESS, LH₂ TANK INSULATION CHARACTERISTICS, AND PROPELLANT NPSP REQUIREMENTS AT THE ENGINES INTERFACES (INCLUDING TRANSIENT EFFECTS CAUSED BY ENGINE SHUTDOWN SIMULATING AN INFLIGHT FAILURE) SHALL BE DEMONSTRATED.
- (4) THE COMPATIBILITY OF THE ENGINE(S) TO VEHICLE MECHANICAL, ELECTRICAL, AVIONICS, FLUID, GAS AND PERFORMANCE INTERFACE, INCLUDING REDUNDANCY VERIFICATION, AND ENGINE THROTTLING EFFECTS ON THE VEHICLE SYSTEMS FOR REDUCED (IF APPLICABLE) AND MAXIMUM POWER LEVELS SHALL BE DEMONSTRATED WITHIN THE LIMITS PRACTICAL FOR GROUND TESTING.

- #### o DESCRIPTION:
- 'BOILERPLATE' CONSTRUCTION MAIN PROPELLANT TANKS CAPABLE OF OPERATING PRESSURE REQUIRED TO SIMULATE FLIGHT LEVEL ENGINE INLET PRESSURES. THREE GFE MAIN ENGINES. BOILERPLATE THRUST REACTION STRUCTURE INCORPORATING ENGINE INTERFACING FLIGHT VEHICLE HARDWARE AND LOCALLY ADJACENT BACK-UP STRUCTURE. FLIGHT CONFIGURED FEEDLINES, PRESSURIZATION, HYDRAULICS/TVC AND INCLUDED COMPONENTS. INSTRUMENTATION, ACTUATOR CONTROL AND GROUND SIMULATED AVIONICS. OPERATIONAL TYPE INTERFACING G.S.E. (E.G., FLOW METERING UNITS).

MAIN PROPULSION SYSTEM INTEGRATION TEST UNIT (CONTINUED)

- o SCOPE: ESTABLISH COMPATIBILITY OF THE SYSTEM AND GSE AND THEIR ABILITY TO PROVIDE CONTROLLED VEHICLE PNEUMATICS AND LIQUID AND GASEOUS PROPELLANT LOADINGS AND UNLOADINGS INCLUDING MAXIMUM LOADING RATES REQUIRED FOR A MINIMUM LAUNCH COUNTDOWN TIME. DEMONSTRATE PROPELLANT TANK SAFING TECHNIQUES (LAUNCH SCRUB AND NORMAL POST LANDING RECOVERY). DEMONSTRATE SIMULTANEOUS PROPELLANT LOADING CAPABILITY INCLUDING MINIMUM PROPELLANT LOADING TIME. DETERMINE ACCURACIES OF THE PROPELLANT TANK LEVEL SENSORS INCLUDING THE OVERFILL SENSORS AND THE CAPABILITY OF THE GSE TO MAINTAIN PROPER LIQUID LEVEL. DETERMINE TANK ULLAGE BACK PRESSURE FROM THE VENT SYSTEM. DETERMINE LO_2 AND LH_2 PREPRESSURIZATION RATES; ESTABLISH EFFECTIVENESS OF THE MAIN TANK PRESSURIZATION DIFFUSER AND COMPARE THE ULLAGE GAS COLLAPSE FACTOR TO PREDICTED VALUES. VERIFY SATISFACTORY ENGINE FEED SYSTEM CHILLDOWN AND NET POSITIVE SUCTION PRESSURE (NPSP) CHARACTERISTICS FOR ENGINE PRESTART. DEMONSTRATE THE COMPATIBILITY OF THE PERTINENT INTERFACES WITH ELECTRICAL AND HYDRAULIC SUBSYSTEMS. DEMONSTRATE THE ABILITY OF THE ENGINE ACTUATORS TO CONTROL ENGINE POSITION THROUGHOUT THE FLIGHT GIMBAL ENVELOPE. VERIFY THAT ENGINE START AND SHUTDOWN TRANSIENT CONDITIONS ARE WITHIN ALLOWABLES (I.E., NPSP, FLOW OF GO_2 , GH_2 , AND HELIUM, ELECTRICAL POWER, AND AVIONICS OPERATIONAL CHARACTERISTICS). VERIFY THE CHARACTERISTICS OF THE THRUST STRUCTURE LOADING PROFILE. DETERMINE THE PRESSURE CONTROL CHARACTERISTICS OF THE MAIN TANK DURING THE START TRANSIENT. VERIFY THE CAPABILITY OF THE PNEUMATIC CONTROL AND PURGE SYSTEMS. DEMONSTRATE THE ENGINE ACTUATOR POSITIONING CONTROL DURING START AND SHUTDOWN TRANSIENTS. VERIFY VEHICLE-STRUCTURE-TO-ENGINE DYNAMIC COUPLING RESPONSE WITHIN THE LIMITS OF TEST ARTICLE CONFIGURATION AND HOLD-DOWN. VERIFY ENGINE AND MAIN PROPULSION SYSTEM PERFORMANCE AT RATED (AND REDUCED, IF APPLICABLE) THRUST. VERIFY SATISFACTORY VEHICLE SYSTEM RESPONSE AND PROPELLANT SUPPLY CHARACTERISTICS DURING A SINGLE ENGINE(S) SHUTDOWN. VERIFY PERFORMANCE OF THE DEPLETION SENSORS. VERIFY MAXIMUM-RATE GIMBALLING RESPONSE.

AVIONICS SYSTEM TEST UNIT (ASTU) (AND SOFTWARE VALIDATION COMPLEX)

o REQUIREMENTS

- (1) INTEGRATION OF AVIONIC SUBSYSTEMS INCLUDING REDUNDANCY MANAGEMENT
- (2) VERIFICATION OF DESIGN PERFORMANCE GOALS AND SUBSYSTEM FUNCTIONAL EMI COMPATIBILITY
- (3) INTEGRATION AND VERIFICATION OF AVIONIC INTERFACES WITH OTHER SYSTEMS
- (4) DEVELOPMENT OF OPERATING, CHECKOUT AND SERVICING PROCEDURES
- (5) VALIDATION OF FLIGHT SOFTWARE

o DESCRIPTION

THE ASTU WILL CONSIST OF A COMPLETE SHIP SET OF ENGINEERING MODEL AND PROTOTYPE AVIONIC HARDWARE. INSTALLATION OF THE EQUIPMENT, CABLE LENGTHS AND INTERFACES WILL BE DUPLICATED WITHIN PRACTICAL LIMITS. WITH THE EXCEPTION OF THE ELECTRICAL DISTRIBUTION SYSTEM, THE NON-AVIONIC SYSTEM INTERFACES WILL BE REPRESENTED WITH SOFTWARE OR SIMPLE HARDWARE SIMULATORS. TEST SOFTWARE AND A COMMERCIAL COMPUTER WILL BE USED TO FACILITATE CLOSED-LOOP SIMULATED MISSION TESTING FOR ALL PHASES FROM PRE-FLIGHT CHECKOUT AND LAUNCH THROUGH LANDING AND SAFING. FLIGHT SOFTWARE VALIDATION BY REAL-TIME EXECUTION OF THE SOFTWARE PROGRAM IN THE FLIGHT COMPUTERS UNDER DYNAMIC CLOSED-LOOP CONDITIONS REPRESENTATIVE OF ACTUAL FLIGHT WILL EMPLOY COMMERCIAL COMPUTATION EQUIPMENT TO PROVIDE VEHICLE, ENVIRONMENTAL, AND END INSTRUMENT MATH MODELS AND PROVIDE INPUTS TO AND ACCEPT OUTPUT COMMANDS FROM THE ASTU HARDWARE.

A V I O N I C S S Y S T E M T E S T U N I T (A S T U) (C O N T ' D)
(A N D S O F T W A R E V A L I D A T I O N C O M P L E X)

o SCOPE

THE ASTU TEST PROGRAM WILL BE USED ON A CONTINUING BASIS COMMENCING UPON BUILDUP OF THE ENGINEERING MODEL AIRCRAFT MODE AVIONIC HARDWARE AND PHASE INTO A COMPLETE SYSTEM UNIT WITH THE ADDITION OF PROTOTYPE ORBITAL MODE AVIONICS HARDWARE.

THE MAJOR INTEGRATION EFFORTS UTILIZING THE ASTU ARE:

- o AIRCRAFT/SPACECRAFT AVIONICS SUBSYSTEM INTEGRATION
- o AVIONICS/ELECTRICAL POWER DISTRIBUTION AND CONTROL SYSTEM INTEGRATION
- o AVIONICS/GSE INTEGRATION
- o ORBITER/HO TANK (SIMUL) AVIONICS INTEGRATION
- o ORBITER/BOOSTER (SIMUL) AVIONICS INTEGRATION

OTHER AVIONICS INTEGRATION TESTS, SUCH AS, HYDRAULICS AND PROPULSION MAY REQUIRE DEDICATED AVIONICS HARDWARE OR SIMULATORS DUE TO PHYSICAL TEST LOCATION OR CONCURRENT TEST SCHEDULES. SOFTWARE VALIDATION WILL CONSTITUTE APPROXIMATELY 3 MONTHS EFFORT PRIOR TO FHF (AERO) AND APPROXIMATELY 5 MONTHS EFFORT PRIOR TO FMOF (ORBITAL). THE ASTU WILL BE AVAILABLE FOR SUPPORT OF THE HORIZONTAL AND VERTICAL FLIGHT TEST PROGRAM AS NEEDED.

o SCHEDULE

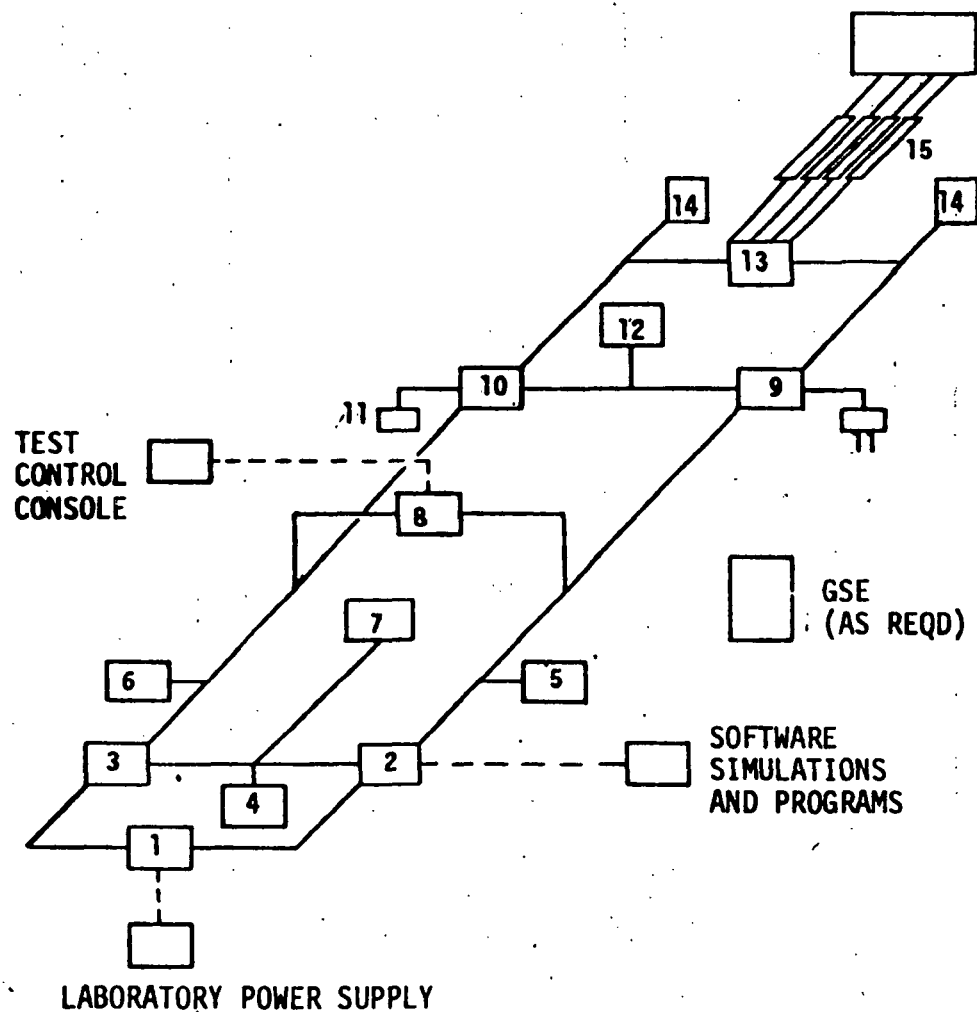
CONCEPTUAL DESIGN OF THE ASTU WILL START SHORTLY AFTER ATP WITH SYSTEM BUILDUP COMMENCING IMMEDIATELY AFTER CDR WITH THE AIRCRAFT MODE AVIONICS HARDWARE. INTEGRATION TESTING OF THE AIRCRAFT MODE AVIONICS (HARDWARE AND SOFTWARE) WILL BE COMPLETED APPROXIMATELY 1 MONTH PRIOR TO FHF. INTEGRATION TESTING OF THE ORBITAL MODE AVIONICS (HARDWARE AND SOFTWARE) WILL BE COMPLETED APPROXIMATELY 2 MONTHS PRIOR TO FMOF. SOFTWARE VALIDATION FOR AIRCRAFT MODE AVIONICS WILL BE COMPLETED BY FHF. SOFTWARE VALIDATION FOR ORBITAL MODE AVIONICS WILL BE COMPLETED BY FMOF. THE ASTU SETUP WILL REMAIN IN EXISTENCE UNTIL ALL PRODUCTION VEHICLES OF PHASE D ARE OPERATIONAL.

AVIONICS SYSTEMS TEST UNIT (ASTU) DESCRIPTION

<u>EQUIPMENT</u>	<u>GSE</u>	<u>OBJECTIVES</u>
1. COMPLETE SHIP SET OF AVIONICS EQUIPMENT (REDUNDANT)	1. ORBITER TO BOOSTER ELECTRICAL SIMULATION	1. INTEGRATION OF AVIONIC SUBSYSTEMS
o GUIDANCE, NAVIGATION & CONTROL	2. BOOSTER INTERFACE SIMULATOR	2. VERIFICATION OF DESIGN PERFORMANCE GOALS
o OPERATIONAL INSTRUMENTATION	3. DC POWER SUPPLY	3. DEVELOPMENT & VERIFICATION OF AVIONIC INTERFACES WITH OTHER SUBSYSTEMS
o COMMUNICATION AND TRACKING	4. AC POWER SUPPLY	4. VERIFICATION OF VEHICLE SOFTWARE DESIGN APPROACH
o DISPLAYS AND CONTROLS	5. GUIDANCE AND NAVIGATION GSE (BTE)	5. DEVELOPMENT OF PROCEDURES
o FLIGHT SOFTWARE	6. DISPLAY & CONTROL GSE (BTE)	o OPERATING
2. COMPLETE SHIP SET OF ELECTRICAL DISTRIBUTION EQUIPMENT	7. FCS GSE (BTE)	o CHECKOUT
o INVERTERS	8. INSTRUMENTATION GSE (BTE)	o SERVICING
o TRANSFORMER/RECTIFIERS	9. COMMUNICATION & NAVAID TEST SETS	
o CIRCUIT BREAKERS	10. MONITOR & DISPLAY CONSOLE (MDAC)	
o BUSES	11. HO TANK INTERFACE SIMULATOR	
o FUSES	12. MISC. CABLING, ETC.	
o ETC.		
3. SYSTEM SUPPORT		
o EQUIPMENT RACKS		
o INSTRUMENT PANEL MOCKUP		
o MASTER TEST CONTROL PANEL		
o TEST SOFTWARE		
o ELECTRICAL POWER		
o ELECTRICAL LOADS		
o ANTENNA LOADS		
4. DEVELOPMENT FLIGHT TEST INSTRUMENTATION		

AVIONICS SYSTEM TEST UNIT (ASTU) (CONCEPT)

LAB DRIVE OF
OF AC GENERATORS



- 1 FORWARD MAIN POWER CONTROL UNITS
- 2 LEFT FORWARD AVIONICS BAY
- 3 RIGHT FORWARD AVIONICS BAY
- 4 BOOSTER/HO TANK AVIONICS INTERFACE
- 5 LEFT NAVIGATION BASE - GUIDANCE AND NAVIGATION SENSORS
- 6 RIGHT NAVIGATION BASE
- 7 PAYLOAD AVIONICS INTERFACE
- 8 CABIN CONTROLS AND DISPLAYS
- 9 LEFT AFT. AVIONICS BAY
- 10 RIGHT AFT AVIONICS BAY
- 11 WHEEL WELL GSE INTERFACES
- 12 VERTICAL POSITION GSE INTERFACE
- 13 AFT MAIN POWER CONTROL UNITS
- 14 MAIN ENGINE INTERFACES
- 15 AC GENERATORS

HYDRAULIC AND CONTROLS TEST UNIT (HCTU)

o REQUIREMENTS

- (1) DEVELOPMENT AND PERFORMANCE VERIFICATION OF HYDRAULIC SUBSYSTEMS
- (2) INTEGRATION OF THE TOTAL HYDRAULIC SYSTEM INCLUDING --
 - VERIFICATION OF DESIGN PERFORMANCE GOALS
 - DEMONSTRATION OF FAILURE TOLERANCE
- (3) INTEGRATION OF HYDRAULIC AND ELECTRONIC FLIGHT CONTROL SYSTEM
- (4) DEVELOPMENT AND VERIFICATION OF INTERFACES WITH NON-HYDRAULIC SUBSYSTEMS
 - ECLS
 - AVIONICS
 - MAIN PROPULSION
 - CREW SYSTEMS CONTROLS AND DISPLAYS
 - FLIGHT SIMULATOR
- (5) DEVELOPMENT AND VERIFICATION OF HYDRAULIC SYSTEM OPERATING, CHECKOUT AND SERVICING PROCEDURES

o DESCRIPTION

THE ENTIRE HYDRAULIC SYSTEM IS MOUNTED ON A LABORATORY TYPE STRUCTURAL FRAMEWORK WHICH SIMULATES VEHICLE SPATIAL POSITIONS. COMPONENT INSTALLATION, LINE LENGTHS, PLUMBING GEOMETRY AND MATERIALS/METHODS OF FABRICATION ETC. WILL DUPLICATE THE ACTUAL INSTALLATION AS NEARLY AS PRACTICAL. PRODUCTION ACTUATORS ARE EMPLOYED TO OPERATE LANDING GEAR, SPEED BRAKES, AERODYNAMIC CONTROL SURFACES, ETC. WHICH ARE SIMULATED WITH RESPECT TO WEIGHT, C.G., MOMENT OF INERTIA, AND FLIGHT LOADING AS APPROPRIATE TO ACTUATING SYSTEM FORCES. PRODUCTION AERO-FLIGHT AUGMENTATION AND CONTROL AVIONICS AND APPLICABLE SPACE-CRAFT GN&C AVIONICS WILL BE USED FOR EVALUATION OF FLIGHT CONTROL DURING HORIZONTAL AND ENTRY TRANSIENT FLIGHT MODES. A COMMERCIAL COMPUTER AND TEST SOFTWARE WILL PROVIDE AVIONICS DATA MANAGEMENT AND CONTROL FUNCTIONS. APU POWER TO THE HYDRAULIC PUMPS AND THE ELECTRICAL POWER SUPPLY WILL BE SIMULATED. A CREW STATION WITH NECESSARY CONTROL AND DISPLAY FUNCTIONS WILL BE PROVIDED TO PERMIT PILOT INPUTS AND EVALUATIONS.

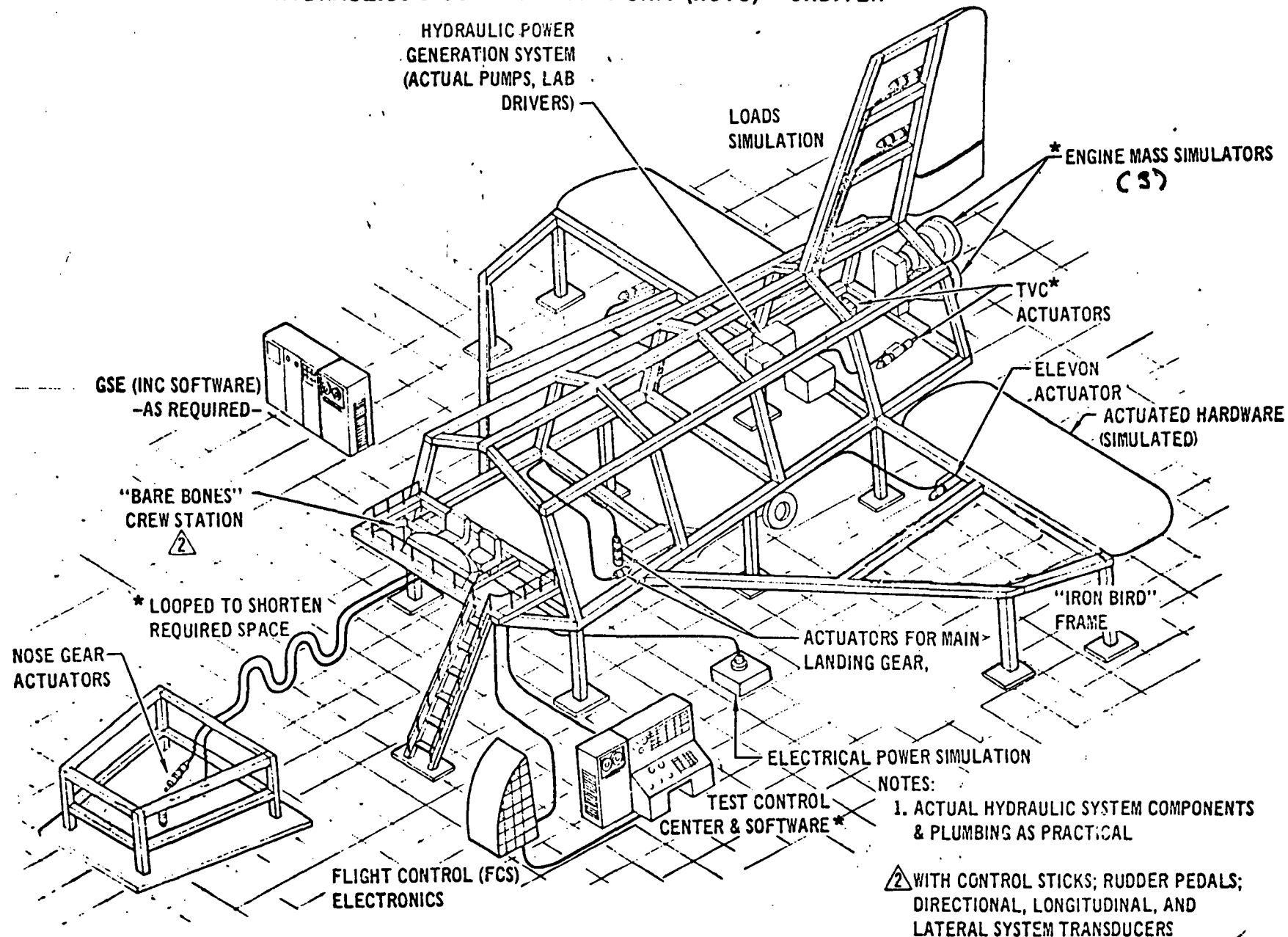
o SCOPE

APPROXIMATELY 3 3/4 YEARS OF TEST ACTIVITY IS ENVISIONED WITH APPROXIMATELY 30 MONTHS OF THIS EFFORT DEVOTED TO FCS ELECTRONICS INTEGRATION TESTING.

ORBITER HYDRAULICS AND CONTROLS TEST UNIT (HCTU) DESCRIPTION

EQUIPMENT	SIMULATORS	GSE
1. COMPLETE SHIP SET OF HYDRAULIC EQUIPMENT - o LANDING GEAR AND DOOR ACTUATION - o NOSE GEAR STEERING - o SPEED BRAKE ACTUATION - o ANTI-SKID BRAKES - o RUDDER AND ELEVONS ACTUATION - o THRUST VECTOR CONTROL - o PUMPS, RESERVOIRS, FILTERS, VALVES, FLUID LINES, ETC. 2. COMPLETE SHIP SET OF AERO-FLIGHT AUGMENTATION AND CONTROL AVIONICS AND APPLICABLE SPACECRAFT GN&C AVIONICS. 3. REQUIRED CREW STATION DISPLAYS FOR HYDRAULICS AND FLIGHT CONTROL SYSTEM 4. APPLICABLE PORTIONS OF DEVELOPMENT FLIGHT INSTRUMENT (DFI) 5. SET OF ELECTRICAL INTERFACE HARDWARE FOR 1. THRU 5. EQUIPMENT NOTE: ALL IN FLIGHT VEHICLE SPATIAL ARRANGEMENT IN AN 'IRON BIRD' TEST RIG.	1. HARDWARE - o LANDING GEAR STRUTS AND WHEELS - o RUDDER AND ELEVONS - o SPEED BRAKE - o MAIN ENGINES (MASS ONLY) - o ELECTRICAL POWER - o APU (DRIVE ACTUAL PUMPS) - o MINIMUM CREW STATION (MOCKUP) - o LOAD DEVICES FOR HYDRAULICALLY ACTUATED ITEMS (e.g., ELEVONS) - o TEST CONDUCTORS CONSOLE - o FLUID COOLING 2. SOFTWARE - o LOAD PROGRAMS - o FCS STABILIZATION PROGRAMS	1. HYDRAULICS SERVICING AND FLUSH UNIT 2. HYDRAULIC SYSTEM CHECKOUT EQUIPMENT

HYDRAULICS & CONTROLS TEST UNIT (HCTU) - ORBITER



MDC E0558
PART III
15 MARCH 1972

5-38

MCDONNELL DOUGLAS

TRW



CORPORATION

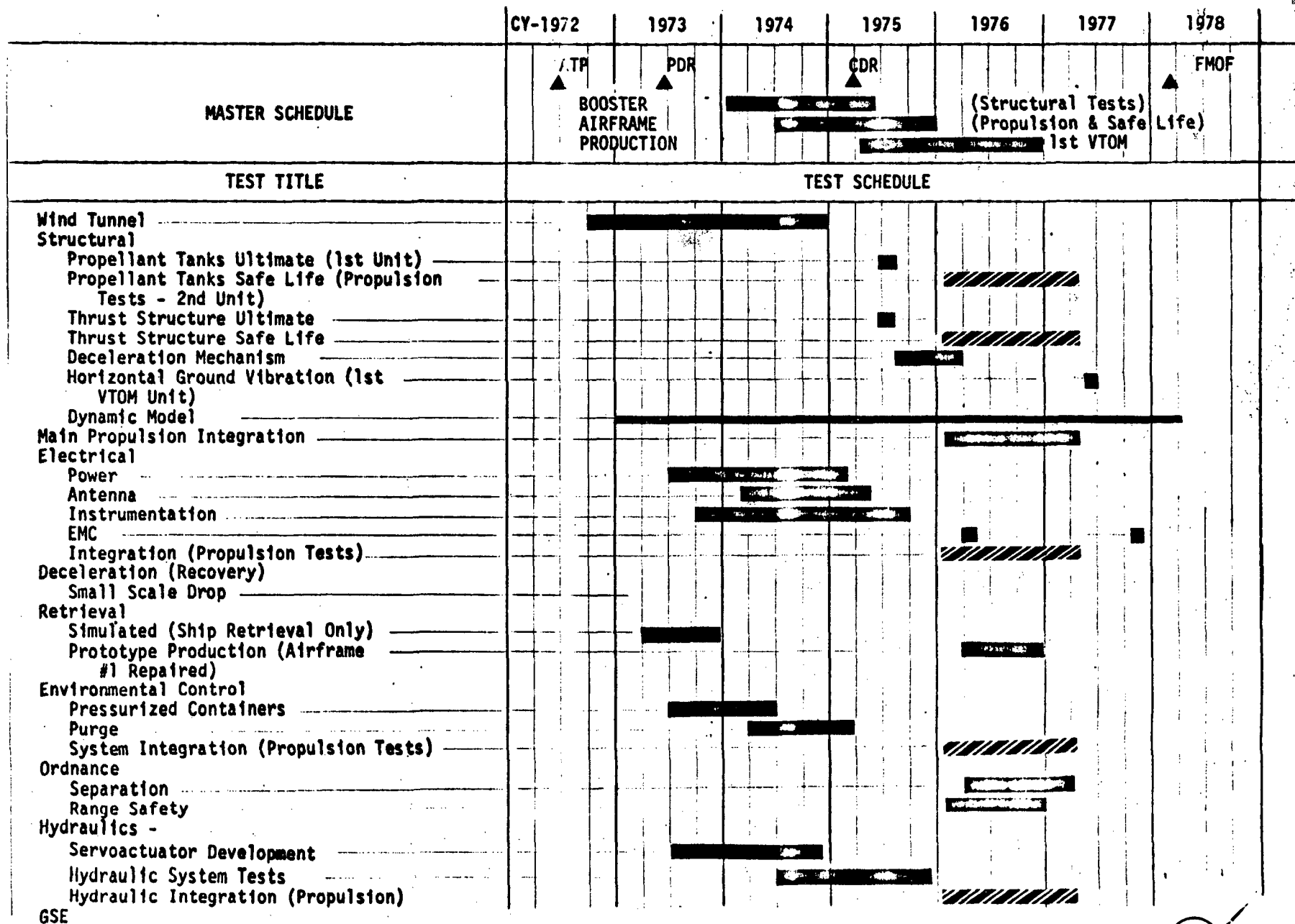
BOOSTER GROUND TEST COMPARISON

- STRUCTURE
 - DIFFERENCES IN APPROACH
 - FACILITY REQUIREMENTS
- PROPULSION
 - DIFFERENCES IN APPROACH
 - FACILITIES REQUIREMENTS
- ELECTRICAL, HYDRAULICS, ORDNANCE, ENVIRONMENTAL
- DECELERATION AND IMPACT
- VERTICAL FLIGHT DEVELOPMENT

SRAO TESTING SCHEDULE

The SRAO Testing Schedule shows the availability of Booster Airframes and their relationship to major ground tests. In addition, each major subsystem testing relationship is depicted. Each subsystem test approach is described in detail in the following pages.

SRAO TESTING SCHEDULE



SRAO BOOSTER STRUCTURAL TESTS

The thrust structure will be incrementally loaded to ultimate. The second thrust structure will be life cycle tested on the propulsion test article. The propulsion test article propellant tanks will not be cycled sufficiently for life cycle verification during the propulsion tests. Therefore, additional propellant loading and pressurization tests will be conducted to verify sufficient cycle life capability. The thrust structure must be removed following the propulsion (and tank) tests for final life cycle verification.

The heat shield will be tested as large sections to verify heat, acoustic and structural integrity. These panels are expected to be removed and repaired between launches. This repair and reuse will be verified during these tests.

Structural bending mode shape will be obtained on the first flight article. These tests will be made with the Booster horizontal while supported on air bags. The Booster and Orbiter/Ho Tank system coupled responses will be determined analytically.

The Booster to Orbiter Ho Tank adapter will be incrementally loaded to ultimate while attached to the fuel tank. This can be accomplished without penalty to the fuel tank because its higher factor of safety prevents the maraging tank material from reaching yield even though the aluminum adapter structure reaches ultimate.

Fatigue testing of the propellant tanks will be accomplished on the second production tanks. These tanks will also be used for the propulsion integration testing.

The first production thrust structure will be fitted with the deceleration mechanism and the speed brakes deployed under simulated proof loads predicted at the time of Booster staging. Speed brake retraction will then be accomplished while predicted proof retraction loads are applied. These tests verify the speed brake functional mechanisms operation with proof loads. The speed brakes will be removed and one petal incrementally loaded to ultimate. Another petal will be cyclically loaded for

SRAO BOOSTER STRUCTURAL TESTS (CONTINUED)

fatigue verification. Component pieces of the articulating mechanism not stressed to ultimate in these tests will be tested to ultimate as components. If thermal loads become design critical these loads will be simultaneously applied.

The structural test requirements are the same for each configuration considered; however, the implementation approach may differ for each configuration as a result of configuration differences. All structure is qualified by stressing a single production article to its design condition including its margin or factor of safety to demonstrate that each similarly produced article will have that factor of safety. Each production pressure vessel will be proof tested prior to final installation.

The first production propellant tanks will be incrementally pressurized to ultimate. The RP Tank will be pressurized with water (hydrostatic) which provides the design axial pressure gradient. A proof test will screen out all critical flaw sizes to assure 100 operational cycles based on fracture mechanics. Based on a conservative fracture analysis (4:1 factor of safety for cycle life) this provides an operational life of 25 cycles. The LOX Tank is proof tested filled with LN₂ in order to obtain the same life cycle capability. Each Booster which remains operational beyond 25 launches will require a repeat proof test at the launch site which will qualify the tanks for another 25 cycles.

SRAO BOOSTER STRUCTURAL TESTS

PROPELLANT TANKS

- FIRST PRODUCTION TANK PRESSURIZED TO PROOF, ULTIMATE AND BURST
- EACH SUBSEQUENT PRODUCTION UNIT PROOF TESTED
- BOOSTER/ORBITER TANK ADAPTER MECHANICALLY LOADED WHILE ATTACHED TO SRAO TANK
- CRYOGENIC AND PRESSURIZATION FATIGUE CYCLING ACCOMPLISHED ON PROPULSION TEST UNIT

THRUST STRUCTURE

- FIRST UNIT MECHANICALLY LOADED TO PROOF, ULTIMATE AND FAILURE
- SECOND UNIT FATIGUE (SAFE LIFE)

BOOSTER TO ORBITER TANK ADAPTER

- FIRST UNIT MECHANICALLY LOADED TO PROOF, ULTIMATE AND FAILURE WHILE ATTACHED TO PRESSURIZED SRAO TANK

SPEED BRAKE

- FUNCTIONAL OPERATION AT PROOF EXTENSION AND RETRACTION LOADS
- PROOF, ULTIMATE AND FAILURE MECHANICAL LOADS EXTENDED

DYNAMICS

- BOOSTER HORIZONTAL GROUND VIBRATION TEST ON FMOF BOOSTER

HEAT SHIELD

- THERMAL AND ACOUSTIC CYCLIC TESTS INCLUDING WATER EXPOSURE

TRAO BOOSTER STRUCTURAL TESTS

The structural test requirements for the TRAO configuration are the same as the series burn booster (SRAO). The propellant tanks will be qualified by pressurizing the first production tanks incrementally to ultimate and burst. A second set of propellant tanks will be pressure cycled to establish reuse life cycle capabilities. Each production propellant tank will receive a post manufacturing proof test.

Two thrust structures will be required for ground testing. The first will be loaded to ultimate and the second will be fatigue cycled at limit loads. The speed brake and heat shield testing requirements and approach are the same as the series burn booster.

The third and fourth production booster airframes will be utilized with an Orbiter and H0 Tank for a combined vertical ground vibration test. These boosters will be returned to the flight inventory following the ground vibration tests. A combined Booster Orbiter H0 Tank vertical vibration test is required because existing analytical coupling tools are not adequate for complex structures assembled side-by-side.

TRA0 BOOSTER STRUCTURAL TESTS

PROPELLANT TANKS

- FIRST PRODUCTION TANK PRESSURIZED TO PROOF, ULTIMATE AND BURST
- SUBSEQUENT PRODUCTION TANKS PROOF TESTED (LIMIT X 1.05)
- CRYOGENIC AND PRESSURIZATION CYCLIC TESTING USING SECOND PRODUCTION TANK

THRUST STRUCTURE

- MECHANICAL LOADS TO PROOF AND ULTIMATE
- SAFE LIFE

SPEED BRAKE

- FUNCTIONAL OPERATIONAL AT DEPLOYMENT AND RETRACTION PROOF LOADS
- PROOF AND ULTIMATE LOADS (ONE PETAL) DEPLOYED (AERODYNAMIC DECELERATION)

DYNAMICS

- THIRD AND FOURTH AIRFRAMES UTILIZED FOR BOOSTER/ORBITER VERTICAL GROUND VIBRATION TESTING - RECYCLED TO INVENTORY

HEAT SHIELD

- THERMAL AND ACOUSTIC

RF - 1B/HiPc BOOSTER STRUCTURAL TESTS

Structural requirements for the F-1 powered Booster or the HiPc Booster are identical. Two expended propellant tanks are required for ground testing. The first propellant tank will be pressurized incrementally to ultimate and burst. The second propellant tank will be cyclically pressurized to verify safe life characteristics. Each subsequent propellant tank will be proof tested following manufacturing.

Two ground test thrust structure test articles are required. The first will be incrementally loaded to failure and the second will be cyclically limit loaded to verify safe life.

A single Booster to Orbiter HO Tank adapter will be mechanically loaded to failure. No other ground tests are required as this adapter unit is expended on each flight.

Speed brake and heat shield structural, thermal and acoustic testing are identical to the series burn booster (SRAO) tests.

The first flight Booster will be vibrated in the horizontal position to obtain basic bending mode characteristics and axial compressive characteristics. The test will be accomplished in the horizontal position in order to take advantage of existing facilities. Analytical coupling of the Booster and Orbiter HO Tank is within state-of-the-art techniques.

RF-1B/H₁P_c BOOSTER STRUCTURAL TESTS

PROPELLANT TANKS

- FIRST PRODUCTION TANK PRESSURIZED TO ULTIMATE
- EACH SUBSEQUENT PROPELLANT TANK PROOF TESTED
- SECOND PRODUCTION TANKS PRESSURE FATIGUE (SAFE LIFE)

THRUST STRUCTURE

- FIRST UNIT LOADED TO PROOF, ULTIMATE AND FAILURE
- SECOND UNIT CYCLIC LOADED (FATIGUE - SAFE LIFE)

BOOSTER TO ORBITER HO TANK ADAPTER

- MECHANICALLY LOADED TO PROOF, ULTIMATE AND FAILURE

SPEED BRAKE

- FUNCTIONAL OPERATION AT PROOF EXTENSION AND RETRACTION LOADS
- BRAKE EXTENDED MECHANICALLY APPLIED PROOF, ULTIMATE AND FAILURE LOADS

DYNAMICS

- BOOSTER HORIZONTAL GROUND VIBRATION TEST ON FMOF BOOSTER

HEAT SHIELD

- THERMAL AND ACOUSTIC CYCLIC TESTS INCLUDING WATER EXPOSURE

SRM BOOSTERS STRUCTURAL TESTS

The SRM structure will not be reused. Therefore, life cycle (fail safe) tests are not required for the SRMs. The propellant tank will be pressurized incrementally to burst while any additional stress loads imposed by the thrust structure or adapters are simultaneously applied. The heat shields structural, thermal and acoustic testing are the same as the series burn booster.

Adapter sections are required both forward and aft of the solid rocket motor to provide attachment to the HO Tank. These structures must also provide a near uniform load distribution at the interface to the SRM case. One structural test unit of both the forward and aft adaptors will be mechanically loaded incrementally to failure to verify their design load capability including margins.

SRM BOOSTERS STRUCTURAL TESTS

PROPELLANT TANKS (MOTOR CASE)

- PRODUCTION UNIT PRESSURIZED TO PROOF - SUBSEQUENTLY INSPECTED FOR INSULATION FAILURE - PRESSURIZED TO ULTIMATE AND FAILURE. TANK BENDING LOADS APPLIED DURING PRESSURIZATION.
- EACH PRODUCTION UNIT PROOF TESTED.

THRUST STRUCTURE

- ULTIMATE MECHANICAL LOADS

FORWARD AND AFT ADAPTER SECTIONS

- LIMIT, PROOF AND ULTIMATE LOADS APPLIED MECHANICALLY

HEAT SHIELDS

- THERMALLY AND ACOUSTIC LIMIT AND ULTIMATE CONDITION

BOOSTER STRUCTURES TEST REQUIREMENT SUMMARY

A summary of each of the different Booster configurations structural test requirements is shown on the opposite page. It summarizes the differences in testing requirements and approaches of each of the different configurations that has been discussed on the previous pages. Structural test facilities were not identified on each of the previous pages. Each of the propellant tank qualification and acceptance tests have been assumed to be completed at the manufacturing facility. All other structural assemblies will be tested at the primary or appropriate subcontractor facility.

BOOSTER STRUCTURES TEST REQUIREMENT SUMMARY

	<u>SRAO</u>	<u>TRA0</u>	<u>RF-1B</u>	<u>H1Pc</u>	<u>SRA0-SRM</u>	<u>TRA0(SRM)</u>
PROPELLANT TANKS						
ULTIMATE PRESSURE	✓	✓	✓	✓	✓	✓
ULTIMATE MECHANICAL LOADS		✓				✓
FATIGUE (SAFE LIFE)	✓	✓	✓	✓		
PRODUCTION PROOF TESTING	✓	✓	✓	✓	✓	✓
THRUST STRUCTURE						
ULTIMATE LOADS	✓	✓	✓	✓	✓	✓
FATIGUE (SAFE LIFE)	✓	✓	✓	✓		
ADAPTER STRUCTURE ULTIMATE	✓		✓	✓	✓	✓
DECELERATION DEVICES						
FUNCTIONAL AT PROOF LOADS	✓	✓	✓	✓		
ULTIMATE LOADS (ONE SECTION)	✓	✓	✓	✓		
FATIGUE (SAFE LIFE-ONE SECTION)	✓	✓	✓	✓		
HEAT SHIELDS						
THERMAL AND ACOUSTIC (SEGMENTS)	✓	✓	✓	✓	✓	✓

PROPELLANT TANK TESTS TO BE COMPLETED AT ASSEMBLY FACILITY. LIQUIDS AT MICHOU, SRM AT SRM CONTRACTOR

THRUST STRUCTURE, ADAPTER SECTIONS, DECELERATION DEVICES AND HEAT SHIELDS TESTS AT APPROPRIATE CONTRACTORS FACILITIES

PROOF TEST PHILOSOPHY

A fracture toughness analysis of the series burn booster (SRAO) maraging steel tanks indicated that an ambient proof test of the fuel tank would assure 100 successful reuses before any remaining flaw could grow to a critical size. Based on a conservative 4:1 reuse philosophy this would allow 25 launches between proof tests. The fuel tank will be proof tested vertically with water which adequately simulates the tank design pressure gradient. The proof test will be at 95 percent of design yield stress.

The LOX Tank will be subjected to a similar test; however, the proof test medium will be LN₂. The LOX Tank utilizes cryogenic allowable stresses. In order to screen out critical flaw sizes it is necessary to stress the material to near 95 percent of design yield stress. This can only be accomplished at near operating LOX temperatures. The proof test at 95 percent of design yield stress assures 100 reuses based on fracture toughness analysis. This allows 25 launches between proof tests similar to the above.

A cost comparison was made assuming conditions requiring a LOX Tank proof test required between each launch versus the cryogenic LOX Tank proof test every 25 launches. The study indicated a cost advantage to proof testing only every 25 launches. A proof test between each launch would incur a significant schedule penalty on the Booster turnaround cycle. This schedule impact is also avoided by the cryogenic LOX Tank proof test each 25th launch.

PROOF TEST PHILOSOPHY

- HYDROSTATIC PROOF TEST FUEL TANK AFTER MANUFACTURE
- CRYOGENIC PROOF TEST LOX TANK AFTER MANUFACTURE
 - PROOF TEST SCREENS OUT CRITICAL FLAWS FOR LESS THAN 100 CYCLES
 - CONSERVATIVE FACTOR ON REUSE (4:1) ALLOWS 25 LAUNCHES
BEFORE IN SERVICE REPROOF REQUIRED
- REPROOF AT LAUNCH SITE AFTER 25 LAUNCHES - SAME AS FACTORY
PROOF

DYNAMIC TEST REQUIREMENTS

Dynamic test requirements are not identical for each vehicle configuration. The Orbiter vibration test requirements are identical for each configuration of booster considered. Booster and Booster/Orbiter dynamic test requirements are configuration dependent. Tank end loaded structural coupling analytical techniques have been developed on previous programs and verified by subsequent testing. These analytical tools are considered adequate for analytical coupling of all proposed HO Tank end loaded configurations. The dynamic coupled characteristics of large structures assembled side-by-side cannot be done with the same confidence as the tank end loaded configurations. Therefore, the twin or parallel burn configurations require that the Booster and Orbiter/HO Tank dynamic characteristics be verified by a ground test. The chart on the opposite page summarizes both Orbiter and Booster vibration test requirements.

DYNAMIC TEST REQUIREMENTS

REQUIREMENT	FLYBACK	SRAO	TRAO	TRAO(SRM)	RF-1B	HIPc
° WIND TUNNEL TESTING: STABILITY; FLUCTUATING PRESSURE ENVIRONMENTS: FLUTTER & BUFFET	X	X	X	X	X	X
° DYNAMIC MODEL TESTS OF ORBITER, ORBITER-HO TANK, & ORBITER-HO TANK - BOOSTER STRUCTURAL ARRANGEMENTS	X	X	X	X	X	X
° FLUIDS-STRUCTURE INTERACTION USING SCALE MODELS OF HO TANK & BOOSTER TANKS	X	X	X	HO TANK ONLY	X	X
° LOW LEVEL DYNAMIC RESPONSE AND/OR VIBRO-ACOUSTICS OF PERTINENT FULL SCALE STRUCTURAL COMPONENTS (E.G., AERO CONTROL SURFACES, BODY STRUCTURE SECTIONS)	X	X	X	X	X	X
° HORIZONTAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER FLIGHT VEHICLE	REQUIRED INDEPENDENT OF BOOSTER USED					
° HORIZONTAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF BOOSTER FLIGHT VEHICLE	X	X	*	*	X	X
° FULL SCALE VERTICAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER-HO TANK	REQUIRED INDEPENDENT OF BOOSTER USED					
° FULL SCALE VERTICAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF BOOSTER TANKS/BODY STRUCTURE	*	*	*	*	*	*
° FULL SCALE VERTICAL ATTITUDE GVT (LOW LEVEL DYNAMIC RESPONSE) OF ORBITER-HO TANK-BOOSTER	*	*	X	X	*	*

*AMENABLE TO ANALYSIS - MAY REQUIRE TESTING

SRAO PROPULSION TESTS

The primary propulsion test is the propulsion integration testing. The series burn booster is fabricated of maraging steel which allows a dedicated production test article to be utilized for the propulsion integration tests. The second production article fabricated will be utilized for the propulsion integration tests and safe life structural tests simultaneously. The test article will include production or high quality prototype propulsion, avionics, hydraulics and environmental control systems hardware. Prototype PFRT quality main engines will be utilized. The main propulsion test requirements include the development of operational procedures including maintenance and launch checkout procedure verification. Specific propulsion tests will be the verification of loading and unloading design characteristics, propellant tank purging technique verification as well as level sensing accuracy and all associated GSE interfacing. Tank pressurization and in-flight pressurization characteristics will also be verified. The POGO separation system will be pressure pulsed to verify pressure decoupling from the engine. Main engine gimbaling response and its effect on engine characteristics will be identified. The main propulsion integration test article is also the primary integration article for avionic, hydraulics, and environmental control systems.

A general philosophy is to develop and qualify components and then assemble all components for system level testing without doing subsystem level integration tests. The main propulsion fuel tank pressurization subsystem is a complex subsystem which is an extension of state-of-the-art design. In addition, it is somewhat autonomous to the remainder of the main propulsion system. Because of its complexity it is necessary to integrate this subsystem and verify its capability before integrating this subsystem with all other subsystems on the main propulsion test article. These tests will be conducted at the existing contractor's or a major subcontractor's facility. The LOX tank pressurization subsystem is an extension of existing design approaches and does not require any subsystem integration testing prior to the main propulsion integration tests.

Portions of the main propulsion system will be exposed to sea water during the recovery operations. A part of the propulsion integration testing will subject this hardware to sea water exposure and then conduct the decontamination and checkout procedures planned during normal launch operations. The vehicle will be static fired following these decontamination and checkout procedures to demonstrate the effectiveness of decontamination and subsequent checkout.

The propulsion integration tests for the series pressure fed booster will be accomplished at the launch facility. The test article is a production vehicle dedicated to ground testing. It will provide a launch facility and GSE checkout and will not require simulation of any launch site facility peculiar requirements. In addition, it will allow development of the operational maintenance and checkout procedures and GSE.

SRAD PROPELLSION TESTS

PROGRAM MILESTONES (▲ PER TD, ▲ ASSUMED)			CY-1972	1973	1974	1975	1976	1977	1978
			▲ ATP	▲ PQR		▲ CUR			▲ FMOF
			BOOSTER AIRFRAME PRODUCTION	#1	#2	#3	#4		
TEST TITLE	TEST DESCRIPTION	TEST HARDWARE	TEST SCHEDULE						COMMENTS
Propulsion Integration Tests	Integration of MPS, Avionics, ECS, Hydraulics and GSE. First test on MPS cluster including complete hydraulic & pressurization systems. Loading, unloading, safing, level control, ground-vehicle control verification, prepressurization, pressurization performance, NPSP, gimbal response & control, POGN, pneumatics control & purge, maintenance, checkout & operational procedures & techniques.	2nd Production Structure Propulsion, Avionics, ECS, & Hydraulics. Prototype M.E. (Maraging steel tanks - less than 5% above limit to simulate engine flight inlet pressures.)					Installations Test		Facility - KSC launch pad
LON Pressurization	Component verification. Minimal integration of pumps and controller.						Components Qualified Pumps & Controller Integrated		Contractor's Facility
RP Pressurization	Subsystem tested as complete unit to verify performance capability and compatibility to stage. Develop loading, unloading, safing, maintenance & checkout techniques and procedures.	Prototype propulsion hardware with simulated R/T tanks & facility instrumentation & controls.					Component Development Subsystem Integration Component Qualification		Contractor Facility
Salt Water Exposure	External exposure to sea water spray simulating ocean recovery exposure. Operational decontamination & checkout turnaround technique followed by a static firing.	Propulsion Integration Test Article							

SRAO/TRAO UNIQUE PROPULSION TESTS

A portion of the main propulsion system for the series pressure fed booster requires special test emphasis. The fuel tank pressurization system design concept has not been previously demonstrated on a large propulsion system. Several characteristics of hydrazine decomposition requires development. The effect of catalyst bed contamination on decomposition efficiencies has not been addressed. Contamination materials and the definition of allowable amounts of contamination and/or contamination measurement techniques have not been thoroughly evaluated. Both of these characteristics will require detailed materials tests to develop adequate design information. The size of the required catalyst bed is larger than any system used to date. The effects of increasing catalyst bed size can only be verified by testing. Large heat exchangers will be required to reduce the temperature of the gas entering the fuel tank. A portion of this heat will be taken to raise the helium temperature entering the LOX tank. The remainder of the excess heat must be taken out in a second heat exchanger in the fuel tank. The primary concern with the heat exchangers will be obtaining adequate thermal balance across extremely large heat exchangers.

Most of main propulsion system testing is an extension of current technology and design. Perhaps the major design concern for propulsion integration will be to verify that engine-to-engine and/or engine-to-stage driven pressure cross coupling does not exist; i.e., verify lack of POGO. POGO peculiar testing will be accomplished by detailed dynamic tests of feed lines including identification of axisymmetric line bulging modes. Booster axial compressive modes will be determined during booster horizontal ground vibration. The POGO suppression device will have been tested at the engine manufacturers to determine the amount of pressure oscillation decoupling its effects between the stage and engine. These POGO ground test data can be analytically coupled to determine the amount of POGO resistance of the booster.

SRAO/TRAO UNIQUE PROPULSION TESTS

FUEL TANK PRESSURIZATION

HYDRAZINE CATALYST SIZE (FLOWRATE)

HYDRAZINE CATALYST REUSABILITY

- EXTENSION OF STATE-OF-THE-ART
- EXTENSION OF STATE-OF-THE-ART. LACK OF QUANTITATIVE DATA DELINEATING ALLOWABLE THERMAL RATES, CONTAMINANTS AND THEIR BED EFFICIENCY LOSS VERSUS LEVEL OF CONTAMINATION

HEAT EXCHANGER

- ADDITION OF AMMONIA OR USE OF LOX AND/OR RP FOR HEAT EXCHANGER REQUIRES NEW DEVELOPMENT. MINIMAL STATE-OF-THE-ART EXTENSION.

MAIN ENGINE

- EXTENSION OF EXISTING CONCEPTS - SCHEDULE MOST CRITICAL
- ENGINE CLUSTER CROSS COMMUNICATION CRITICAL - LESS EXPERIENCE CLUSTERING PRESSURE FED ENGINE SYSTEMS

CONFIGURATIONS TEST DIFFERENCES - PROPULSION

Each of the different booster configurations considered require some differences in test approach. These differences are identified on the adjacent summary chart. Significant differences are:

1. A production structure is utilized for the series pressure fed booster and a battleship structure is utilized for others. Battleship tanks are required for the twin pressure fed. F-1 and HiPc boosters because their production structure is aluminum. The aluminum structure does not provide sufficient margin below yield to be acceptable for ground test.
2. The series pressure fed main propulsion test article will be tested at KSC. Parallel pressure fed configurations will be tested at MSFC because they cannot be tested on the launch site without significant modifications to the operational equipment. F-1 and HiPc boosters are scheduled to be tested at MSFC because the battleship configuration also causes complications in mating to a launch facility.
3. The fuel tank pressurization subsystem for both the series and twin pressure fed boosters utilize decomposed hydrazine for pressurization. This system is sufficiently complex that a subsystem integration is required prior to propulsion integration tests. The F-1 and HiPc configurations utilize conventional pressurization systems that will be tested for the first time on the propulsion integration test article.

CONFIGURATIONS TEST DIFFERENCES - PROPULSION

	<u>SRAO</u>	<u>TRAO</u>	<u>RF-1B</u>	<u>H1Pc</u>	<u>SRM</u>
PROPULSION INTEGRATION TEST	YES	YES	YES	YES	YES
STRUCTURE	PRODUCTION	BATTLESHIP	BATTLESHIP	BATTLESHIP	PRODUCTION
ENGINE	PROTOTYPE	PROTOTYPE	PRODUCTION	PROTOTYPE	PRODUCTION
FACILITY	KSC	MSFC	MSFC/KSC	MSFC/KSC	CONTRACTOR
LOX TANK PRESSURIZATION SUBSYSTEM INTEGRATION	NO	NO	NO	NO	N/A
FUEL TANK PRESSURIZATION SUBSYSTEM INTEGRATION	YES	YES	NO	NO	N/A
HARDWARE	PROTOTYPE	PROTOTYPE			
FACILITY	CONTRACTOR	CONTRACTOR			
TVC DEVELOPMENT	YES	NO	YES	YES	YES/NO
POGO DEVELOPMENT	YES (MAJOR)	YES (MAJOR)	YES	YES	NO
COMPONENT	YES	YES	YES	YES	
ENGINE MANUFACTURER	YES	YES	YES	YES	
PROPULSION INTEGRATION	YES	YES	YES	YES	
SEA WATER EXPOSURE	YES	YES	YES	YES	YES (REUSE)
DECONTAMINATION, CHECKOUT AND TEST ON PROPULSION TEST UNIT	YES	YES	YES	YES	YES (REUSE)

156 SRM BOOSTER DEVELOPMENT/QUAL

MAJOR TESTS

The solid rocket motor (SRM) components that will require development and qualification are identified on the following page. These components will then be integrated into the SRM and tested as a complete assembly. The structural hardware test requirements have been delineated in previous paragraphs. The SRM development described on subsequent pages will measure ballistics characteristics and insulation effectiveness and margins. After each development firing, motor insulation will be measured to verify the amount and char and mapped to verify uniform charring distribution. Minimum thickness of insulation will determine the amount of design margin for the entire motor case. Nozzle erosion will be measured similarly. Each of these measurements will be compared to insulation measurements made following SRM manufacture. The thrust termination (TT) system will be verified by functionally using that system on two development firings and one qualification firing. Both the thrust termination port trajectory and the net axial and lateral thrust after TT will be measured.

156 SRM BOOSTER DEVELOPMENT/QUAL

MAJOR TESTS

SUBSYSTEMS/COMPONENTS

- 0 IGNITER
- 0 THRUST TERMINATION
- 0 SEGMENT SEAL DESIGN
- 0 AVIONICS/RANGE SAFETY
- 0 ORDNANCE
- 0 TVC (IF REQUIRED)

STRUCTURAL

- 0 ATTACH STRUCTURE
- 0 SKIRTS & FAIRINGS
- 0 MOTOR CASE HYDROBURST
- 0 SEPARATION SIMULATION
- 0 TVC ATTACH (IF REQUIRED)

SRM

- 0 MOTOR BALLISTICS
- 0 NOZZLE ABLATIVES
- 0 INSULATION DESIGN
- 0 IGNITION SYSTEM
- 0 ORDNANCE SYSTEM
- 0 THRUST TERMINATION BALLISTICS
- 0 TVC (IF REQUIRED)

STAGE

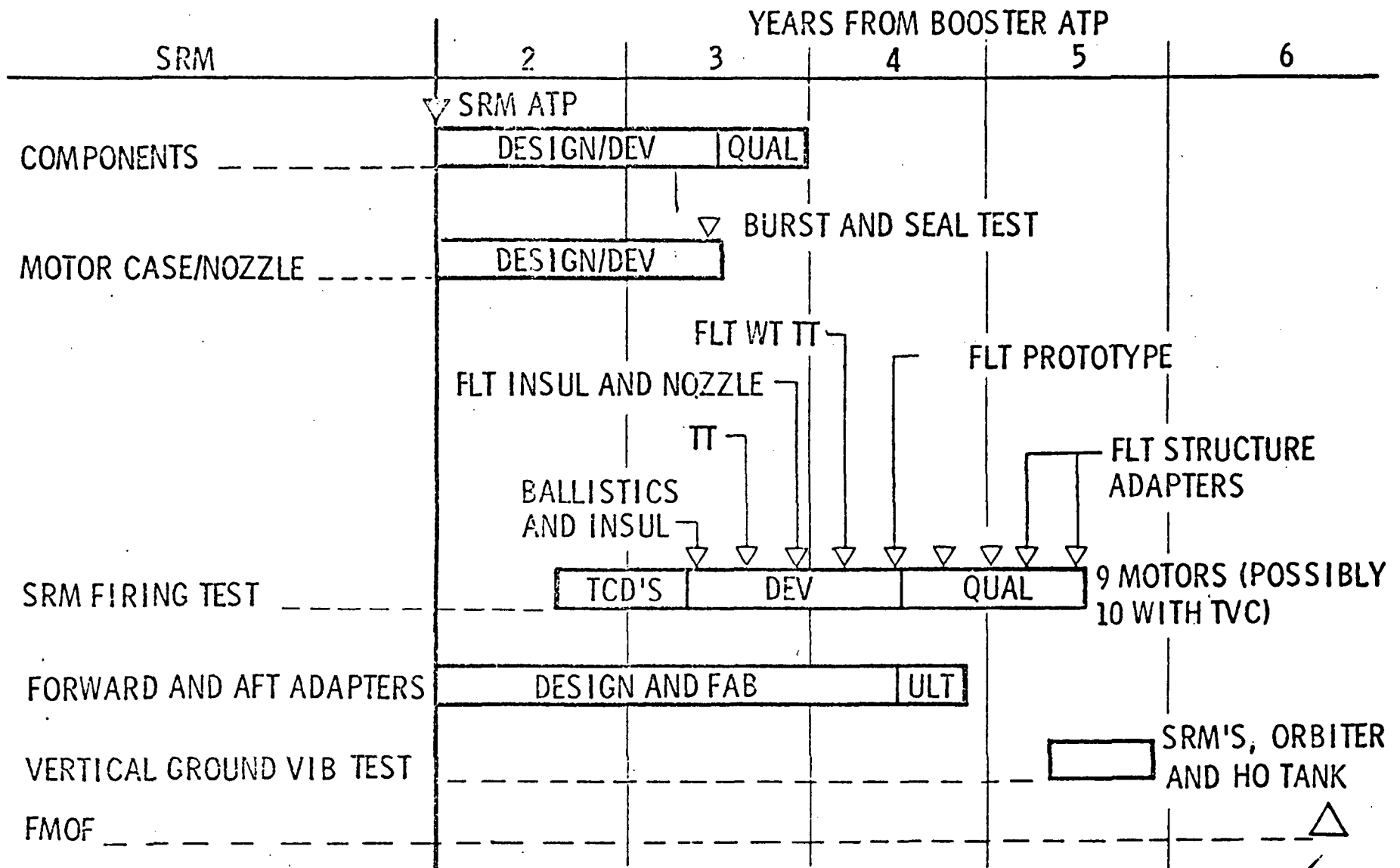
- 0 INTEGRATION
- 0 EMI
- 0 FLIGHT

DEVELOPMENT SCHEDULE
PARALLEL 156 SRM CONFIGURATION

Nine SRM firings are scheduled for development and qualification. Additional SRM firings will be required if a thrust vector control system is required. Each of the motor firings will be with fully loaded motors. Three of the firings will be less than flight duration as a result of thrust termination testing. Five of the nine firings will be utilized for SRM characteristics development. The final four firings will be for motor qualification. Two of these qualification firings will utilize the flight SRM/HO Tank structure adapters to verify acceptable structure loading on the rocket motor case and to measure the effect of the forward adapter on TT part trajectory and thrust.

The components which require development and qualification and the structural tests required for the SRM and its adaptors were identified on the previous pages.

DEVELOPMENT SCHEDULE PARALLEL 156 SRM CONFIGURATION



ENVIRONMENTAL CONTROL SYSTEM TESTS

Environmental control development testing will be accomplished early during the Phase C Program to establish environmental enclosure container sealing techniques. Electronics equipment containers will be opened for inspection or maintenance after each launch. The seal reusability and leakage after multiple reuse will be established to determine if a locked up container pressure is adequate for flight or if a gas make-up system is required and what its gas consumption would be.

Thermal conditioning development will be limited to "Cold Plate" integration with electronic equipment. The cold plate is actively conditioned on the ground when the electronic subsystems are being used. During flight the equipment and attachment structure provide sufficient mass to maintain the equipment within temperature limits without a coolant source.

The electronic sealed containers and the avionics ground cooling subsystems will be integrated with the remainder of the booster equipment on the propulsion integration test hardware. In addition, this will be the first evaluation of the active ground purge system for environmental conditioning of cryogenic components.

ENVIRONMENTAL CONTROL SYSTEM TESTS

			CY-1972	1973	1974	1975	1976	1977	1978	
PROGRAM MILESTONES (▲ PER TD, ▲ ASSUMED)			▲ ATP BOOSTER AIRFRAME PRODUCTION	▲ PDR #1	#2 #3 #4	CDR ▲			PMDF ▲	
TEST TITLE	TEST DESCRIPTION	TEST HARDWARE	TEST SCHEDULE							COMMENTS
Container Pressurization and Purge System	Breadboard distribution and control stage and GSE system to verify system integrity, establish ground and onboard gases consumption and determine purge required to maintain components within specification limits during ground holds.	Prototype development hardware in spatial array simulating stage arrangement.	Specimen Prep	Test						Tests at contractor facility.
ECS	Additional subsystem verification will be obtained utilizing prototype production hardware during the Propulsion Integration Testing.	Prototype production hardware on flight stage.								
Purge	Breadboard of GSE and onboard ECS subsystems to verify cooling and heating system efficiencies and power requirements. System will also verify temperature conditioning distribution capability and compatibility with other subsystems.	Development hardware including simulated loads. Final verification on Propulsion Integration Test Article.	Specimen Prep	Test						Contractor facility

ELECTRICAL TESTS

The booster electrical subsystems make extensive use of existing hardware. Antenna, power distribution, instrumentation and controls subsystem development will be limited to prototype hardware breadboards to establish basic hardware compatibility. Each of these subsystems will be developed independently. The first integration of all of the electrical systems will be in the propulsion integration test (PIT) article. The first integrated system electromagnetic compatibility (EMC) tests will be accomplished on the PIT article. Final EMC verification will be accomplished during the first booster flight readiness firing at the launch site and during final checkout after mating with the Orbiter.

ELECTRICAL TESTS

			CY-1972	1973	1974	1975	1976	1977	1978	
PROGRAM MILESTONES (▲ PER TD, ▲ ASSUMED)			▲ ATP	▲ POR		▲ CDR				
			BOOSTER AIRFRAME PRODUCTION	#1	#2	#3	#4			
TEST TITLE	TEST DESCRIPTION	TEST HARDWARE	TEST SCHEDULE							COMMENTS
Antenna Tests	Develop antenna shape to provide best radiation pattern. Determine "blind" spots - identify all potential radiation "gaps" during launch and reentry. Determine necessary stage antenna location(s). Make a preliminary evaluation of EMC.	Prototype antenna mounted in structure simulating Booster shape and material. Orientation between flight antenna & ground antenna variable.	Spec	sch	Prep.	Test				
Power Distribution	Develop breadboard power distribution system to evaluate voltage spikes and losses at use points. Also verify recharge and reusability of Booster batteries.	Wiring spatial array like production. Simulated or prototype loads. Power from facility & prototype production systems.	Specimen	Prep.	Test					Contractors facility
Instrumentation System	Verify instrumentation system component compatibility and compatibility with Critter & Antenna Systems.	Development hardware.			Specimen Preparation	Testing				
EMC	Verify Booster overall EMC.	Booster EMC verified on Propulsion Integration Test & on first launch unit final checkout. Booster-Orbiter-Launch System EMC verified, utilizing first VTO stage.			Propulsion Integration		Booster Test			
Avionics-Component Compatibility	Electrical compatibility with other sub-systems shall be verified as a part of the Main Propulsion Integration, Deseleration System, remaining GSE & Recovery Systems compatibility will be verified on the first flight vehicle.	N/A								
F2P	Provides first opportunity to verify all systems compatibility in launch environmental conditions.	Production Stage								

SRAO HYDRAULIC TESTS

The booster hydraulic system components will be integrated into a prototype hydraulic system test unit (HSTU) to verify the hydraulic system compliance to basic design criteria before integration with the remainder of the booster systems. Some of the hydraulic components are of new design and most of the components have not been utilized together in a single system. The complete hydraulic system, using a ground power source for the Booster APU, will be functioned together to assure engine positioning capability before utilization on the propulsion integration tests (PIT). The hydraulic system, including Booster APU, will be integrated with all other Booster systems on the PIT.

SRAO HYDRAULICS TESTS

			CY-1972	1973	1974	1975	1976	1977	1978	
PROGRAM MILESTONES (▲ PER TD, ▲ ASSIGNED)			ATP ▲	PDR ▲	#1 BOOSTER AIRFRAME PRODUCTION	#2 #3 #4	CDR 2p			PMOF ▲
TEST TITLE	TEST DESCRIPTION	TEST HARDWARE	TEST SCHEDULE							COMMENTS
Servoactuator Tests	Develop response and position feedback closed loop system to meet frequency and accuracy requirements. Verify load requirements and determine systems response and overtravel characteristics.	Facility supplied by hydraulic systems. Prototype servoactuator and feedback systems. Dummy loads.	Development Tests		Test Hardware Preparation					Contractors facility baselined - Alternate MSFC lab
Hydraulic System Test Unit (HSTU)	Utilize pump-servoactuator feedback system to verify system compliance, accuracy, response characteristics and integrated system compatibility.	Facility power source during prototype production pump. Prototype production hydraulic and electrical components dummy loads.	Specimen Preparation		Testing					Contractor facility baselined - Alternate MSFC lab
Integrated System Compatibility	Hydraulic system compatibility will be initially verified through HSTU tests. Total subsystem verification realized through: Propulsion Integration Tests VAF PMOF	Prototype Production Production - Flight Production - Flight								

CONFIGURATION DEVELOPMENT COMPARISON

Range safety explosive hardware will be verified by testing of production explosive hardware on plate material similar to production structure. The thrust termination, separation, and ignitor hardware will be verified by test on production hardware. All electronic/ordnance interfaces will be verified by simulators.

The comparison chart on the opposite page identifies the avionics, environmental control, hydraulics and ordnance tests which are required for each candidate configuration. The differences in ground test requirements between configurations shown are relatively insignificant.

CONFIGURATION DEVELOPMENT COMPARISON

	<u>SRAO</u>	<u>TRAO</u>	<u>RF-1B</u>	<u>H1Pc</u>	<u>SRAO(SRM)</u>	<u>TRAO(SRM)</u>
AVIONICS						
POWER	X	X	X	X	X	X
INSTRUMENTATION	X	X	X	X	X	X
ANTENNA	X	X	X	X	X	X
EMC	X	X	X	X	X	X
ENVIRONMENTAL CONTROL						
CONTAINERS	X	X	X	X		
PURGE	X	X	X	X	X	X
HYDRAULICS						
SERVOACTUATOR	X		X	X	X	
SUBSYSTEM	X		X	X	X	
ORDNANCE						
SEPARATION	X	X	X	X	X	X
RANGE SAFETY	X	X	X	X	X	X
THRUST TERMINATION					X	X
GG&ME IGNITION					X	X

WIND TUNNEL OCCUPANCY HOURS COMPARISON AND RATIONALE

The number and type of wind tunnel tests required vary depending on the configuration considered. The chart on the opposite page compares proposed configuration wind tunnel test hours required to those identified for Phase B. The exact number of hours is not as significant as the ratio of that number to its Phase B counterpart. The chart presents a brief rationale of why there is a difference from Phase B. The differences between each configuration considered can be evaluated by comparing their net differences to Phase B.

WIND TUNNEL OCCUPANCY HOURS COMPARISON AND RATIONALE

	<u>PHASE B-2 STAGE FULLY REUSABLE (REFERENCE)</u>	<u>FLYBACK</u>	<u>SRAO/RF-1B/H1Pc</u>	<u>TRAO</u>	<u>TRAO(SRM)</u>	<u>RETRO GLIDER</u>
BOOSTER ALONE	28,240	20,000 JET FLAP CANARD DELETED; LOWER STAGING VELOCITY.	3,000 NO FLYBACK, BODY OF REVOLUTION LOWER STAGING VELOCITY.	2,500 NO FLYBACK, BCDY OF REVOLUTION SMALLER THAN SERIES, LOWER FINENESS RATIO & LOWER STAGING VELOCITY.	300 SRM BODY DATA ONLY FOR TRAJEC- TORY ANALYSIS TO SATISFY RANGE SAFETY.	18,000
MATED AND PROXIMITY	12,140	8,000 SIMPLER MATING ARRANGE- MENT WITH SERIES MATE, LOWER STAGING VELOCITY.	6,000 SAME FLYBACK; BODY OF REVOLUTION, NO BOOSTER FLYBACK (GREATLY SIMPLI- FIES SEPARATION & PROXIMITY TESTS)	10,000 PIGGY-BACK MAT- ING MORE COMPLEX THAN TANDEM MATE (SEP. & PROXIMITY TESTING) NO FLY- BACK. BODIES OF REVOLUTION SIMP- LER THAN REFERENCE.	8,000 BOOSTERS NOT RECOVERED; LESS INSTRUMENTATION DURING TEST (ON SRM'S) NO ITERA- TIVE TESTING GENERATED BY BOOSTER ALONE TESTS.	8,000
ORBITER	27,430	29,000 ADDED EXTERNAL TANK REQUIRES TANK PLUS ORBITER & TANK ALONE TEST DELTAS.	29,000	29,000	29,000	29,000

WATER IMPACT TEST FOR SRAO/TRAO

Generic water impact tests of nose cone shapes and entry angle versus entry velocity have been made during the Phase B Extension. These data were assumed to be adequate to define no more than two nose shapes for evaluation during Phase C/D. The chart on the following page describes model size and defines facility requirements for final design data acquisition. If additional generic testing is required, additional models and a substantial number of tests, and therefore, test hours, will be added.

WATER IMPACT TEST FOR SRAO/TRAO

- CONCEPT/SCOPE: APPROXIMATELY 7 PERCENT (MAXIMUM) SCALED MODEL (DIMENSIONS, MASS AND MASS DISTRIBUTION, INERTIA); VERTICAL AND HORIZONTAL VELOCITY COMPONENTS AND ATTITUDE AS VARIABLES; ACCELERATIONS, PRESSURES, FORCES (NOSE AND CG LOAD CELLS), AND FILM DATA.
- FACILITY HOURS: 560 (BASED ON ONE WEEK SET-UP AND CHECKOUT + AN ALLOTTED 50 TESTS CONDUCTED ONE/DAY ON CONSECUTIVE WORKING DAYS + 15 DAYS OF MODEL AND TESTING EQUIPMENT MODIFICATION AND CHECKOUT)
- FACILITIES PROPOSED FOR USE: NASA-MSC LANDING AND IMPACT FACILITY 338
- NEW FACILITIES REQUIRED: NONE ANTICIPATED.

TESTS FOR SRAO/TRAO RECOVERY DEVELOPMENT

Recovery testing is an integral part of many other subsystems testing. The wind tunnel testing will analyze reentry stability and drag characteristics with the drag flaps deployed. This data will predict the booster impact location and terminal velocity before retrorocket ignition. The retrorockets will be developed separately as a solid rocket propulsion device. The avionics (retrorocket ignition, altitude sensors, controls) equipment will be tested with the avionics system. Special drop tests and/or vacuum chamber pressure tests will be made of barometric height controls and/or radar altimeters. Scaled models will be utilized to predict water entry booster loads. Towing and handling loads will be measured on a full scale development structure utilized for retrieval testing. The entire recovery system will be tested as an entire integrated system on the first vertical launch. The chart on the opposite page identifies the different types of tests applicable to the recovery system.

Several other tests were evaluated which attempt to gain integrated recovery system confidence before the first booster launch. A booster only launch was considered but dropped because the cost for simulators and some "ballast" payload and launch and recovery expense are not justifiable. The recovery test utilizes the same, plus additional, hardware as the first Booster-Orbiter launch, all of which has the same success/failure risk as the first vertical flight. The operation of the recovery system does not impact orbiter safety or reliability. Therefore, the only advantage of a booster launch to evaluate the recovery system is an earlier scheduled launch date than the first Booster-Orbiter launch.

A similar test launching a production ground test booster specimen, a production flight booster or a battleship booster on a S-IB Booster was also considered. This concept was not cost effective similar to the above.

TESTS FOR SRAO/TRAO RECOVERY DEVELOPMENT

<u>TESTS</u>	<u>BRAKING ROCKET SYSTEM</u>	<u>PARACHUTE SYSTEM</u>
° WIND TUNNEL - ENTRY ATTITUDE BEHAVIOR (3,000 HOURS)	X (INCLUDE BOOSTER SPIN-UP)	X (INCLUDE CHUTES DEPLOY- MENT & PERFORMANCE)
° SCALED MODEL - WATER IMPACT	X	X
° SCALED MODEL - WATER TOWING	X	X
° DRAG FLAPS STRUCTURAL & FUNCTIONAL (DEPLOYMENT) VERIFICATION	X	X
° ROCKET MOTOR QUALIFICATION	X	-
° PYROTECHNIC DEVICES QUALIFICATION	X	X (CHUTE DEPLOY DEVICES)
° AVIONIC COMPONENT QUALIFICATION & INTEGRATION ON ASTU AND/OR SIMULATED FLIGHT TEST	X	X
° FULL SCALE PARACHUTE DEPLOYMENT (CARGO AIRCRAFT DROP USING MAXIMUM PRACTICAL BODY WEIGHT)	-	X
° FULL SCALE OPERATIONAL TYPE RECOVERY FROM SIMULATED WATER IMPACT POINT (FLIGHT VEHICLE LESS SUBSYSTEMS NOT PERTINENT TO TEST PURPOSE)	X	X
° VTO FLIGHT TEST - DESIGN LAUNCH CONFIGURATION; ORBITER MANNED	X	X

VTOM DEVELOPMENT CONCEPT

The first five (5) launches are considered "development" launches. The Booster preparation for the first launch will include each test and checkout technique planned for an operational booster. The primary difference in development launches and operational launches booster preparation will be in the extent of testing required and the amount of available data and conservatism used in its evaluation. During the development launch preparation some testing will be required to verify (gain confidence) that a proposed procedure works effectively. Once this has been established the level of test verification can be reduced or eliminated. Pre and post launch data evaluation will be most conservative during the development launches. The quantity of data will be the greatest because of the added development flight instrumentation (DFI). In addition, there will be only limited trend data available for comparative evaluation. The result of this will be that more test verification will be required until the confidence in assessing booster system health is accumulated. This data base is an important result from the development flights. The development launch preparation will allow a logical progressive transition from preparation based where possible on the last flight's data.

VTOM DEVELOPMENT CONCEPT

- PERFORM ALL "NORMAL" TURNAROUND MAINTENANCE AND CHECKOUT FUNCTIONS
 - FINALIZE MAINTENANCE REQUIREMENTS
 - ESTABLISH CHECKOUT PROCEDURES AND MOST EFFICIENT OPERATIONAL WORK FLOW PATHS

- DEVELOPMENT PECULIAR TESTING
 - DETAILED FUNCTIONAL PRETEST CHECKOUT (SIMILAR TO FACTORY ACCEPTANCE)
 - EXTENSIVE SALT SENSITIVE WIPE TESTS TO EVALUATE DECONTAMINATION PROCEDURE
 - CONSERVATIVE DATA EVALUATION - ESTABLISH "NOMINAL" INDICATORS
 - DFI - ADDITIONAL DATA EVALUATION TO CORRELATE WITH OPERATIONAL DATA
 - FRF FIRST FIVE BOOSTERS

- PROGRESSIVE TRANSITION FROM DETAILED GROUND TEST VERIFICATION TO VERIFICATION BASED ON LAST FLIGHTS SUCCESSFUL PERFORMANCE

PURPOSE AND INTENT OF THE VARIOUS ACCEPTANCE TESTS

EQUIPMENT PRE-INSTALLATION ACCEPTANCE:

- o TO VERIFY PROCURED COMPONENTS AND CONTRACTOR-BUILD COMPONENTS AND ASSEMBLIES CONFORM TO DESIGN AND PERFORMANCE SPECIFICATIONS PRIOR TO INSTALLATION

SUBASSEMBLY MANUFACTURING IN-PROCESS TESTS:

- o TO VERIFY PROPER ASSEMBLY AND INTEGRITY OF SUCH SUBASSEMBLIES AS ELECTRICAL WIRE HARNESSSES, CABLING, FLUID AND GAS LINES, AND MECHANICAL SYSTEMS COMPONENTS

MAJOR ASSEMBLY MANUFACTURING IN-PROCESS TESTS:

- o TO VERIFY PROPER ASSEMBLY AND INTERFACE HOOK-UP INTEGRITY OF ITEMS SUCH AS ELECTRICAL CIRCUITS, CABLING, FLUID AND GAS LINES, AND MECHANICAL LINKAGE

MAJOR ASSEMBLY SUBSYSTEMS ACCEPTANCE:

- o TO VERIFY PROPER ASSEMBLY AND THAT SUBSYSTEM INTEGRITY, OPERATION, AND PERFORMANCE ARE WITHIN DESIGN SPECIFICATIONS

FINAL ASSEMBLY SUBSYSTEMS ACCEPTANCE:

- o TO VERIFY PROPER INSTALLATION INTEGRITY, PERFORMANCE SPECIFICATION COMPLIANCE, FUNCTION AND OPERATION OF EACH SUBSYSTEM

FINAL ASSEMBLY COMBINED SUBSYSTEMS ACCEPTANCE:

- o TO PERFORM AN ALL-UP SYSTEMS TEST IN WHICH ALL SUBSYSTEM INTERFACES ARE VALIDATED AND CHECKED OUT

PREFLIGHT TESTS (HORIZONTAL):

- o TO PERFORM A SERIES OF GROUND TESTS TO CHECK PROPER OPERATION OF ALL SUBSYSTEMS THAT WILL BE CALLED UPON TO OPERATE DURING HORIZONTAL FLIGHT (ORBITER ONLY)

FLIGHT ACCEPTANCE TEST

- o TO PERFORM THOSE FINAL ACCEPTANCE TESTS (INCLUDING HORIZONTAL FLIGHTS) TO VERIFY READINESS FOR OPERATIONAL USE OF THE VEHICLE (ORBITER ONLY)

ACCEPTANCE TEST FLOW

EQUIPMENT ACCEPTANCE TEST
(P.I.A.)

SUBASSEMBLY SUBSYSTEM TEST
(MFG. IN-PROCESS)

SUBASSEMBLY SUBSYSTEM TEST
(MODULE)

FINAL ASSEMBLY SUBSYSTEM TEST

COMBINED SUBSYSTEM TEST

PREFLIGHT TEST
(HORIZONTAL)

FLIGHT ACCEPTANCE TEST

REFURBISHMENT

PHASE B EXTENSION IMPACT ON ACCEPTANCE TEST

MINIMAL IMPACT ON PHASE B ACCEPTANCE TEST PLAN

o TEST REQUIREMENTS REMAIN THE SAME:

- o VERIFY PROPER ASSEMBLY
- o VERIFY SUBSYSTEMS' PERFORMANCE WITHIN DESIGN SPECIFICATIONS

o TEST APPROACH IS SIMILAR:

- o ORBITER - PROGRESSES FROM COMPONENT ACCEPTANCE THROUGH HORIZONTAL FLIGHT ACCEPTANCE
- o BOOSTER - PROGRESSES FROM COMPONENT ACCEPTANCE THROUGH FINAL FACTORY ACCEPTANCE
- o EXTERNAL TANK- PROGRESSES FROM COMPONENT ACCEPTANCE THROUGH FINAL FACTORY ACCEPTANCE

LAUNCH SITE TESTS

PRIMARY PURPOSE:

ASSURE FLIGHT READINESS PRIOR TO COMMITTING SHUTTLE SYSTEMS
TO VERTICAL FLIGHT

SECONDARY PURPOSE:

ESTABLISH THE BASE UPON WHICH SUBSEQUENT OPERATIONAL TURNAROUND
ACTIVITIES CAN BE BUILT

CHANGES FROM PHASE B

ALTHOUGH THE BOOSTER AND ORBITER HAVE CHANGED CONSIDERABLY, --
THE REQUIREMENTS FOR, AND THE APPROACH TO -- LAUNCH SITE TESTING
IS BASICALLY UNCHANGED

COMPONENTS OF LAUNCH SITE TESTS

Launch site tests encompass those ground tests required to assure flight readiness prior to committing the Shuttle to vertical flight. A secondary, but important purpose of this section of the test plan is to establish the base upon which subsequent operational turnaround activities can be built.

The impact of the Phase B Extension baseline configuration, SRAO, upon the Phase B launch site test requirements and approaches is minimal. Basically the same functions must be performed. These functions or components are outlined on the facing page. Following receipt of the Orbiter from Horizontal Flight Test maintenance is performed prior to pre-mate testing. A variance from Phase B is that the Booster has of course not been flight tested, but is received directly from the manufacturer.

Pre-mate testing follows the same course as in Phase B, namely a logical program of subsystem, combined subsystems, EMC and Flight Readiness Firing tests.

Post-mate testing, culminating in vertical launch of the Shuttle, is accomplished in much the same way as in Phase B.

Turnaround of the vehicles for subsequent relaunch is similar, the major differences include water retrieval operations of the baseline Booster and readiness of the external tank.

COMPONENTS OF LAUNCH SITE TESTS

READINESS OF SHUTTLE SYSTEM FOR INITIAL VERTICAL FLIGHTS

- o PERFORM GSE/FACILITY READINESS TESTS
- o PERFORM VEHICLE MAINTENANCE
- o PERFORM PREMATE TESTS

AS APPLICABLE:

- o SUBSYSTEMS TESTS
- o EMC TESTS
- o FLIGHT READINESS FIRINGS
- o PERFORM POST MATE VALIDATION TESTS
- AS APPLICABLE:
 - o INTEGRATED SYSTEMS TESTS
 - o GROUND VIBRATION TESTS
 - o COUNTDOWN DEMONSTRATION TESTS
 - o EMC TESTS
- o PERFORM LAUNCH OPERATIONS

TURNAROUND OF VEHICLES FOR RELAUNCH

- o POSTLANDING AND/OR WATER RETRIEVAL OPERATIONS
- o MAINTENANCE
- o PRELAUNCH
- o LAUNCH

[IMPACT OF PHASE B EXTENSION CONFIGURATION CHANGES ON OUR APPROACH IS MINIMAL]

SPACE SHUTTLE FLIGHT TESTS

GENERAL

ORBITER ONLY FLIGHT TESTS

BOOSTER ONLY FLIGHT TESTS

MATED/VERTICAL FLIGHT TESTS

SPACE SHUTTLE FLIGHT TESTS

GENERAL

- o PURPOSE & INTENT
- o FLIGHT TEST OBJECTIVES
- o TECHNOLOGY CONCERNS
- o FLIGHT TEST METHODS AVAILABLE FOR AREAS OF CONCERN
- o ENVELOPE EXPLORATION SUMMARY

SPACE SHUTTLE FLIGHT TEST PROGRAM

PURPOSE AND INTENT OF FLIGHT TESTS

FLIGHT TESTING SHALL BE EMPLOYED TO THE EXTENT NECESSARY TO
VERIFY OPERATIONAL SUITABILITY WHERE VERIFICATION CANNOT BE
OBTAINED MORE ECONOMICALLY FROM GROUND TESTS

FLIGHT TEST OBJECTIVES

- o EVALUATION AND DEVELOPMENT OF HARDWARE CHARACTERISTICS AND OPERATIONAL PROCEDURES
- o CORRELATION OF FLIGHT DATA WITH GROUND TEST RESULTS AND DESIGN ANALYSIS IN SUPPORT OF SYSTEMS VERIFICATION
- o VERIFICATION OF OVERALL SYSTEM OPERATION INCLUDING BOOSTER, ORBITER, GROUND SUPPORT EQUIPMENT AND FACILITIES
- o CREW TRAINING (GROUND AND FLIGHT)
- o DEVELOPMENT OF SUFFICIENT CONFIDENCE IN ONBOARD CHECKOUT AND CONTROL EQUIPMENT AND PROCEDURES TO ALLOW ROUTINE OPERATIONAL FLIGHTS WITHOUT EXTENSIVE GROUND CONTROL, MONITORING, AND SUPPORT
- o VERIFICATION AND REFINEMENT OF GROUND SUPPORT EQUIPMENT, FACILITIES, AND PROCEDURES TO OBTAIN MINIMUM TIME, HIGH CONFIDENCE TURNAROUND

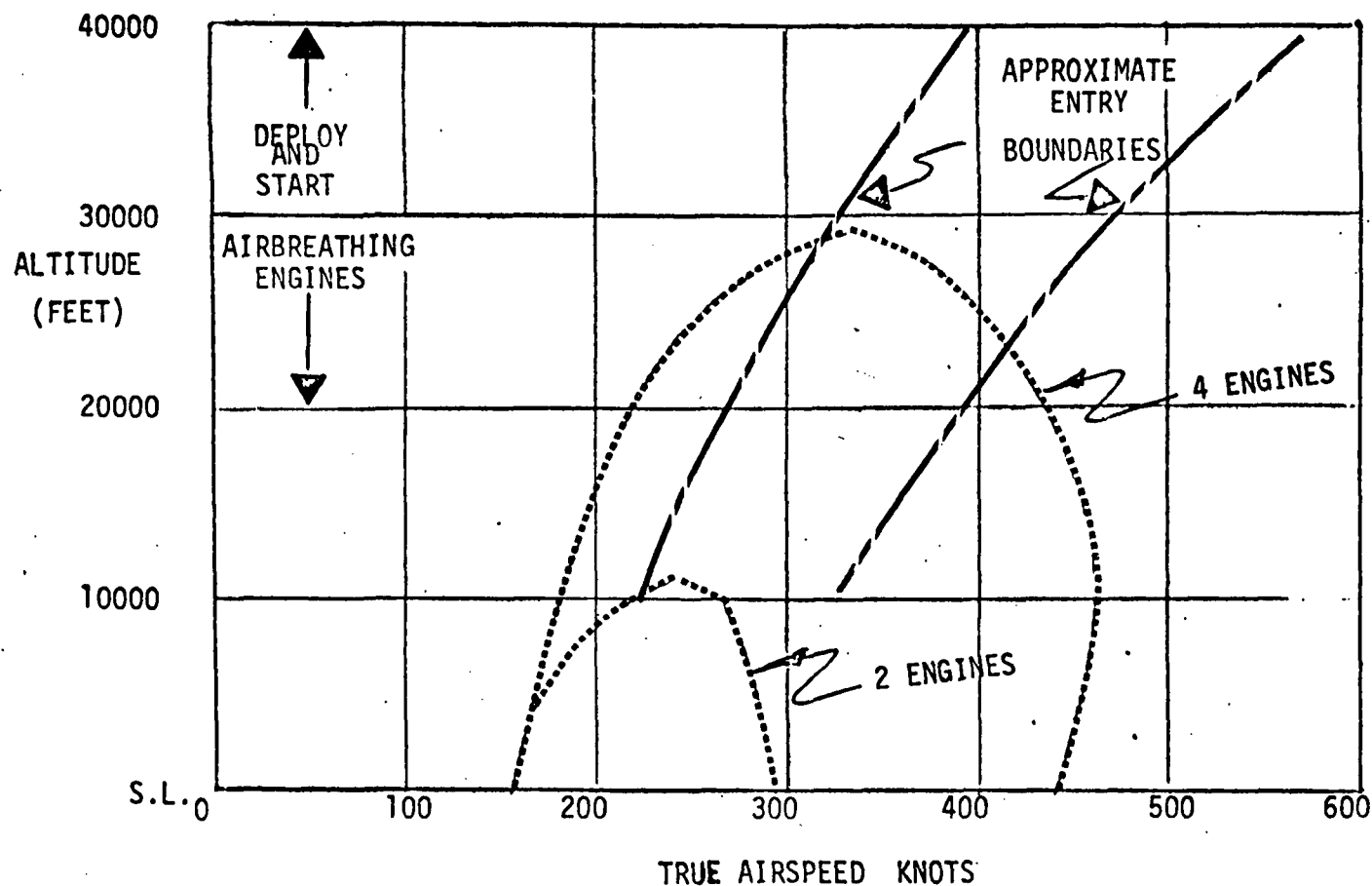
SPACE SHUTTLE FLIGHT TESTS
ORBITER ONLY FLIGHT TESTS

- o HORIZONTAL FLIGHT TEST OBJECTIVES
- o HORIZONTAL FLIGHT TEST ENVELOPES
- o DEVELOPMENT OF HORIZONTAL TEST PROGRAM
- o HORIZONTAL FLIGHT TEST PLAN
- o TEST SITE SELECTION
- o DEVELOPMENT FLIGHT INSTRUMENTATION
- o ROLES AND RESPONSIBILITIES

HORIZONTAL FLIGHT TEST OBJECTIVE

**TO ACHIEVE THOSE OVERALL FLIGHT TEST OBJECTIVES WHICH CAN BE
REACHED VIA THE HORIZONTAL - AIRBREATHING FLIGHT ENVELOPE OF
THE ORBITER (ESSENTIALLY THE APPROACH AND LANDING, AND FERRY
PHASE OF ORBITER MISSION)**

ORBITER HORIZONTAL OPERATING ENVELOPE



HORIZONTAL FLIGHT TEST PRIORITIES

1. TEST IN AREAS OF THE ENVELOPE WHERE WE EXPECT TO BE ON RETURN FROM FIRST ORBITAL FLIGHT
2. TEST TO COVER AREAS TO BE CLEARED FOR OPERATIONAL FLIGHTS
3. TEST IN AREAS REQUIRED FOR OPERATIONAL FERRY CAPABILITY

HORIZONTAL FLIGHT TEST TEST CATEGORIES

FLIGHT CHARACTERISTICS

- o PRELIMINARY EVALUATION
- o STABILITY & CONTROL
- o PERFORMANCE
- o BUFFET & MINIMUM CONTROL
- o AIRSPEED CALIBRATION

AIRFRAME GROUP

- o STRUCTURES
- o LANDING & RECOVERY

PROPULSION GROUP

- o AIRBREATHING

CREW STATION GROUP

- o ENVIRONMENTAL CONTROL
- o CREW SYSTEMS, DISPLAYS & CONTROLS

AVIONICS GROUP

- o GUIDANCE & NAVIGATION
- o COMMUNICATIONS & NAVAIDS
- o FLIGHT CONTROL ELECTRONICS
- o DATA MANAGEMENT - SOFTWARE
- o AVIONICS DISPLAYS & CONTROLS

POWER SUPPLY GROUP

- o ELECTRICAL POWER
- o HYDRAULIC POWER

MISCELLANEOUS & FERRY

- o FERRY
- o MISCELLANEOUS

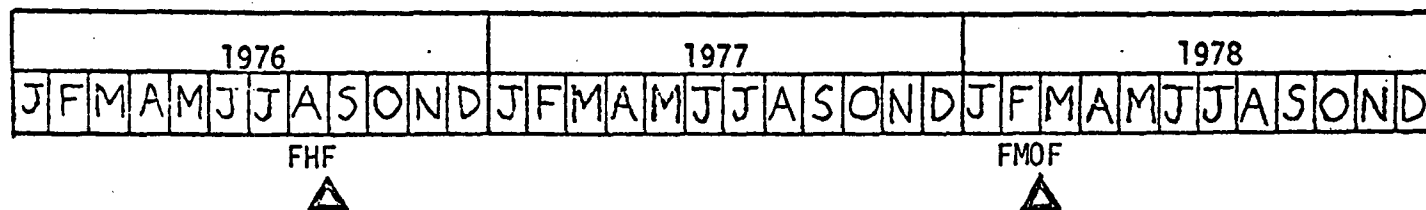
HORIZONTAL TEST PROGRAMS OF DIFFERENT SIZES

PROGRAM SCOPE	ESTIMATED FLIGHT HOURS BY TEST CATEGORY					ESTIMATED TOTAL FLIGHT
	AERO	STRUCT	PROPULSION	EQUIPMENT	MISC	
VERIFICATION WITH BUILDUP, NORMAL DEVELOPMENT PLUS AGENCY DEMONSTRATION	393	86	171	686	164	1500
VERIFICATION WITH BUILDUP AND NORMAL DEVELOPMENT	275	60	120	480	115	1050
VERIFICATION WITH BUILDUP AND MODEST DEVELOPMENT	130	25	46	181	20	402
VERIFICATION WITH BUILDUP	103	25	25	90	20	263
VERIFICATION ONLY	67	12	10	32	0	121
VERIFICATION SPOT CHECK	24	5	5	16	0	50

ORBITER
←
BASELINE

HORIZONTAL FLIGHT TEST PLAN

ORBITER



ORBITER
S/N 1

238 FLIGHT HOURS
STABILITY & CONTROL, PERFORMANCE,
STRUCTURES, LANDING & RECOVERY,
PROPULSION, AVIONICS

76
FLIGHT
HOURS
AVIONICS

TO
VERTICAL
FLIGHT TEST
PLAN

ORBITER
S/N 2

60
FLIGHT
HOURS
AVIONICS

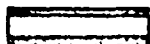
TO VERTICAL
FLIGHT TEST PLAN

11 FLIGHT HOURS

TEST SITES



EDWARDS AFB



KSC

NOTE: 17 FLIGHT HOURS ALLOTTED
FOR FERRY BETWEEN SITES

HORIZONTAL TEST SITE SELECTION

TEST TYPE	TEST SITE		
	ST L	EDWARDS	KSC
SHAKEDOWN, ACCEPTANCE	X		
INFLIGHT VERIFICATION OF OPERATIONAL CRUISE-BACK AND LANDING PROCEDURES AND NAVAIDS BOTH VEHICLE AND OPERATIONAL SITE			X
HIGH RISK TESTING (ENGINE AIRSTARTING, ENGINE HANDLING, ENGINE OUT PERFORMANCE, LIMITS OF CONTROLABILITY, HIGH ENERGY LANDING EVALUATION, BRAKING TESTS)		X	

CONSIDERATIONS

- o EMERGENCY FACILITIES
- o WEATHER
- o EXISTING TEST FACILITIES
- o AIRSPACE
- o COMMON TEST BASE
- o SUPPORT REQUIREMENTS

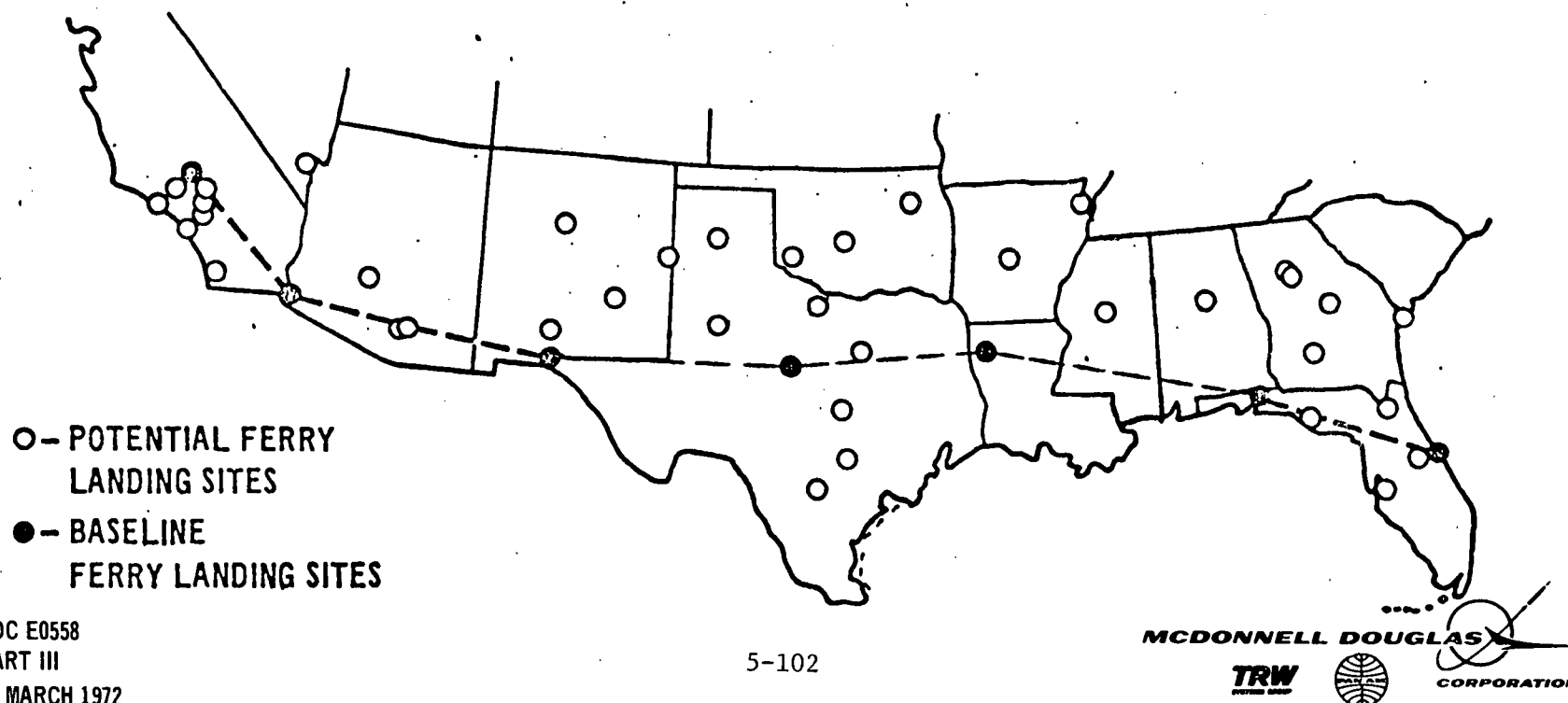
FERRY PLAN GROUND RULES

- o USE ONLY AIRPORTS WITH RUNWAYS $\geq 10,000$ FEET,
RUNWAY WEIGHT BEARING CAPACITY (TWIN WHEEL) $\geq 180,000$ LBS.
- o USE THE MINIMUM NUMBER OF HOPS.
- o MAXIMUM DISTANCE FOR ANY HOP = 450 N.M.
- o USE MILITARY AIRPORTS.
- o USE AIRPORTS WITH THE LOWEST ELEVATION.

SPACE SHUTTLE FLIGHT TEST PLAN

BASELINE FERRY PLAN EAFB TO KSC

FLIGHT LEG	DISTANCE N.MI.	RUNWAY DIMENSIONS FEET	FIELD ELEVATION FEET	RUNWAY WT. BEARING CAPACITY - POUNDS (TWIN WHEEL GEAR)
EDWARDS AFB		15,000 X 300	2,302	200,000
TO YUMA MCAS	210	13,300 X 200	213	225,000
TO BIGGS AAF	420	13,572 X 300	3,947	330,000
TO DYESS AFB	330	13,500 X 300	1,789	250,000
TO BARKSDALE AFB	320	11,754 X 300	167	260,000
TO EGLIN AFB	390	12,000 X 300	85	205,000
TO CAPE KENNEDY	330	TO BE CONSTRUCTED	APPROX S.L.	



HORIZONTAL FLIGHT TEST INSTRUMENTATION SYSTEM REQUIREMENTS

SIZE

USEABILITY

FLEXIBILITY

COMPATABILITY

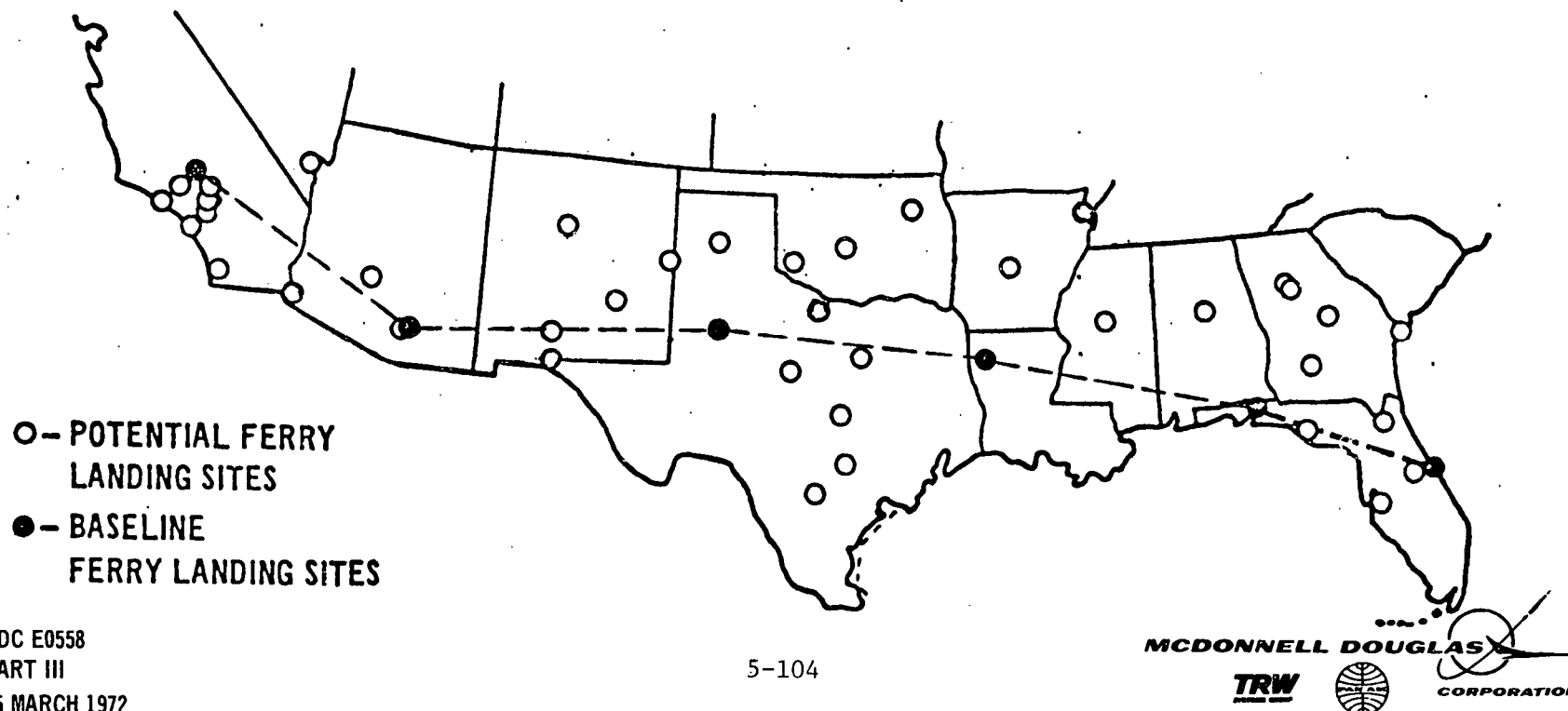
COMMONALITY

MINIMUM SCAR

SPACE SHUTTLE FLIGHT TEST PLAN

ALTERNATE FERRY PLAN EAFB TO KSC

FLIGHT LEG	DISTANCE N.MI.	RUNWAY DIMENSIONS FEET	FIELD ELEVATION FEET	RUNWAY WT. BEARING CAPACITY - POUNDS (TWIN WHEEL GEAR)
EDWARDS AFB		15,000 X 300	2,302	200,000
TO DAVIS-MONTHAN AFB	390	13,645 X 200	2,705	210,000
TO REESE AFB	450	10,500 X 150	3,338	100,000 (SWL25)
TO BARKSDALE AFB	430	11,754 X 300	167	260,000
TO EGLIN AFB	390	12,000 X 300	85	205,000
TO CAPE KENNEDY	330	TO BE CONSTRUCTED	APPROX. S.L.	TO BE CONSTRUCTED



ORBITER DFI (HORIZONTAL) MEASUREMENT SUMMARY

SUBSYSTEM	MEASUREMENTS	TYPE OF MEASUREMENTS				
		HIGH LEVEL ANALOG	LOW LEVEL ANALOG	DIGITAL	DISCRETE	FM
ECLS	125	53	62	0	10	0
HYDRAULIC POWER	102	74	18	0	10	0
STRUCTURE	603	97	287	0	0	219
THERMAL PROTECTION	5	5	0	0	0	0
LANDING & DECELERATION	60	44	8	0	8	0
AUXILIARY POWER UNIT	98	34	52	0	12	0
MECHANICAL SYSTEM	58	14	0	0	44	0
ELECTRICAL POWER	174	86	43	0	26	19
FLIGHT GUIDANCE & CONTROL	137	66	30	26	15	0
CONTROLS & DISPLAYS	51	11	0	0	40	0
GUIDANCE, NAV. & CONTROL	27	17	0	0	10	0
AIR BREATHING PROPULSION	240	170	26	0	0	44
INSTRUMENTATION	32	20	8	0	4	0
TOTALS	1712	691	534	26	179	282

HORIZONTAL FLIGHT TEST PROGRAM

BASELINE PLAN

Roles and Responsibilities

FUNCTION	ROLE	
	CONTRACTOR	NASA
OVERALL TEST PLAN	ORIGINATES	APPROVES
FLIGHT PLANNING		
SELECT TEST CONDITIONS	DESIGNATES	CONCURS/APPROVES
SCHEDULING	PERFORMS	OBSERVES
COORDINATION WITH FACILITIES	PERFORMS	SUPPORTS
FLIGHT OPERATIONS		
AIR CREWS	SUPPLIES	APPROVES/PARTICIPATES
IN FLIGHT DATA MONITORING	PERFORMS	WITNESSES
TRACKING	PERFORMS	SUPPORTS
DATA HANDLING		
PROCESSING	PERFORMS	SUPPORTS
ANALYSIS	PERFORMS	MONITORS/APPROVES
CONFIGURATION CONTROL		
CHANGE TO VEHICLE	PERFORMS	OBSERVES/APPROVES
INSTRUMENTATION	MAINTAINS	WITNESSES
VEHICLE MAINTENANCE	PERFORMS	INSPECTS

TESTS FOR SRAO/TRAO RECOVERY DEVELOPMENT

TESTS	BRAKING ROCKET SYSTEM	PARACHUTE SYSTEM
o WIND TUNNEL - ENTRY ATTITUDE BEHAVIOR (3,000 HOURS)	X (INCLUDE BOOSTER SPIN-UP)	X (INCLUDE CHUTES DEPLOY- MENT & PERFORMANCE)
o SCALED MODEL - WATER IMPACT	X	X
o SCALED MODEL - WATER TOWING	X	X
o DRAG FLAPS STRUCTURAL & FUNCTIONAL (DEPLOYMENT) VERIFICATION	X	X
o ROCKET MOTOR QUALIFICATION	X	-
o PYROTECHNIC DEVICES QUALIFICATION	X	X (CHUTE DEPLOY DEVICES)
o AVIONIC COMPONENT QUALIFICATION & INTEGRATION ON ASTU AND/OR SIMULATED FLIGHT TEST	X	X
* o FULL SCALE PARACHUTE DEPLOYMENT (CARGO AIRCRAFT DROP USING MAXIMUM PRACTICAL BODY WEIGHT)	-	X
o FULL SCALE OPERATIONAL TYPE RECOVERY FROM SIMULATED WATER IMPACT POINT (FLIGHT VEHICLE LESS SUBSYSTEMS NOT PERTINENT TO TEST PURPOSE)	X	X
* o VTO FLIGHT TEST - DESIGN LAUNCH CONFIGURATION; ORBITER MANNED	X	X

* FLIGHT TESTS

ADDITIONAL CANDIDATE TESTS - SRAO/TRAO RECOVERY

- *
 - o BOOSTER FLIGHT TEST PRIOR TO FMOF
 - o LAUNCH ON EXISTING BOOSTER
 - o MODIFY BOOSTER FOR SELF-LAUNCH
 - o LARGEST PRACTICAL SCALE MODEL AIRDROPS -- INCLUDING SCALED CHUTE OR ROCKET DECELERATION SYSTEM
- o FULL SCALE WATER IMPACT DROP (FROM 350 FEET IF NO DECELERATION SYSTEM USED)

* FLIGHT TESTS

FIRST VERTICAL FLIGHT TEST OBJECTIVES

PRIMARY
SAFE LAUNCH AND RECOVERY

SECONDARY
STRUCTURES
MAIN PROPULSION
AERODYNAMICS
THERMODYNAMICS

OMS AND ACPS
NAVIGATION
COMMUNICATIONS
ECLS

VERTICAL FLIGHT TEST OBJECTIVES

SPECIFIC

BUILD UP TO CRITICAL CONDITIONS IN INCREMENTS WHERE POSSIBLE

DEMONSTRATE MINIMUM AND MAXIMUM PAYLOAD CAPABILITY (BOTH LAUNCH AND RECOVERY)

DEMONSTRATE MAXIMUM FORWARD AND AFT C. G. CONDITIONS (BOTH LAUNCH AND RECOVERY)

DEMONSTRATE CROSSRANGE CAPABILITY

FIRST VERTICAL FLIGHT CONSTRAINTS

- o FLIGHT PROFILE SHALL NOT EXPOSE VEHICLE(S) TO MORE CRITICAL CONDITIONS THAN THAT FOR WHICH DESIGNED.

LOWER ASCENT DYNAMIC PRESSURE
LOWER BOOSTER ENTRY HEATING AND LOADS
LOWER ORBITER ENTRY HEATING AND LOADS

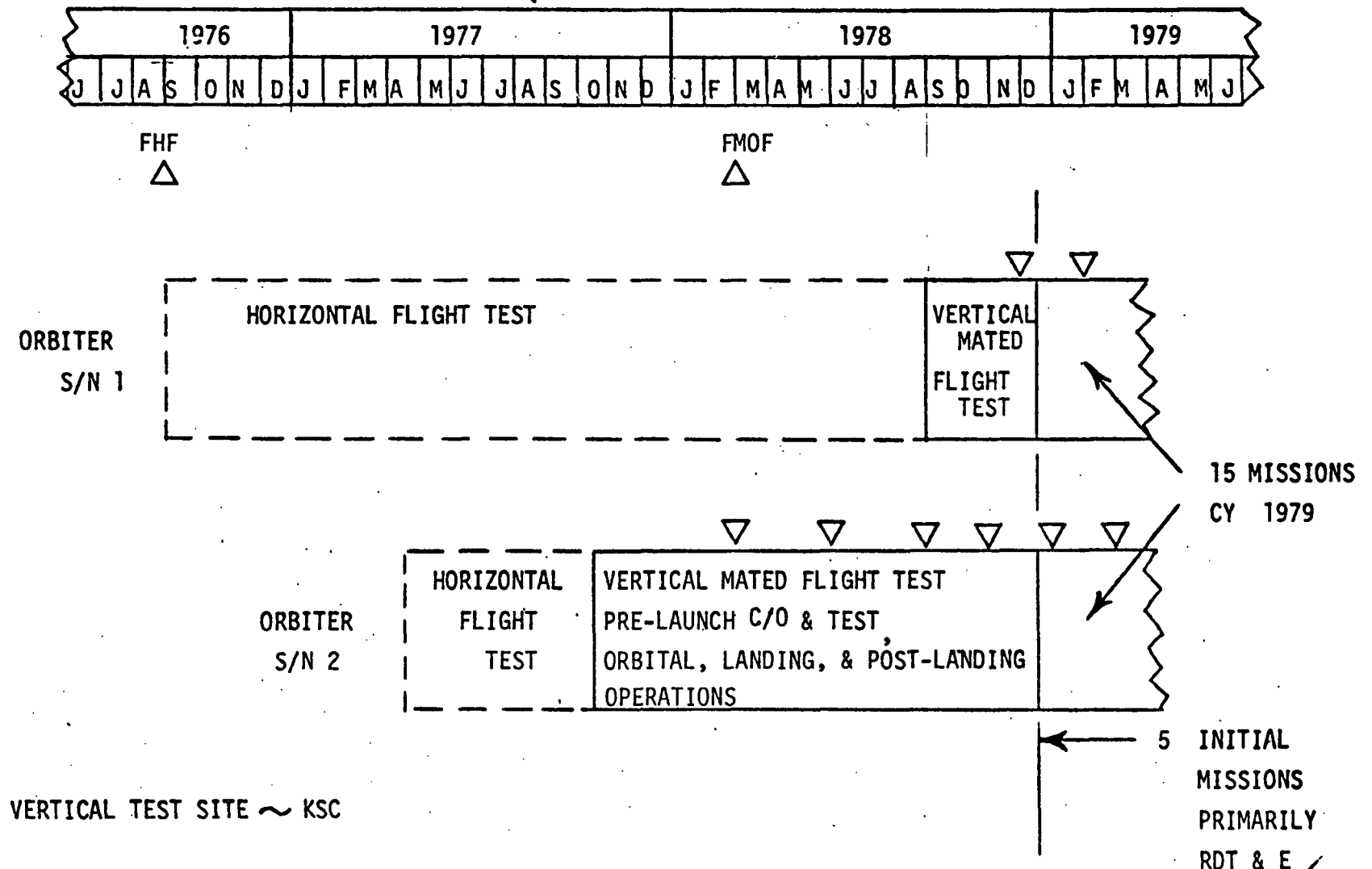
- o RANGE SAFETY RESTRICTIONS
- o MSFN OR SIMILAR COMMUNICATIONS, DATA, AND TRACKING REQUIRED.

INSERTION
BOOSTER ENTRY AND RECOVERY
EARLY REVOLUTIONS OF ORBITER
ORBITER ENTRY AND RECOVERY

- o DAYLIGHT VFR WEATHER REQUIRED AT LAUNCH SITE AND AT PRIMARY AND SECONDARY LANDING SITES.
- o ORBITER TO CARRY SUFFICIENT JP FUEL FOR 100 MILES CRUISE.
- o REENTRY PLAN TO BE OPTIMIZED FOR "DEADSTICK" LANDING.

VERTICAL FLIGHT TEST PLAN

ORBITER



ORBITER DFI (VERTICAL) MEASUREMENT SUMMARY

SUBSYSTEM	MEASUREMENTS	TYPE OF MEASUREMENTS				
		HIGH LEVEL ANALOG	LOW LEVEL ANALOG	DIGITAL	DISCRETE	FM
ECLS	191	67	124	0	0	0
HYDRAULIC POWER	52	24	18	0	10	0
MECHANICAL SYSTEMS	48	14	20	0	14	0
STRUCTURE	591	97	275	0	0	219
FLIGHT GUIDANCE & CONTROL	71	12	14	30	15	0
THERMAL PROTECTION	480	0	480	0	0	0
LANDING & DECELERATION	25	17	8	0	0	0
AUXILIARY POWER UNIT	50	10	40	0	0	0
ELECTRICAL POWER	69	30	23	0	0	16
GUIDANCE, NAV. & CONTROL	77	17	0	50	10	0
ACS/CMS	164	0	164	0	0	0
CONTROLS & DISPLAYS	51	11	0	0	40	0
MAIN PROPULSION	204	112	76	0	0	16
AIR BREATHING PROPULSION	78	38	8	0	0	32
INSTRUMENTATION	29	0	0	0	0	29
TOTALS	2180	449	1250	80	89	312

VERTICAL MATED FLIGHT TEST PROGRAM

BASELINE PLAN

Roles and Responsibilities

FUNCTION	ROLE	
	CONTRACTOR	NASA
OVERALL TEST PLAN	RECOMMENDS	ORIGINATES/APPROVES
FLIGHT PLANNING		
SELECT TEST CONDITIONS	RECOMMENDS	DESIGNATES
SCHEDULING	SUPPORT	PERFORMS
COORDINATION WITH FACILITIES		PERFORMS
FLIGHT OPERATIONS		
AIR CREWS		SUPPLIES
IN FLIGHT DATA MONITORING	SUPPORTS	PERFORMS
TRACKING		PERFORMS
DATA HANDLING		
PROCESSING	SUPPORT	PERFORMS
ANALYSIS	SUPPORT/ PERFORMS	PERFORMS
CONFIGURATION CONTROL		
CHANGE TO VEHICLE	PERF/RECOM	INSTIGATES/APPROVES
INSTRUMENTATION	MAINTAINS	CONTROL
VEHICLE MAINTENANCE	PERFORMS	DIRECT/INSPECT

GROUND & FLIGHT OPERATIONS

MDC E0558
PART III
15 MARCH 1972

6-1



PHASE B EXTENSION OPERATIONS REQUIREMENTS

The Ground Operations requirements for the Phase B Extension are noted on pages 6-3 through 6-5. The requirements noted are those that have changed as well as new ones which were generated due to configuration changes.

The Space Shuttle requirements had no significant changes, however, the Booster requirements were deleted and new ones generated. This was necessitated by the drastic change in configuration. The Booster configurations considered were SRAO, TRAO, SRAO-SRM, TRAO-SRM, recoverable vehicle with F-1 engines and recoverable vehicle with high Pc engines.

The Orbiter requirements associated with the Phase B data dump generally were unchanged. However, additional requirements were added as a result of the OMS, APU and ACPS modular concept in the Phase B Extension.

The Flight Operations requirements for the Orbiter have not changed significantly. However, the Booster requirements for Phase B are deleted for the extension configuration.

GROUND OPERATIONS REQUIREMENTS

- o SPACE SHUTTLE REQUIREMENTS:
 - o NO SIGNIFICANT CHANGES OR ADDITIONS
- o BOOSTER REQUIREMENTS:
 - o DELETE EXISTING REQUIREMENTS
 - o ADD FOLLOWING REQUIREMENTS:
 - o TANKS WILL BE PURGED TO ACCEPTABLE SAFE LEVEL PRIOR TO MOVING THE VEHICLE INTO MAINTENANCE AREA (ALL EXCEPT SOLIDS)
 - o THE VEHICLE SHALL HAVE MAINTENANCE AND TESTING ACCESSIBILITY IN BOTH THE HORIZONTAL AND VERTICAL POSITION (ALL EXCEPT SOLIDS)
 - o EQUIPMENT THAT WILL BE USED FOR DEVELOPMENT TEST ONLY WILL NOT BE INTEGRAL WITH OPERATIONAL HARDWARE WHERE POSSIBLE AND WILL BE ACCESSIBLE FOR EASE OF REMOVAL (ALL EXCEPT SOLIDS)
 - o ANY BOOSTER MUST BE CAPABLE OF MATING AND INTERFACING WITH ANY ORBITER/EXTERNAL TANK COMBINATION (ALL)
 - o THE VEHICLE SHALL BE CAPABLE OF BEING LIFTED WITHOUT LOAD DISTRIBUTION GSE DEVICES WHICH REQUIRE LARGE NUMBERS OF FASTENERS (ALL)
 - o THE VEHICLE SHALL BE CAPABLE OF WITHSTANDING A SEA STATE OF 5 WITHOUT ASSISTANCE FROM PERSONNEL OR EQUIPMENT FOR A MAXIMUM OF 4 DAYS (ALL EXCEPT SOLIDS)
 - o THE VEHICLE MUST HAVE DEVICES WHICH WILL AID IN LOCATING IT UNDER POOR VISIBILITY CONDITIONS (ALL EXCEPT SOLIDS)
 - o EQUIPMENT MUST BE PROVIDED TO REMOTELY INDICATE THE SAFETY STATUS OF THE VEHICLE CRITICAL SYSTEMS PRIOR TO THE CREW APPROACHING IT AFTER WATER IMPACT (ALL EXCEPT SOLIDS)

GROUND OPERATIONS REQUIREMENTS

o BOOSTER REQUIREMENTS (CONTINUED)

- o THE VEHICLE SHALL BE CAPABLE OF BEING REMOTELY SAFED TO AN ACCEPTABLE LEVEL FOR CREW HANDLING IN THE OCEAN (ALL EXCEPT SOLIDS)
- o THE COMPONENTS OF THE VEHICLE SHALL BE ISOLATED IN SEALED, PRESSURIZED CONTAINERS TO PROTECT THEM FROM THE SEA ENVIRONMENT (ALL EXCEPT SOLIDS)
- o THE VEHICLE SHALL BE CAPABLE OF BEING TOWED IN THE OCEAN IN A SEA STATE 4 (ALL EXCEPT SOLIDS)
- o THE VEHICLE MUST BE CAPABLE OF BEING FLUSHED AND PURGED WITH A MINIMUM OF BREAKING INTO FLIGHT HARDWARE (ALL EXCEPT SOLIDS)
- o THE VEHICLE MUST BE CAPABLE OF BEING ASSEMBLED IN SEGMENTS (SOLIDS ONLY)

o ORBITER REQUIREMENTS

- o REQUIREMENTS REMAIN THE SAME EXCEPT DELETE (N) AND ADD THE FOLLOWING:
 - o THE EXTERNAL HYDROGEN-OXYGEN TANK SHALL NOT REQUIRE PRESSURE FOR STABILIZATION WHILE ERECTED
 - o DURING THE DEVELOPMENT PHASE, BOTH THE HORIZONTAL AND VERTICAL FLIGHT TESTING, THE ACTIVITIES, PROCEDURES AND OPERATIONAL TECHNIQUES WILL BE AS SIMILAR TO THE OPERATIONAL PHASE AS POSSIBLE
 - o THE VEHICLE SHALL HAVE THE CAPABILITY OF REPLACING THE OMS MODULE IN A MATED CONFIGURATION
 - o THE VEHICLE SHALL HAVE THE CAPABILITY OF REPLACING THE ACPS MODULE IN A MATED CONFIGURATION

GROUND OPERATIONS REQUIREMENTS

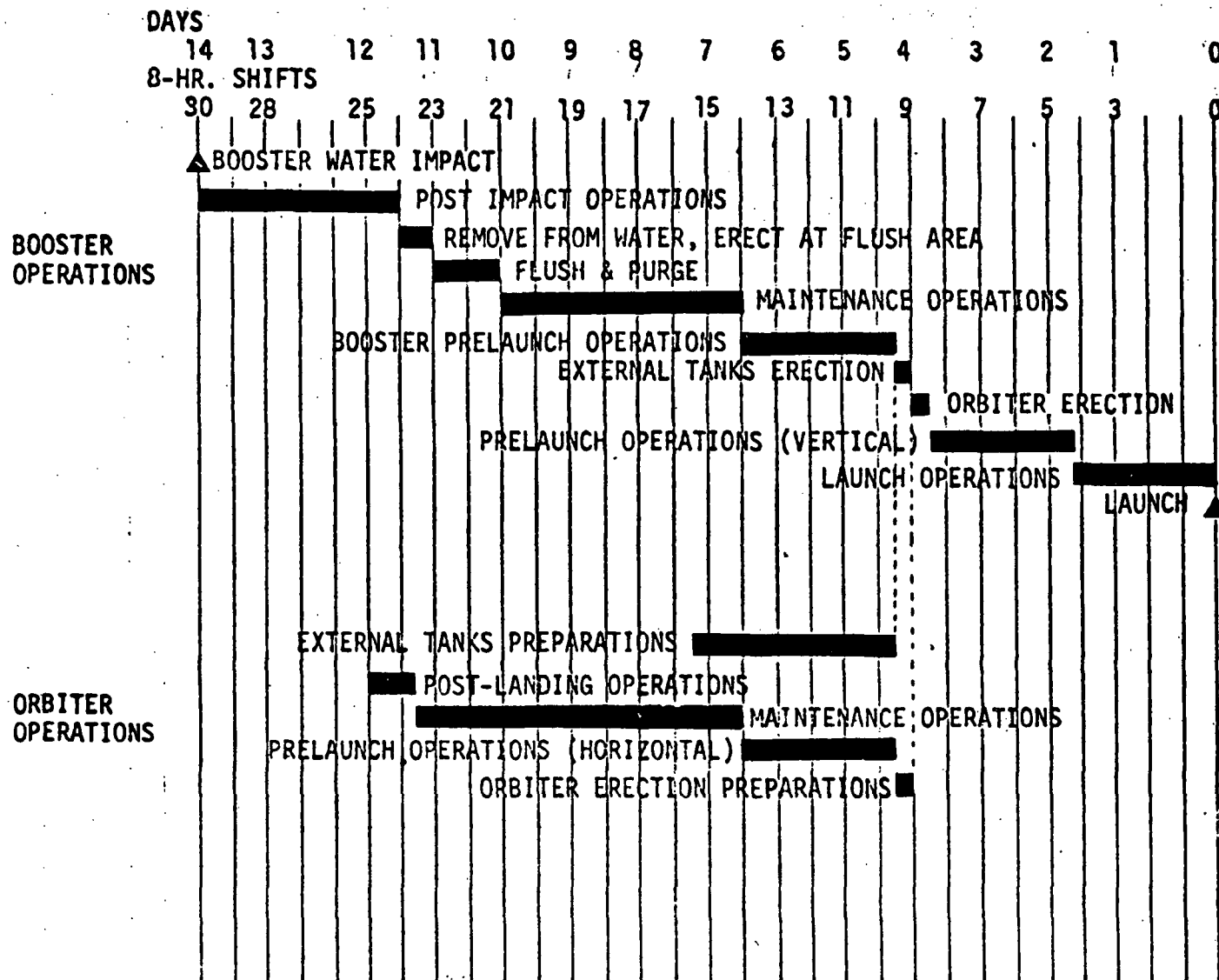
o ORBITER REQUIREMENTS (CONTINUED)

- o THE VEHICLE SHALL HAVE THE CAPABILITY OF REPLACING THE APU MODULE IN A MATED CONFIGURATION
- o LIKE MODULES SHALL BE INTERCHANGEABLE
- o ACPS/OMS MODULE ALIGNMENT CHECKS SHALL BE MADE ONLY ON THE INITIAL INSTALLATION OF THE FIRST MODULE. MOTOR ALIGNMENT CHECKS WILL NOT BE REQUIRED ON SUBSEQUENT MODULE INSTALLATIONS
- o ACPS/OMS MODULE TO VEHICLE INTERFACES SHALL BE FULLY VERIFIED FOR FLIGHT USING A MODULE SIMULATOR EXCEPT FOR FLUID/ELECTRICAL CONTINUITY CHECKS
- o CHECKOUT FOLLOWING INSTALLATION OF A SERVICED MODULE SHALL PRECLUDE THE POSSIBILITY OF INADVERTANT PROPELLANT VALVE OPENINGS AND ALSO NOT REQUIRE VALVE POSITION MOVEMENT FOR THE CHECKOUT FUNCTION
- o FOLLOWING A LANDING, THE ACPS/OMS MODULE SYSTEMS SHALL BE CAPABLE OF BEING MANUALLY DEPRESSURIZED TO A SAFE LEVEL FOR REMOVAL AND TRANSPORTATION

SRAO TURNAROUND OPERATIONS

Both the F-1 powered Booster and the High Pc Booster were analyzed to determine the impacts on the turnaround cycle. There were three areas where the effort was significantly more than the Series Burn Pressure Fed Booster: (A) Flush and purge, (B) Maintenance, and (C) Prelaunch. The overall impact is twenty additional hours over the Pressured Fed.

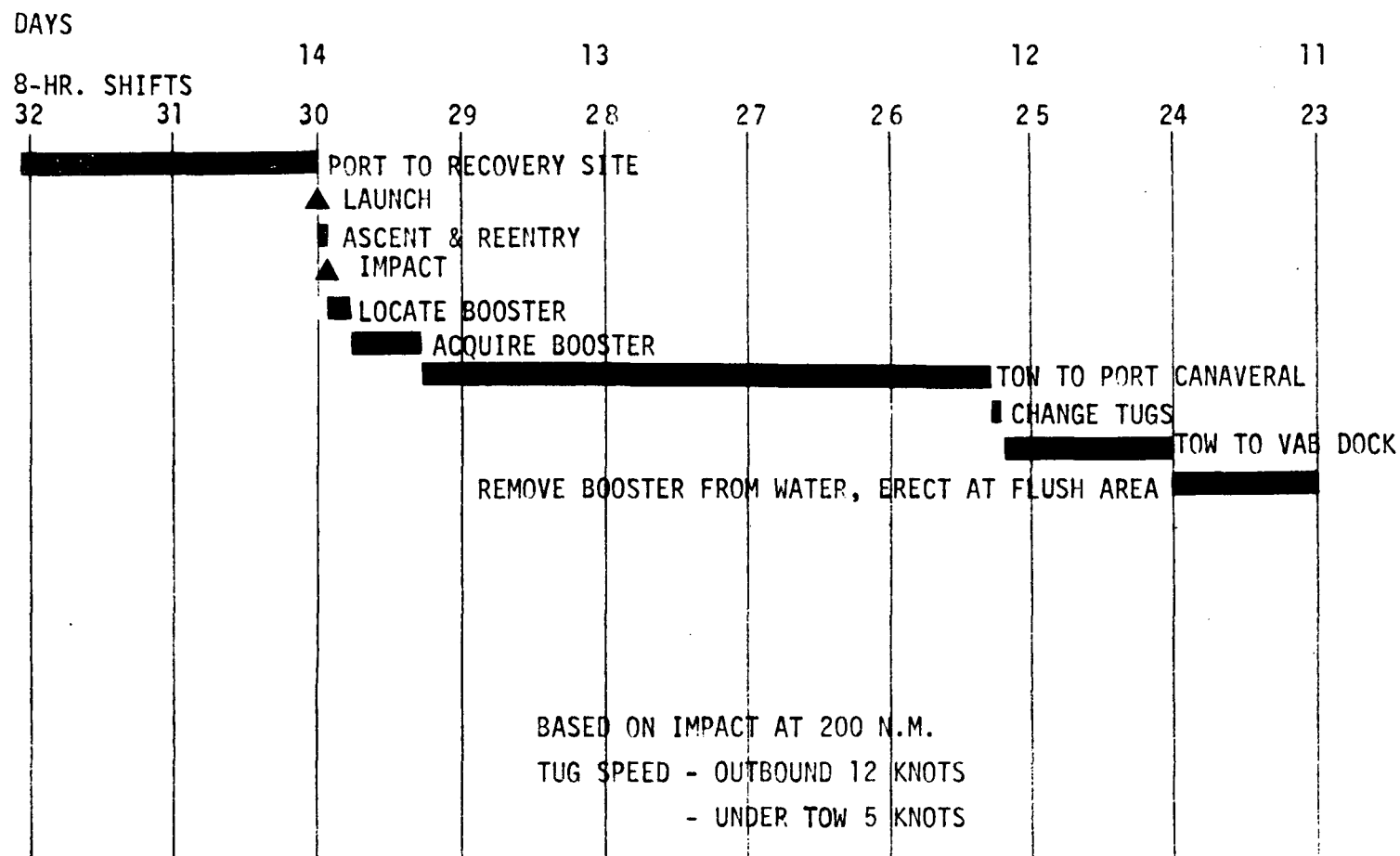
SRAO TURNAROUND CYCLE



SRAO BOOSTER POST IMPACT OPERATIONS

This section replaced the Post Landing Operations of the flyback Booster. This new phase is very time consuming because it covers the tow-back from the point of impact to the launch site. The total time required is seven 8-hour shifts.

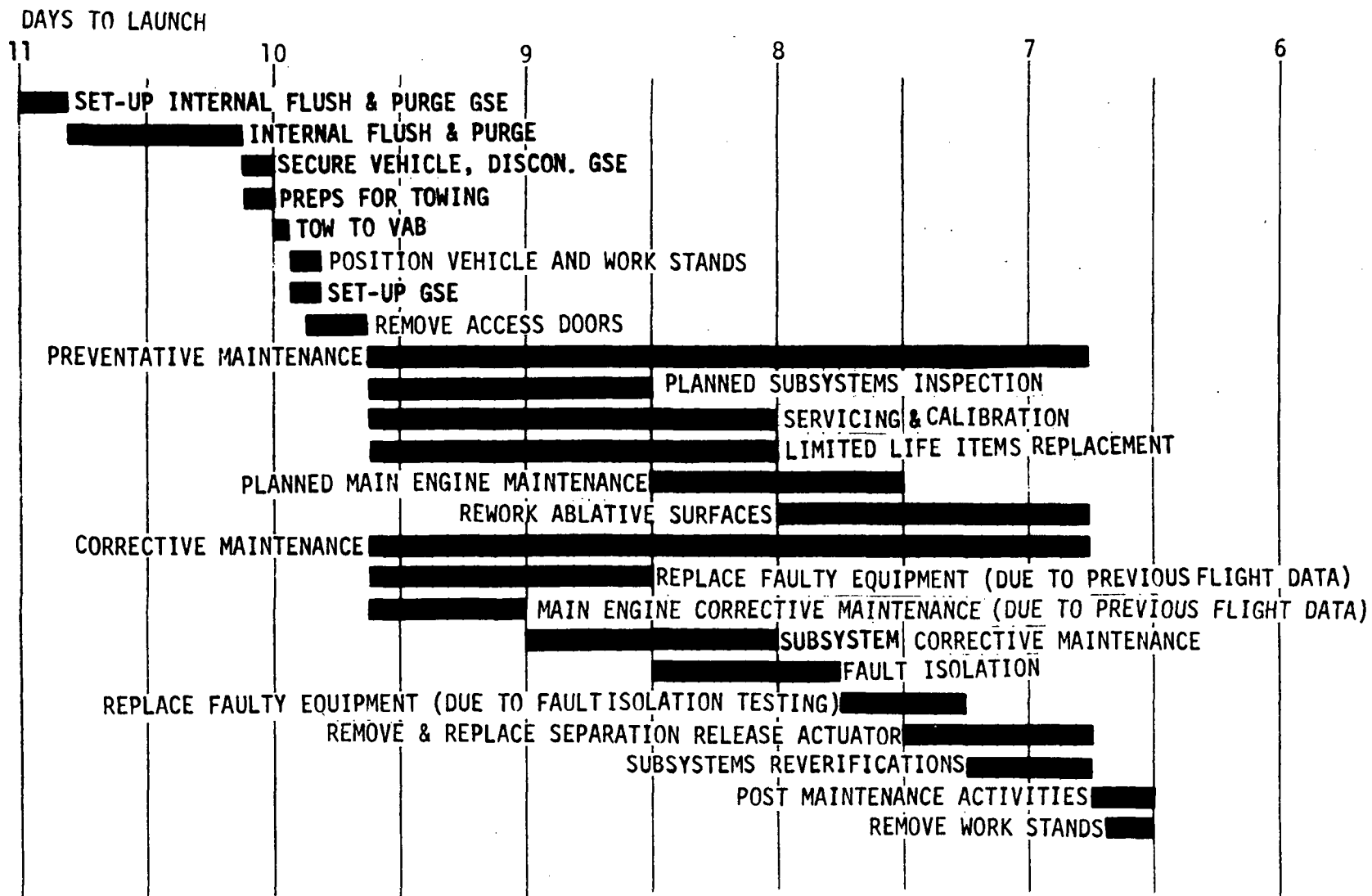
SRAO BOOSTER POST IMPACT OPERATIONS



SRAO BOOSTER MAINTENANCE OPERATIONS

The maintenance cycle has been increased by approximately 1-1/2 shifts. A new item has been added which is two shifts duration and covers the external and minor internal flushing and purging required to remove salt water. The pure maintenance portion was actually reduced by about 1/2 shift due to the Booster having fewer and less complex sybsystems.

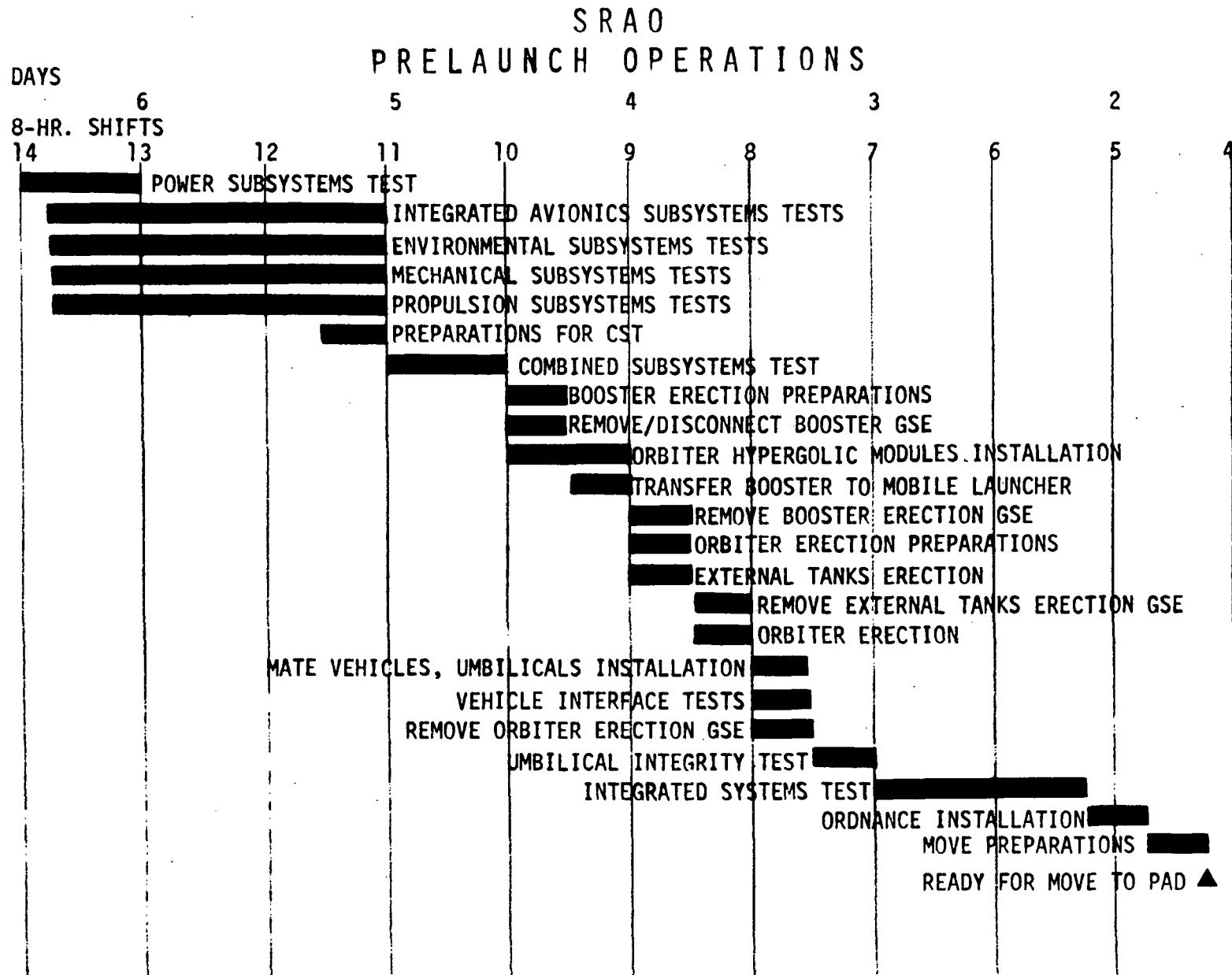
SRAO BOOSTER MAINTENANCE OPERATIONS



SRAO PRELAUNCH OPERATIONS

This phase will require approximately eight more hours than the Pressure Fed Booster. Again, the quantity and complexity of the engines are the major factors. The turbomachinery will require additional time to verify that the critical start sequences are within the operating limits. Also, more time will be required to verify that hot gas and turbomachinery seals have not deteriorated beyond specifications.

Although these vehicles are lighter and easier to handle, the time required for erection is about the same as the Pressure Fed Booster.



TRAO-SRM TURNAROUND CYCLE

The SRM turnaround cycle consists of thirteen days and may be separated into several phases as follows: (1) Receiving, Inspection and Storage; (2) Subsystem Build-up; (3) Assembly of the Skirts, Fairings and Motor Segments on the Mobile Launcher in the VAB; (4) Subsystem Checkout; (5) Integrated Operations; and (6) Launch Operations at the Pad.

Receiving, Inspection and Storage - The motor segments will arrive on rail cars and be stored until required for assembly. Prior to storage, the motor segments will be inspected to verify that no grain separation or damage has occurred during shipping. The segments will be in a controlled environment during shipping and storage. Temperature and humidity will be continuously recorded for verification.

Subsystem Build-up and Motor Assembly - The various stage components will be installed in the skirts prior to assembling the SRM stack. The motor segments will be transferred by rail car from storage directly to the transfer aisle in the VAB. The twin solid motors will be stacked simultaneously on the mobile launcher. Much of the tower will be removed to reduce the weight in order to allow the vehicle to be transferred to pad on an existing crawler/transporter. Four days will be allowed for assembling the solid motors and their subsystems.

SRM Subsystem Checkout - The SRM subsystem checkout will cover three days or six shifts and will commence upon completion of assembly of the motor on the mobile launcher.

These tests will consist of an inspection of the field joints and the grain to verify that the assembly was completed according to design requirements.

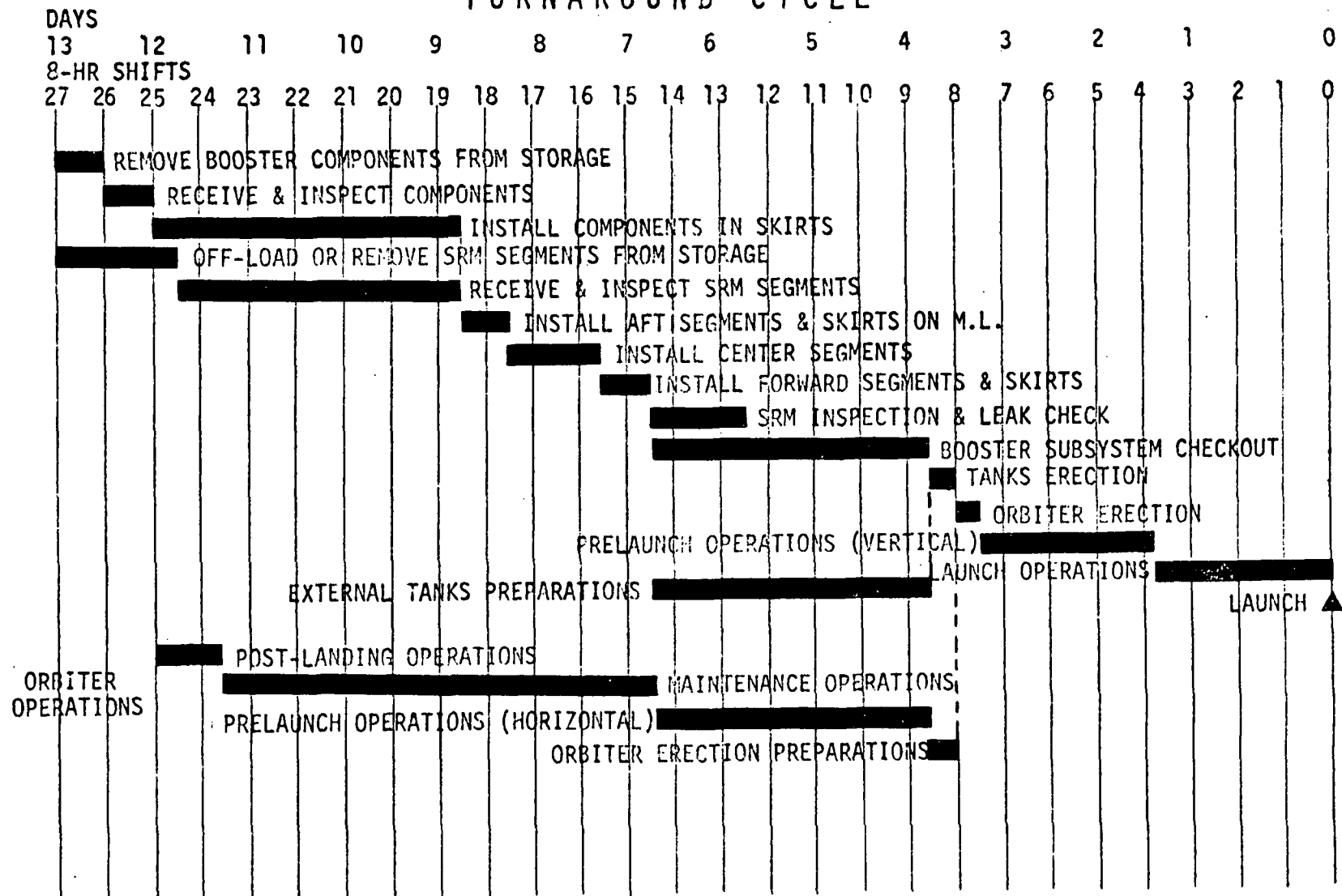
Subsequently, the power will be applied and the various subsystems will be functionally checked including a low pressure leak check of the field joints.

Integrated Operations - This phase will primarily prove that the SRM subsystems will operate in consonance with the Orbiter to complete the mission requirements. The simplicity of the SRM subsystems dictate that the Booster effort during this phase is minimal.

TRAO-SRM TURNAROUND CYCLE
(CONTINUED)

Launch Operations - The SRM's and its subsystems are somewhat dormant during the pad servicing operations. Most servicing will be directed at the Orbiter and its external tank. The major Booster tasks during this phase consist of Range Safety Checks and installation of ordnance igniters.

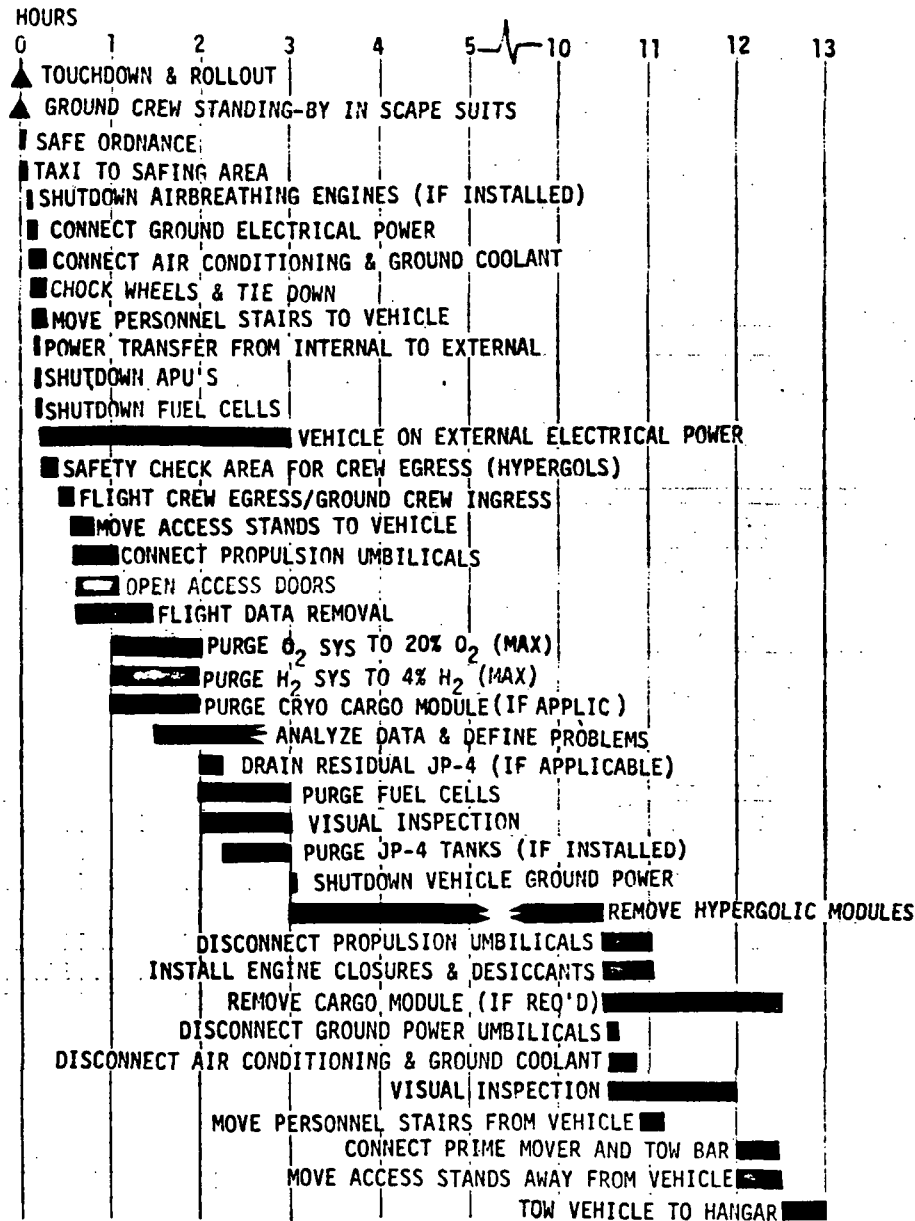
TRA0-SRM TURNAROUND CYCLE



ORBITER POST LANDING OPERATIONS

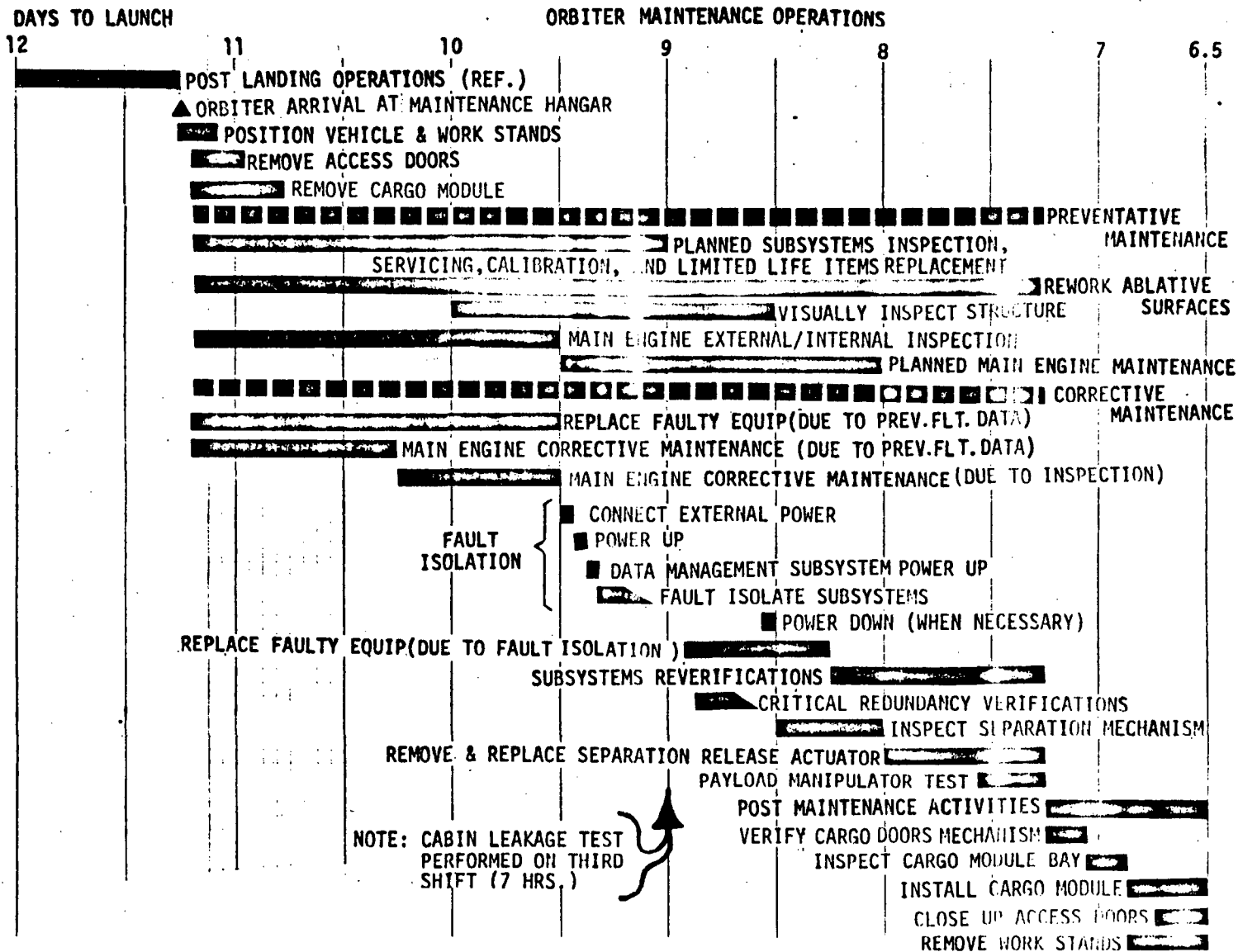
Additional time of 8-1/2 hours was required to remove the hypergolic modules which were not included in Phase B. Purge of the cryogenic systems were reduced slightly because the H₂O tanks became a separate, expendable entity. All of the other post landing operations were effectively the same.

ORBITER POST LANDING OPERATIONS



ORBITER MAINTENANCE OPERATIONS

There were no changes in the time required to perform the maintenance cycle. The reduction in size and the number of systems due to the H0 tank being external was offset by the less sophisticated avionics which will required additional time for fault isolation. Two steps were added that would have been added to the Phase B Orbiter had the operational analysis continued on it. A cabin leakage test was added on the third shift which will require approximately seven hours. This test was scheduled for third shift in order to minimize the impact on other testing during this period. The other test is a payload manipulator functional test which was added just prior to payload installation.



ORBITER PRELAUNCH OPERATIONS

The subsystems checkout was increased by approximately half of a shift due to the avionics reverting to existing design technology. The Phase B data system allowed automatic checkout by the 068B Orbiter design requires the cockpit to be manned and many manual switches to be operated.

An additional eight hours were included for hypergolic modules installation. Hypergolics were introduced subsequent to the end of the Phase B study. An operational analysis indicated that the hypergolic systems would have the least schedule impact if the modules were drained, flushed, purged, checked out and loaded off-line and then installed on the vehicle.

The Combined Subsystems Test (CST) was increased from four to eight hours due to lessened autonomy and more manual switching required.

The Integrated Systems Test Time was increased from four to fourteen hours in order to allow the use of more manual operations from the cockpit). (See Booster Prelaunch Operations Timeline Chart).

SRAO LAUNCH OPERATIONS

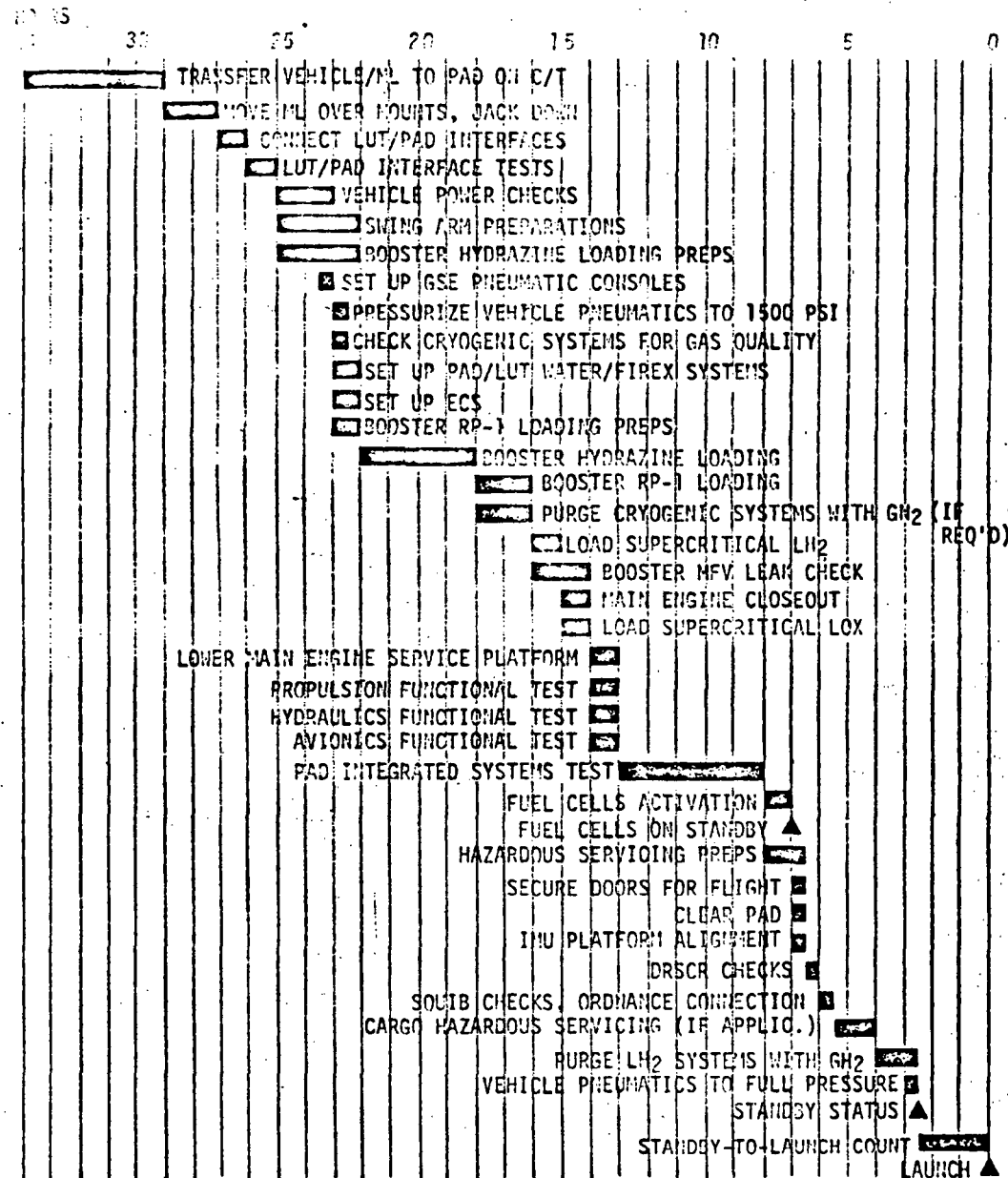
The launch operations phase was increased from 24 to 34 hours. Additional time was required to load Booster RP-1, Booster hydrazine, Orbiter super-critical LOX and LH₂. The Phase B Booster was completely cryogenic and required neither RP-1 nor hydrazine. The fuel cell LOX and LH₂ were tapped-off of the Orbiter main propulsion cryogenic supplies on Phase B.

Additional time was allowed for applying power to the vehicle and for the pad integrated testing because of the additional manual functions required.

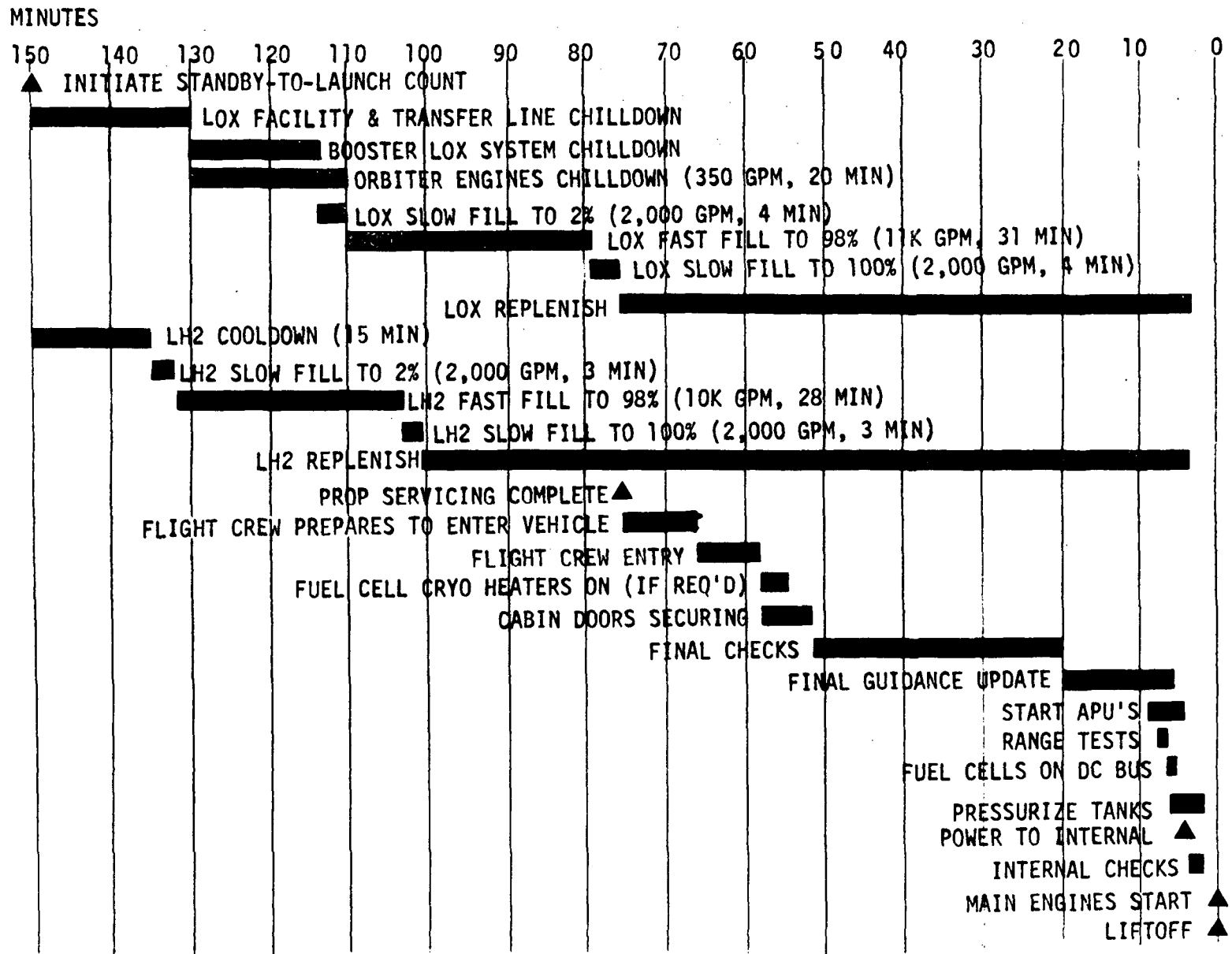
The "Standby-to-Launch" time was not changed from the 2-1/2 hours required on Phase B. The critical path changed from LH₂ loading to LOX loading and the cryogenic loading will be completed earlier. The additional twenty minutes which was gained has been allocated to final checks by the astronauts, again, because of the increase in manual functions in the cockpit.

Starting of the APUs and switching power to internal has been moved from T-20 minutes to slightly less than 10 minutes because the APUs propellants are hypergolic and are not continuously supplied from the ground.

SRAO LAUNCH OPERATIONS



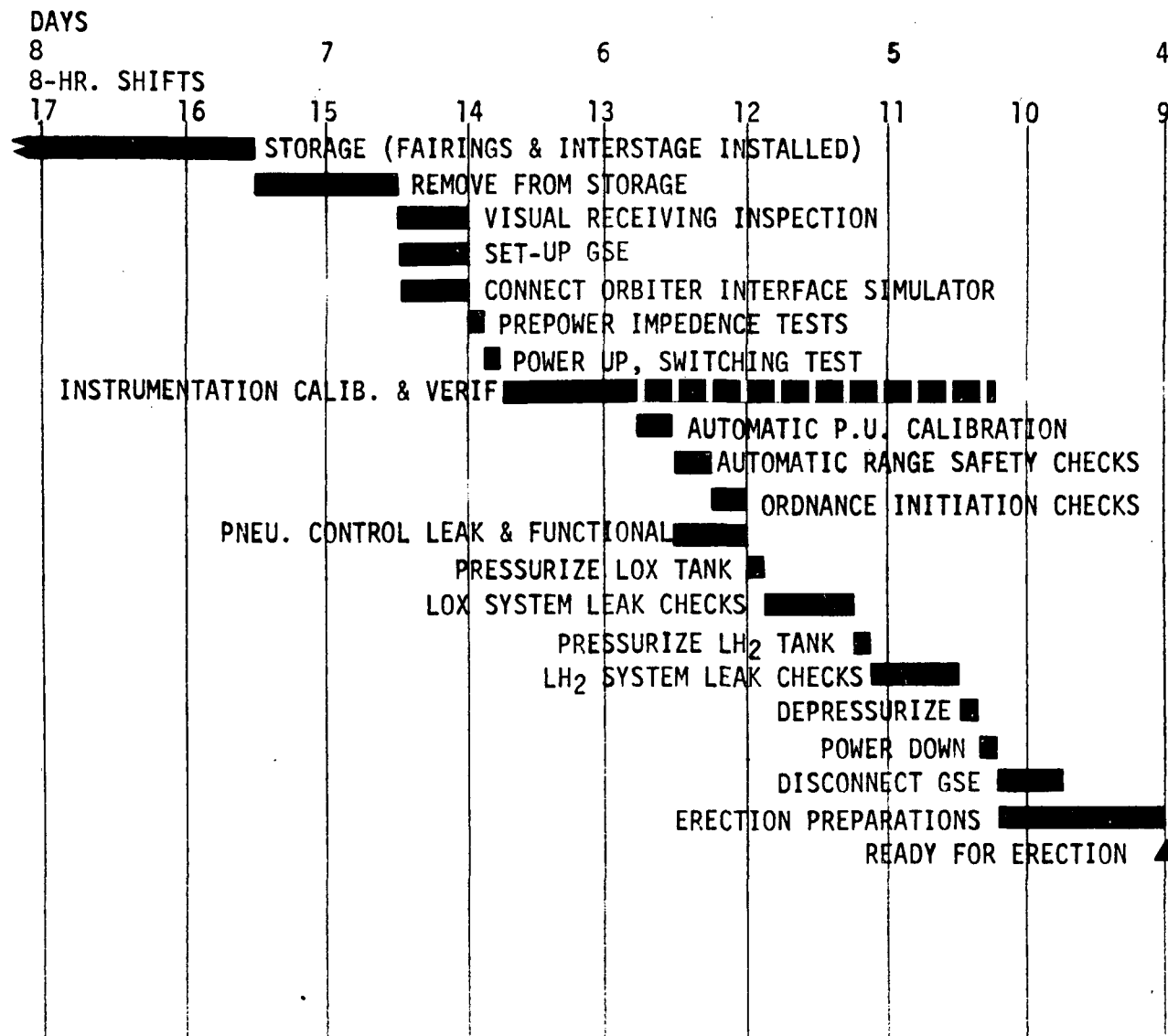
SRAO LAUNCH OPERATIONS (STANDBY-TO-LAUNCH)



EXTERNAL TANKS LAUNCH SITE PREPARATIONS

A new timeline was generated for the H0 tank since it was made external to Orbiter subsequent to Phase B. The timeline covers the period from the "removal from storage" to "ready for erection" for the H0 tank as a separate entity. Approximately 6-1/2 shifts will be required for these operations which will be in parallel to the normal Orbiter maintenance and horizontal prelaunch operations.

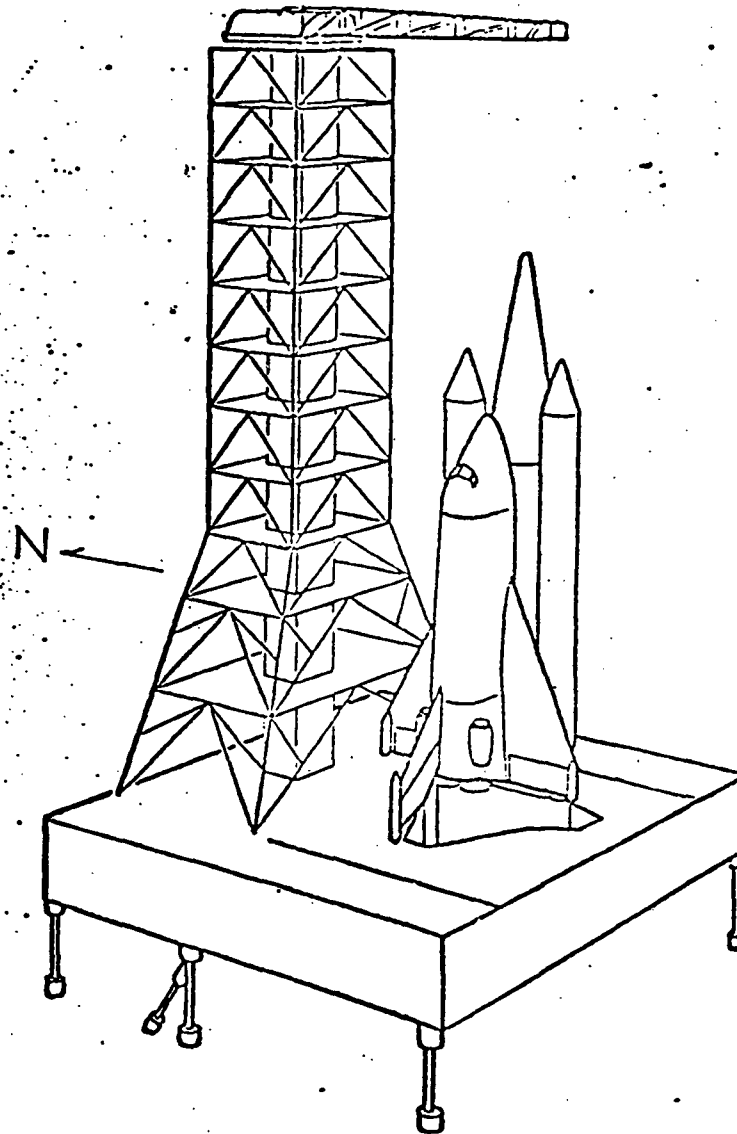
EXTERNAL TANKS LAUNCH SITE PREPARATIONS



GROUND OPERATIONS FACILITY IMPACT

The facility impact can be traced to three primary alterations in Shuttle vehicle configurations. The Phase B Extension configurations use the same concept of ground handling, checkout and launch as recommended for the Phase B. Changes will be required due to the unmanned Booster external hydrogen/oxygen tankage for the Orbiter, and water recovery of the Booster. The following charts present the revised mobile launcher configuration and vehicle orientation. The Twin Solid Parallel concept requires a shorter umbilical tower and a reconfiguration of the launcher deck engine chamber area due to the parallel burn requirement. Swing arm requirements are reduced and a new cargo replacement fixture will be constructed. For the Series Pressure Fed concept a higher umbilical tower is planned. Integral with the umbilical tower is a rotating cargo replacement fixture and vehicle access swing arms. The launcher deck area will adapt to the existing engine chamber with modification to structural hardpoints and interfacing service connections. Following the mated configuration chart, a matrix of facilities required to support the Orbiter and both Booster concepts at Kennedy Space Center is shown. The major impact is the addition of solid handling facilities and deletion of the baseline Booster maintenance facility and support areas. The next chart identifies the changes to the Phase B based on the twin solid Booster concept for both facilities and handling concept revisions. Other baseline facility requirements for control centers, support areas, services, launch pads, etc. essentially are the same as described in Phase B facility and operations documentation.

SHUTTLE-TRAO-SRM
VEHICLE/MOBILE LAUNCHER
MATED CONFIGURATION

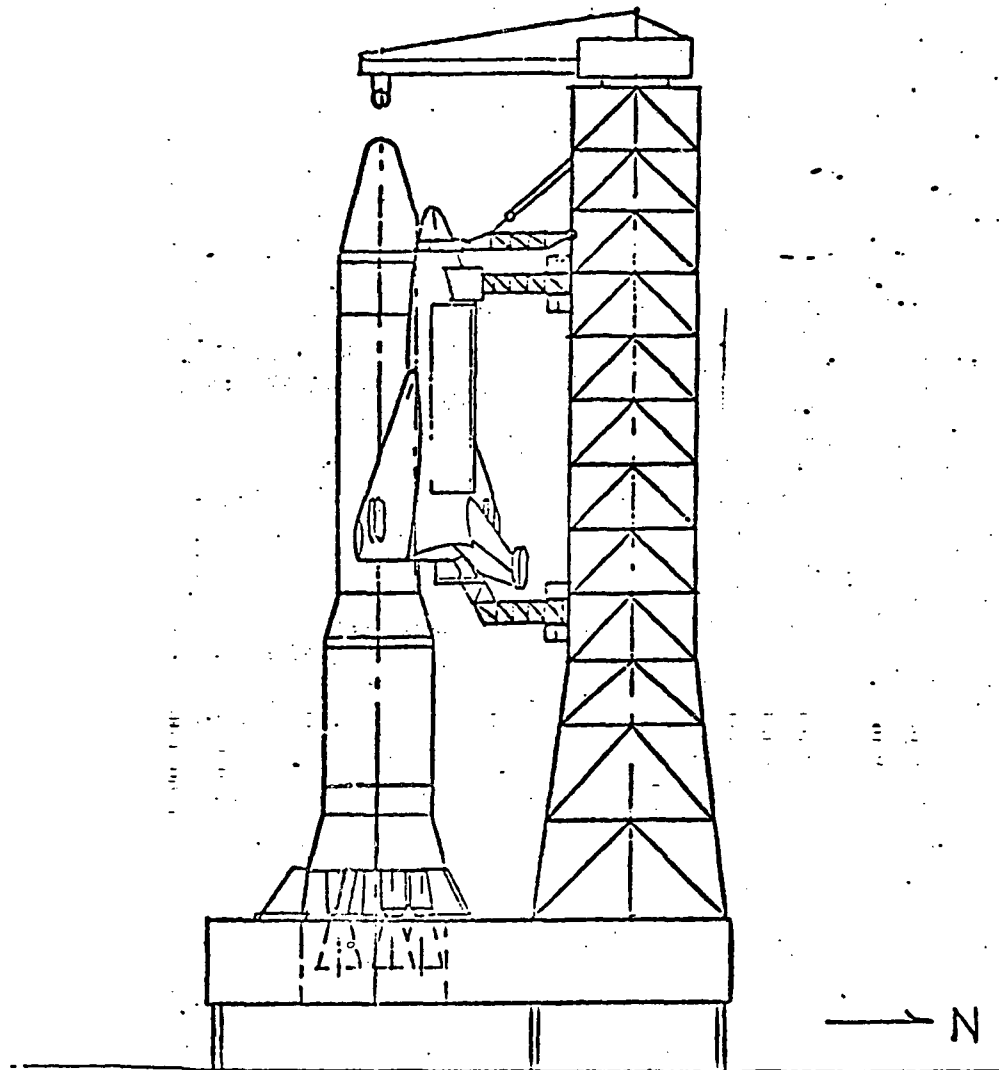


MDC E0558
PART III
15 MARCH 1972

6-28

MCDONNELL DOUGLAS
TRW
CORPORATION

SHUTTLE-SRAO
VEHICLE/MOBILE LAUNCHER
MATED CONFIGURATION



MDC E0558
PART III
15 MARCH 1972

6-29

PHASE B EXTENSION VEHICLE/FACILITY REQUIREMENTS

FACILITY	ORBITER	TRAO (SRM)	SRAO (PF)	FACILITY	ORBITER	TRAO (SRM)	SRAO (PF)
PASSENGER HOUSING	✓			CENTRAL HEATING	✓	✓	✓
LANDING FIELD	✓			FIRE STATIONS	✓	✓	✓
DESERVICE AREA	✓			CAFETERIA	✓	✓	✓
TAXIWAY	✓			PARACHUTE	✓		✓
MAINTENANCE	✓		✓	COMMUNICATIONS (MAINT. & STORAGE)	✓	✓	✓
INTEGRATION	✓	✓	✓	HEAVY EQUIPMENT MAINTENANCE	✓	✓	✓
MOBILE TRANSPORTERS	✓	✓	✓	BASE MAINTENANCE	✓	✓	✓
COMPRESSOR/CONVERTER	✓		✓	OCCUPATIONAL HEALTH	✓	✓	✓
LAUNCH PADS (2)	✓	✓	✓	ADMINISTRATIVE & ENG. OFFICE	✓	✓	✓
LAUNCH CONTROL CENTER	✓	✓	✓	CENTRAL SUPPLY	✓	✓	✓
INSTRUMENTATION/DATA TRACKING	✓	✓	✓	BARGES, CANAL, PORT, BASIN, TUGS		✓	✓
OPTICAL SITES	✓	✓	✓	INDUSTRIAL WATER	✓	✓	✓
CARGO OPERATIONS	✓			PROPELLANT AND GAS STORAGE	✓		✓
FLIGHT CREW	✓			SECURITY	✓	✓	✓
TRAINING (GRD.SYS.)	✓	✓	✓	PHOTOGRAPHIC	✓	✓	✓
ORDNANCE STORAGE AND TEST WAREHOUSES	✓	✓	✓	LIBRARY AND REPRODUCTION	✓	✓	✓
ELECTROMAGNETIC LAB	✓	✓	✓	PROPELLANT PRODUCTION (AT SITE)	✓		✓
AUDITORIUM	✓	✓	✓	ALTERNATE LANDING SITES	✓		
COMMUNICATIONS (GRD)	✓	✓	✓	SOLID INSPECTION		✓	
PROPELLANT SYSTEMS	✓	✓	✓	SOLID STORAGE		✓	
AZIMUGH ALIGNMENT	✓	✓	✓	EXTERNAL TANKAGE STORAGE	✓		
UNIFIED S-BAND	✓			HYDROSTATIC TEST & FLUSH			✓
METEOROLOGICAL	✓			FLIGHT READINESS FIRING FIXTURE	✓		✓
POWER DISTRIBUTION	✓	✓	✓	GROUND VIBRATION TEST FIXTURE	✓		
RAILROADS		✓		THERMAL PROTECTION	✓		
ROADWAYS AND PARKING	✓	✓	✓	PRECISION CLEANING	✓		✓
SEWAGE TREATMENT	✓	✓	✓				

PHASE B EXTENSION DELTA IMPACT OPERATIONS SITE (KSC) FACILITIES

o TWIN SRAO BOOSTERS, EXTERNAL HO TANK AND ORBITER

o KSC BASELINE CHANGES

- o RECONFIGURE DESERVICE/SAFING AREA
- o ADDED RECOVERY SLIP AND GANTRY AT TURNING BASIN
- o ADDED NEW TOW ROADS
- o ADDED EXTERNAL TANK STORAGE (HORIZONTAL) AREA
- o ADDED MODIFICATIONS OF VAB DOORS, RAILWAY, PLATFORMS
- o RECONFIGURED MODIFICATIONS TO MOBILE LAUNCHERS
- o DELETED VEHICLE MAINTENANCE FACILITY
- o ADDED SOLID INSPECTION AND STORAGE
- o ADDED NEW CARGO MODULE ON-PAD CHANGEOUT FIXTURE OPTION
- o REVISED FLAME DEFLECTOR CONFIGURATION

o SHUTTLE/FACILITY CONCEPT CHANGES

- o SOLID BOOSTERS
- o RECOVERY OF SOLID CANNISTERS
- o USE OF EXISTING VAB CRANES FOR SEQUENTIAL SHUTTLE BUILDUP
- o USE OF VAB TRANSFER AISLE FOR BOOSTER ACTIVITIES
- o ORBITER/MOBILE LAUNCHER ORIENTATION CHANGE FOR CLEARANCE ENVELOPE
- o ORBITER FLIGHT READINESS FIRINGS
- o ORBITER GROUND VIBRATION TESTS AT VAB FACILITY

OPERATIONAL SEQUENCES FOR VARIOUS SHUTTLE MISSIONS

A look at the various possible Shuttle missions reveals that any mission can be made up of some combination of eight different operational sequences. All orbital missions include the ascent, tank disposal, payload handling and return to earth sequences. Thus, the only generalized difference between the various orbital missions is whether or not there is to be a rendezvous. Two additional specialized sequences are also required - Ferry Sequence for point to point airplane flight and an Abort Sequence for launch or landing (with ABES) aborts.

From an operational point of view, it is not immediately necessary to consider each possible mission. By investigating the various sequences, a generalized set of requirements and operational impacts can be realized.

OPERATIONAL SEQUENCES FOR VARIOUS SHUTTLE MISSIONS

OPERATIONAL SEQUENCE	SHUTTLE MISSION													
	SPACE STATION RESUPPLY	PROPELLANT DELIVERY	PROPULSIVE STAGE DELIVERY	OOS DELIVERY RETRIEVAL	SATELLITE PLACEMENT	SATELLITE RETRIEVAL & RETRIEVAL	SORTIE	RESCUE	LAUNCH ABORTS	ON-ORBIT ABORTS	DESCENT ABORTS	ABORTS/RETURN	LANDING/GO-AROUND ABORTS	FERRY FLIGHTS
ASCENT SEQUENCE	X	X	X	X	X	X	X	X	X					
RENDEZVOUS SEQUENCE	X	X		X		X	X		X					
ON-ORBIT SEQUENCE			X	X	X		X	X	X					
RETURN TO EARTH SEQUENCE	X	X	X	X	X	X	X	X	X	X	X	X		
PAYLOAD HANDLING	X	X	X	X	X	X	X	X	X	X	X			
FERRY SEQUENCE														X
ABORT SEQUENCE									X			X	X	
TANK DISPOSAL SEQUENCE	X	X	X	X	X	X	X	X	X	X				

MAJOR FLIGHT OPERATIONS FUNCTIONS

The division of major functions between onboard and ground are about the same as for Phase B. However, the ground has a somewhat greater responsibility to provide backup support because of lower onboard avionics redundancy. In addition the division of responsibility among the crew has changed with the addition of a Systems Engineer and Payload Specialist.

MAJOR FLIGHT OPERATIONS FUNCTIONS

MISSION PLANNING

ONBOARD FUNCTIONS

- DETERMINE CURRENT MASS PROPERTIES FOR VARIOUS VEHICLE CONFIGURATIONS
- UPDATE RETURN PHASING & DEORBIT PLAN
- GENERATE CONTINGENCY DEORBIT DATA AS NECESSARY
- COMPUTE REQUIRED VEHICLE ATTITUDES
- MONITOR NOMINAL MISSIONS & EVALUATE EFFECTS OF CHANGES ON NOMINAL MISSIONS
- CALCULATE AND EVALUATE ORBIT SHAPING OR RENDEZVOUS MANEUVERS
- UPDATE LAUNCH GUIDANCE TARGETING

SHARED ONBOARD/GROUND FUNCTIONS

- MONITORING OF SOLAR ACTIVITY
- UPDATES TO CREW ACTIVITY TIMELINES

GROUND FUNCTIONS

- DETERMINE NOMINAL LAUNCH TRAJECTORY
- PROVIDE NOMINAL PRE-MISSION PLANS
- PROVIDE BACKUP MISSION PLANNING SUPPORT TO FLIGHT CREW AS NECESSARY
- LANDING SITE WEATHER MONITOR

FLIGHT DYNAMICS

ONBOARD FUNCTIONS

- UPDATE ORBITER STATE VECTOR USING HORIZON SENSOR AND STAR TRACKER DATA
- DETERMINE THE RELATIVE STATE VECTOR BETWEEN ORBITER AND TARGET VEHICLE
- COMPUTATION OF GUIDANCE TARGETING
- MONITORING EXECUTION OF MANEUVERS AND STATUS OF CURRENT TRAJECTORY
- PERFORMING ALIGNMENTS AND CALIBRATIONS OF THE VARIOUS ONBOARD SENSORS
- MONITORING TRAJECTORY DURING ENTRY
- DETERMINE TANK DISPOSAL TIME AND ATTITUDE

SHARED ONBOARD/GROUND FUNCTIONS

- MONITOR BOOST TRAJECTORY PARAMETERS TO DETERMINE DEVIATION FROM NOMINAL

GROUND FUNCTIONS

- PROVIDE TARGET TRAJECTORY DATA FOR ASCENT AND RENDEZVOUS TARGETING
- PROVIDE ORBITER STATE VECTOR UPDATES BASED ON MSFN OR TDRS TRACKING DATA
- PROVIDE PROCEDURAL OR COMPUTATIONAL SUPPORT UPON REQUEST
- PROVIDE GROUND AIDS FOR CRUISE AND LANDING NAVIGATION
- PROVIDE BACKUP FLIGHT DYNAMIC SUPPORT TO CREW AS NECESSARY
- PREDICT BOOSTER IMPACT POINT

SYSTEMS MANAGEMENT

ONBOARD FUNCTIONS

- MONITOR EMERGENCY CAUTION AND WARNING SYSTEM
- MONITOR AND CORRELATE SYSTEMS PARAMETERS TO VERIFY NOMINAL OPERATION OR DETECT ABNORMAL SITUATIONS
- ISOLATE MALFUNCTIONS TO SUBSYSTEM(S) OR COMPONENT(S) LEVEL AND TAKE APPROPRIATE CORRECTIVE ACTION
- EXERCISE SELF CHECKS OF SYSTEMS/SUBSYSTEMS TO VERIFY PROPER OPERATION
- MONITOR AUTOMATICALLY SEQUENCED FUNCTIONS, INITIATE APPROPRIATE PRE-PROGRAMMED ALTERNATE SEQUENCES AND GENERATE ALTERNATE SEQUENCES
- MANAGE SYSTEMS CONFIGURATION TO UTILIZE SYSTEM RESOURCES
- MANAGE CONSUMABLES AND IDENTIFY OFF NOMINAL USAGE RATES

GROUND FUNCTIONS

- PROVIDE BACKUP SYSTEMS MANAGEMENT SUPPORT TO FLIGHT CREW AS NECESSARY
- PROVIDE SYSTEM CONFIGURATION, STATUS, AND PERFORMANCE DATA KEEPING

BASELINE CREW FUNCTIONAL DIFFERENTIATION

COMMAND PILOT

- ASCENT MONITORING
- ON-ORBIT BURNS
- NOSE DOCKING
- BRAKING
- ENTRY MANUAL BACKUP
- APPROACH AND LAND
- BACKUP PILOT FUNCTIONS
- ON-ORBIT ATTITUDE CONTROL

PILOT

- ASCENT NAVIGATION MONITOR
- RENDEZVOUS NAVIGATION
- ENTRY NAVIGATION
- COMMUNICATION FUNCTIONS
- RADIO AND FINAL APPROACH NAVIGATION
- BACKUP TO COMMAND PILOT
- MANIPULATOR ARM CONTROL
- ACPS COMMAND FOR PAYLOAD OPERATIONS

SYSTEM ENGINEER

- SUBSYSTEM FUNCTION MONITOR
- NON-TIME CRITICAL FAILURE MONITOR
- FAULT ISOLATION
- CIRCUIT BREAKER CONTROL
- FUEL CELL CONTROL
- ECS CONTROL

PAYLOAD SPECIALIST

- PAYLOAD BAY ENVIRONMENT MONITOR
- PAYLOAD MONITOR
- PAYLOAD ACTIVATION AND TEST
- PAYLOAD EVA/IVA ACTIVITY
- PAYLOAD ALIGNMENT (OPTICS SYSTEM)
- PAYLOAD COMMUNICATOR

BASELINE FLIGHT OPERATIONS SYSTEM

The baseline mission operations support concept was developed during Phase B studies. These studies indicated that the major operations cost is using and maintaining an array of remote ground tracking sites such as the Manned Space Flight Network (MSFN). If the proposed Tracking and Data Relay Satellite System (TDRSS) is available, operations cost can be dramatically reduced.

The baseline system makes use of the MSFN (or its 1978 equivalent) during two years of flight test and early operations. The TDRSS is assumed operational in 1980 and during this year both MSFN and TDRSS are used, with the MSFN being phased out. Subsequent to 1980, TDRSS only is used. If TDRSS is not available, the MSFN will continue to be used, but in a "limited" six station configuration.

Initially, the Ground Mission Operations Center (GMOC) is fully manned with 28 console positions. After confidence is established in the onboard Orbiter capabilities, GMOC support is reduced to 21 console positions with 9 of these being an on-call status (i.e., not continuously manned). The concept of a reduced GMOC and a "limited" MSFN is possible because of the high degree of onboard capability in the Orbiter.

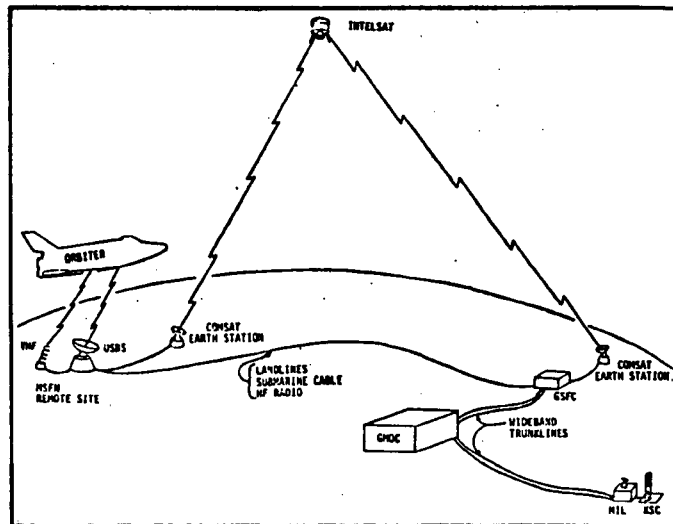
BASELINE FLIGHT OPERATIONS SYSTEM

	1978	1979	1980	1981 AND ON
FLIGHT PHASE	FMOF		OPERATIONAL	
	FLT	EARLY	OPERATIONAL	
	TEST	OPERATIONAL		
COMMUNICATIONS SUPPORT	MSFN	MSFN	MSFN TDRSS	TDRSS
NAVIGATION SUPPORT	H/S-S/T MSFN	H/S-S/T MSFN	H/S-S/T TDRSS MSFN	H/S-S/T TDRSS
GMOC CONSOLES	28	28	21	21
MANNING	FULL TIME	28	12	12*
	ON CALL	0	9	9

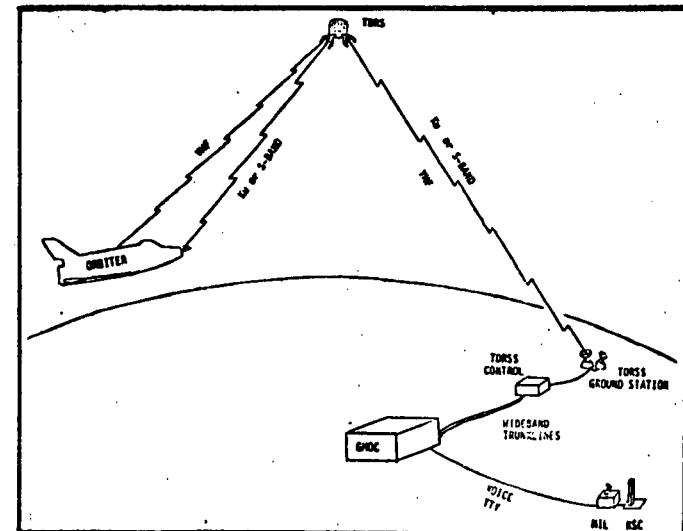
MSFN - MANNED SPACE FLIGHT NETWORK OR ITS 1978 EQUIVALENT

TDRSS - TRACKING & DATA RELAY SATELLITE SYSTEM

H/S-S/T - HORIZON SENSORS & STAR TRACKERS



FLIGHT TEST AND EARLY OPERATIONAL PHASES



OPERATIONAL PHASE USING TDRS

P R O D U C T A S S U R A N C E

MDC E0558
PART III
15 MARCH 1972



PRODUCT ASSURANCE

The Phase B extension effort was directed primarily at configuration definition, and in particular, booster selection. The following data, summarizes and typifies the studies conducted during this period.

- o Booster Reliability Analysis
- o Payload Safety Considerations
- o Propellant Quantity Distance Equivalences.

Data relating to these three items are highlighted in the following pages.

BOOSTER RELIABILITY

Reliability predictions were made for the pressure fed and solid rocket motor booster configurations. A direct comparison of the configurations is not practicable because the series configuration includes Thrust Vector Control (TVC) and the parallel concepts do not have TVC as a baseline. As noted below, little differences in numerical reliability exist.

SRM Predicted Reliability	0.998/Booster
TPFB Predicted Reliability	0.996/Booster
SPFB Predicted Reliability	0.990

Of most interest is the probability of a successful launch. This probability requires that the booster(s) ignite and function through separation.

Twin SRM	$R = 0.998^2 = 0.996$
Series SRM	$R = 0.998^3 = 0.994$
Twin PFB	$R = 0.996^2 = 0.992$
Series PFB	$R = \quad = 0.990$

SRM FLIGHT STATISTICS

The SRM Flight Statistics Table is divided into two sections. The upper section delineates the SRM failure history by vehicle and failure modes. The lower section defines the applicability of the failures to the Shuttle Program. Then, at the bottom of the table, the predicted Shuttle SRM reliability is given.

SRM FLIGHT STATISTICS

VEHICLE	MOTOR FIRINGS	FAILURES	HUMAN ERROR	CASE BURNTHROUGH	NOZZLE FAILURES	ORDNANCE AUTO-IGN.
THOR, STRAP-ONS	486	1	1	—	—	—
TITAN, STRAP-ONS	34	0	—	—	—	—
MINUTEMAN	1298	11	4	4	1	2
SCOUT	310	5	1	1	3	—
TOTAL	2128	17	6	5	4	2

FAILURE CAUSE	SHUTTLE APPLICABILITY	SHUTTLE PREDICTION WITH DESIGN IMPROVEMENT
DESIGN DEFICIENCY		
5—CASE BURNTHROUGH	5	0
4—NOZZLE FAILURES	2	0
2—ORDNANCE AUTO-IGNITION	2	0
HUMAN ERROR		
1—MANUFACTURING	1	1
4—WORKMANSHIP	3	3
TOTAL	13	4

RELIABILITY (BASED ON APPLICABLE FAILURES) = $2111/2124 = 0.9939$

INCORPORATION OF PROPOSED REMEDIES SHOULD INCREASE THE PREDICTED RELIABILITY
TO $2120/2124 = 0.9981$

SOLID ROCKET MOTOR FAILURE HISTORY ASSESSMENT

This table, consisting of 3 pages, describes the problems and remedies of the "THOR", "SCOUT", "MINUTEMAN", and "TITAN" Programs. It also discusses the applicability of these problems to the Shuttle Program.

SOLID ROCKET MOTOR FAILURE HISTORY ASSESSMENT

QUANTITY	PROBLEM	REMEDY	SHUTTLE ABORT CONSIDERATION
5	CASE BURNTHROUGH 1 - SCOUT 3RD STAGE 1 - MINUTEMAN 1ST STAGE 3 - MINUTEMAN 3RD STAGE	INCREASE CASE INSULATION THICKNESS; USE TWO "O" RINGS BETWEEN SEGMENTS.	IF BURNTHROUGH OCCURS ADJACENT TO HO TANK OR ORBITER, TIMELY SENSING MAY NOT BE FEASIBLE AND ABORT NOT POSSIBLE.
4	NOZZLE BURNTHROUGH/EROSION 1 - SCOUT 1ST STAGE NOZZLE BURNTHROUGH 1 - SCOUT 4TH STAGE - GRAPHITE THROAT FRACTURED, PLUGGED THROAT & CAUSED CATASTROPHIC CASE RUPTURE. 1 - SCOUT 4TH STAGE - ONLY 1/2 TOTAL IMPULSE DELIVERED, CAUSE UNKNOWN; POSSIBLY CAUSED BY THROAT EJECTION AND RESULTING PROPELLANT EXTINGUISHMENT. 1 - MINUTEMAN 2ND STAGE NOZZLE BURNTHROUGH FOLLOWING INNER SHELL EJECTION RESULTING FROM POOR BONDING.	INCREASE NOZZLE INSULATION THICKNESS. - - TIGHTEN QUALITY CONTROL & INSPECTION PROCEDURES.	ABORT REQUIRED, TERMINATE THRUST IN BOTH SRMs. GRAPHITE THROAT MATERIAL NOT USED IN LARGE MOTORS. <u>NOT APPLICABLE.</u> GRAPHITE THROAT MATERIAL NOT USED IN LARGE MOTORS. <u>NOT APPLICABLE.</u> ABORT REQUIRED, TERMINATE THRUST IN BOTH SRMs.

SOLID ROCKET MOTOR FAILURE HISTORY ASSESSMENT (Continued)

QUANTITY	PROBLEM	REMEDY	SHUTTLE ABORT CONSIDERATION
2	AUTO IGNITION OF THRUST TERMINATION ORDNANCE 2 - MINUTEMAN 3RD STAGE	PROVIDE AMPLE INSULA- TION.	MUST PROVIDE SENSING SYSTEM AND THRUST TERMINATE REMAIN- ING SRM; DEGRADED MISSION MAY BE POSSIBLE.
5	HUMAN ERRORS. 1 - SCOUT 1ST STAGE WRONG PHENOLIC USED IN THROAT OVERWRAP DEGRADED MISSION RESULT- ED. 1 - MINUTEMAN 1ST STAGE SHIPPING PARTS NOT REMOVED. EXIT CONE BURNTHROUGH OCCURRED. 1 - MINUTEMAN 2ND STAGE TVC GAS GENERATOR NOT ARMED. 2 - MINUTEMAN 3RD STAGE IGNITION FAILURE - SQUIB NOT CONNECTED THRUST TERMINATOR SNAP RING INSTALLED INPROPER- LY RESULTING IN PREMA- TURE MISSION TERMINATION.	TIGHTENED QUALITY CON- TROL AND IMPROVED IN- SPECTION PROCEDURES. TIGHTENED QUALITY CONTROL AND IMPROVED INSPECTION PROCEDURES TIGHTENED QUALITY CONTROL AND IMPROVED INSPECTION PROCEDURES. TIGHTENED QUALITY CONTROL AND IMPROVED INSPECTION PROCEDURES.	ABORT NOT REQUIRED - ACCEPT DEGRADED MISSION PECULIAR TO SWIVEL NOZZLE DESIGN - THEREFORE <u>NOT</u> <u>APPLICABLE.</u> PECULIAR TO MM TVC INSTALL - <u>NOT APPLICABLE.</u> ABORT BY HOLDING DOWN. REDUNDANT IGNITION SYSTEMS SHOULD BE USED

SOLID ROCKET MOTOR FAILURE HISTORY ASSESSMENT (Continued)

QUANTITY	PROBLEM	REMEDY	SHUTTLE ABORT CONSIDERATION
	HUMAN ERRORS (Continued) 1 - THOR ON FIRST TAT LAUNCH THE ELECTRICAL PLUG TO ONE SRM WAS MATED BUT NOT LOCKED. LIQUID MOTOR IGNITION SHOCK DISCONNECTED THE PLUG.	RELOCATED PLUG TO PERMIT ADQUATE INSTALLATION & INSPECTION	ABORT BY HOLDING DOWN - REDUNDANT IGNITION SYSTEMS SHOULD BE USED.

SPACE SHUTTLE PAYLOAD SAFETY CONSIDERATIONS

The hazardous energy sources, and therefore the potentially hazardous conditions which may arise, will vary from mission to mission depending on the payload. Typical sources are listed.

The safety considerations associated with these hazardous energy sources should be evaluated early in the program as they effect the design requirements. Although some aspects of some payloads are not well defined, their safety considerations are paramount, e.g., manned payload requirements.

While the need for payload propellant dumping is quite apparent, radiation shielding and cargo bay purging require further study.

Failure tolerance and pressure vessel safety factor compatibility with orbiter is necessary so that orbiter integrity is not unnecessarily compromised. Payload ejection/abort requirements have not yet been determined.

SPACE SHUTTLE
PAYLOAD SAFETY CONSIDERATIONS

- o PAYLOAD PROPELLANT DUMP PROVISIONS
- o RADIATION SHIELDING
- o CARGO BAY PURGING & INSTRUMENTATION
- o MANNED PAYLOAD REQUIREMENTS
- o FAILURE TOLERANCE COMPATIBILITY WITH ORBITER
- o PRESSURE VESSEL SAFETY FACTOR COMPATIBILITY
- o SOLIDS & PYROTECHNICS INSTALLATION, SAFING & ARMING
- o PAYLOAD EJECTION/ABORT REQUIREMENTS

QUANTITY/DISTANCE - TNT EQUIVALENCE BOOSTER

This table identifies the TNT equivalence for the various propellants which were considered for the Shuttle booster during the Phase B extension. No potential failure modes could be identified that could cause the SRM propellant (PBAN) to detonate. Air Force Manual 127-100 has classified the baseline SRMs as Class II propellants. As such, they constitute a fire hazard and if ignited are subject to vigorous burning. Liquid boosters present both a fire and explosion hazard.

QUANTITY / DISTANCE - TNT EQUIVALENCE BOOSTER

	<u>SRM</u>	<u>LOX/LH₂</u>	<u>LOX/RP-1</u>	<u>LOX/PROPANE</u>
TNT EQUIVALENT*	7 - 8%**	20%***	10%	10%
QUANTITY/DISTANCE (1,000,000 LBS PROPELLANTS)	800 FT	2,770 FT	1,855 FT	1,855 FT

- * AFM 127-100, AMCR 385-100
- ** DYNAMIC IMPACT (STATIC CONDITION .1%)
- *** T.D.-RV-V-70-55, MSFC JULY 1970