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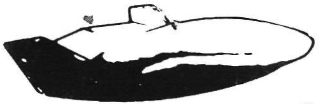
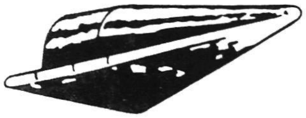


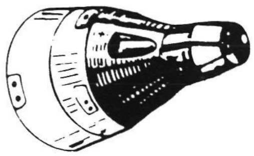
MDC E0308

Phase B System Study
FINAL REPORT

Part III–3
PROGRAM ACQUISITION PLANS

OPERATIONS





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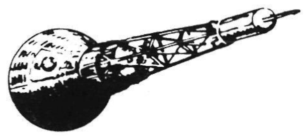

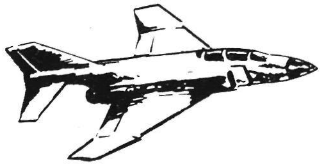

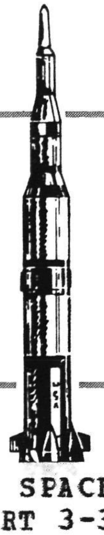

MCDONNELL DOUGLAS
CORPORATION

MARTIN MARIETTA DENVER DIVISION

TRW SYSTEMS GROUP

PAN AM

(NASA-CR-120694) SPACE SHUTTLE PHASE B SYSTEM STUDY. PART 3-3: PROGRAM ACQUISITION PLAN. OPERATIONS Final Report (McDonnell-Douglas Corp.) 378 p
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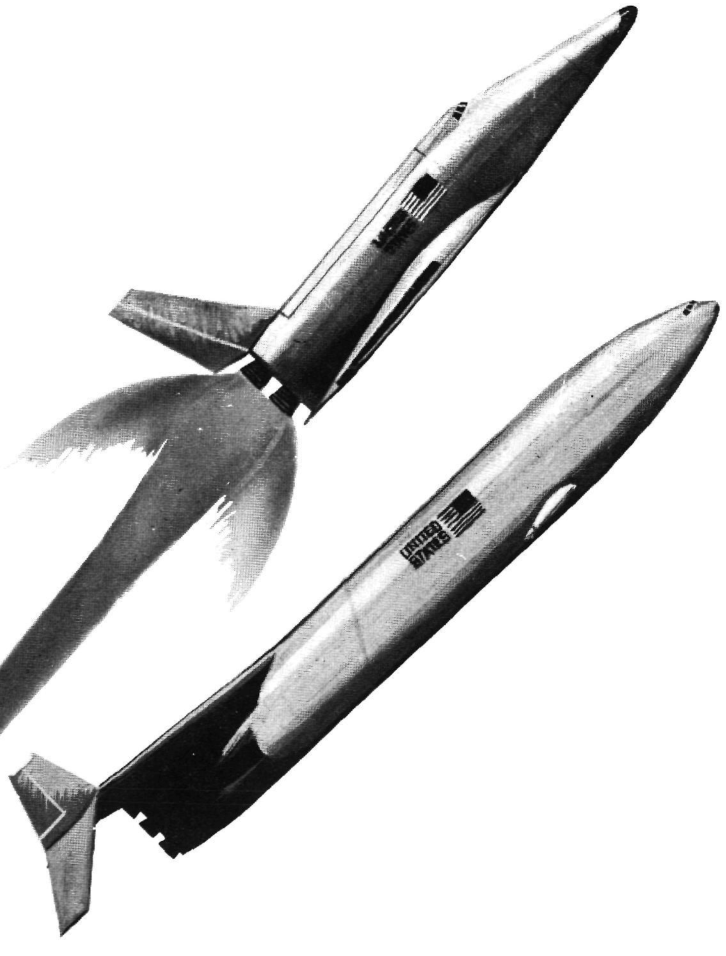
REPORT MDC E0308
30 JUNE 1971

Space Shuttle System

PHASE B STUDY FINAL REPORT

Part III- 3
Program Acquisition Plan

OPERATIONS



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MCDONNELL DOUGLAS CORPORATION
MARTIN MARIETTA DENVER DIVISION
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FOREWORD

Introduction and Summary - The requirements necessary to conduct a Phase C/D program leading to an operational Space Shuttle System, and the McDonnell Douglas Corporation Team approach to implement them are defined in seven Program Acquisition Plans. By report numbers, they are:

MDC E0308 - III -

1 Program Management
2 Engineering and Development
3 Operations
4 Facility Utilization and Manufacturing
5 Test
6 Logistics and Maintenance
7 Cost and Schedule Estimates

The Program Management Plan impacts all of the other plans, by establishing the procedures and management activities for the entire program. Second in order of impact is the Engineering and Development Plan, which defines design and development effort and leads into manufacturing, test, and operation discussions, each in its own volume. The facilities section of the Facilities Utilization and Manufacturing Plan supports the Manufacturing, Operations, and Test Plans by identifying and defining the facilities required. Support requirements, in terms of maintainability, maintenance, logistics engineering, material support and control, supply control, packaging, and handling and transportation are defined in the Logistics and Maintenance Plan. Finally, the Program Cost and Schedule Estimates Plan describes cost/schedule activity and cost analysis methods for the total program.

As applicable, the plans are further categorized into Space Shuttle, Booster, and Orbiter. The following baseline assumptions and ground rules were employed in the Phase B study and are reflected in the plans:

Configuration - To facilitate timely, cost-effective implementation, all plans were developed independent of configuration, wherever practical. Where it was necessary to consider specific configurational aspects, the May 1971 MDC Space Shuttle was used. This configuration is outlined below, along with the other guidelines and assumptions used:

- Delta Orbiter
- Canard Booster
- 550,000 lb thrust main engines
- 1100 nm across range capability
- Two-stage, fully reusable vehicle/system
- Maximum payload capability of 65,000 lb launched due east
- Airbreathing engines burning JP fuel

Phase C/D Management and Organization

- Two vehicle contractors (Booster and Orbiter) are each contracted and managed by one of two NASA centers. A Vehicle System Integration Activity (VSIA) type organization is responsible for the integration of the Space Shuttle System, and delegates integration tasks to one or the other NASA Center/Vehicle contractor combination.
- Innovative management techniques and new ways of doing business to minimize program cost are stressed.

Operations

- The major horizontal flight testing will be conducted at EAFB.
- Final assembly and operational launches (including vertical launch and horizontal shakedown flight test) are conducted at KSC.

- The operational fleet consists of four Orbiters and three Boosters
- Operational life is 10 years

Schedule

- First horizontal flight - June 1976
- First manned orbital flight - April 1978
- Operational phase initiated - July 1979

The remainder of this foreword provides synoptic overviews to this and the remaining six Program Acquisition Plans. The purpose of the overviews is to offer the reader of this plan an insight into the content of the remaining plans.

PROGRAM MANAGEMENT PLAN
(MDC E0308-III-1)

The Program Management Plan defines management requirements and procedures which will permit the contractors, under NASA guidance and direction, to design, build, test, and develop a Space Shuttle System. The plan identifies and describes management activities essential to the conduct of the program. Key issues facing management and the interrelationship of these issues with cost, schedules, and technical performance lead into the Work Breakdown Structure (WBS), management organization, commonality implementation, and management techniques. The WBS, and a detailed definition of the products and services related to the individual WBS elements, is presented.

Organization of the contractor's corporate structure and the Space Shuttle Program team are discussed, and organization charts presented. Management contacts and interrelationships among MDC, NASA, teammates, and subcontractors are discussed. Such discussion includes approaches for conducting the necessary reviews and meetings, techniques for communication processes, procedures for interface control documentation for hardware-to-hardware interfaces and joint operating agreements for establishing and recording working relationships between contractors.

The commonality implementation section describes such concepts as the use of similar or interchangeable parts, as well as the economies inherent in common design approaches, similar technical depth, shared test and analytical results.

Management techniques, including the MDC Management Information System, which plans, controls, and provides visibility into project and functional cost and schedule performance within the WBS framework, are presented. Configuration management procedures discussed include identification, control, and status accounting for the baseline configuration and changes thereto.

PROGRAM MANAGEMENT PLAN
(MDC E0308-III-1)

The approach to data management, vehicle acceptance, traceability, make or buy, and subcontract management are presented as part of the management techniques section.

The appendix outlines the approach to three alternate MDC-suggested contracting options and compares these options with the baseline.

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

This plan defines the requirements for the total engineering effort involved in the design of the Space Shuttle System and the approach to implement these requirements. The plan is divided into three sections: Shuttle Systems, Booster, and Orbiter.

Shuttle System - The Space Shuttle section contains only that engineering and integration effort required for the analysis, development and test of the mated configuration. Policy activities, such as critical program categories and commonality control (which would be implemented through a NASA/VSIA-type activity) are also included. Those activities that are involved with the management, engineering, integration, assembly and test of the separate Boosters and Orbiters are included in their respective sections.

Following a discussion of the criticality categories approach and the approach to, and control of, commonality, the management approach for the Space Shuttle is discussed using the VSIA-type organization baseline.

Detail design and development activities include describing the physical and performance characteristics of the Shuttle, critical design analyses (such as boost phase analysis, off-nominal performance evaluation, separation analysis, and abort techniques), and design optimization and effectiveness analyses.

System integration activities include discussions of requirements analysis and allocation, trade study identification for those trade studies to be refined in Phase C, and development of criteria documents to group those criteria for each system and subsystem into a working document.

Test requirements are discussed for the various categories of ground and flight tests to which the Space Shuttle will be subjected. These include tests of the separation system, EMC tests, wind tunnel and dynamic tests of the mated

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

configuration, and vertical flight tests.

Finally, ground support equipment (GSE) critical areas and development problems are discussed and a development schedule presented.

Booster and Orbiter Systems - The Booster and Orbiter sections define the engineering and development requirements, and the approach to implementing these requirements, in the design and development of the Booster and Orbiter and their associated support equipment.

Management procedures, including organization; planning and control; schedules; key engineering activities that affect the timely completion of the design and development; and logic networks are discussed. The section on manpower describes the procedure for making engineering manpower forecasts by work breakdown structure for each engineering discipline and department.

The approach to configuration management, consisting of configuration identification, control and accounting is detailed. A discussion of data management addresses planning for interface control, document control, and program and design review. The role of the Interface Control Working Group (ICWG) and the application of interface control logic are outlined.

In the contingency planning and analysis section, the approach to making allowances for off-nominal task results and resource expenditures is discussed. System engineering and integration is concerned with design studies and analyses for system sizing and design refinement, and with trade studies to refine subsystem development and performance, resolve key issues, and explore growth potential. Major interfaces are defined, and the interface control plan discussed.

Sections 2.3.2.4 (Booster) and 2.3.3.4 (Orbiter) encompass a detailed discussion of subsystems development, including airframe, propulsion, avionics, crew station, and power supply groups.

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

These sections describe each subsystem, potential problems in its development, the approach to design, development, and test, and a development schedule for each subsystem.

The GSE development section discusses the engineering and design approach and acceptance test requirements. Major test articles, simulators and mockups required for Orbiter and Booster development, are described and the purpose of each test defined.

Design and development support requirements from safety, reliability, maintainability, human factors, materials and processes, and design services are discussed, and support activity scheduled.

OPERATIONS PLAN
(MDC E0308-III-3)

This plan defines the requirements for Space Shuttle, ground and flight operation and the MDC approach to implementing those requirements.

The requirements section of this plan is subdivided into Space Shuttle System, Booster, and Orbiter, and contains both ground and flight requirements. The paragraph (or paragraphs) of the approach section pertaining to these requirements is noted. Such notation provides traceability between the requirements and approach sections.

The approach section of the plan is divided into ground and flight operations. Ground operations include the activities from landing rollout through launch. The flight operations section includes activities from liftoff through landing.

The ground operations section discusses the activities from acceptance testing through the launch phase. Turnaround cycle activities are described in detail. This cycle consists of postlanding, maintenance, prelaunch, and launch activities. In addition, detailed timelines of these activities are included. Other activities pertinent to ground operations, such as operational facilities and activation, rescue capability, hold/recycle capability, alternate landing sites (and others) are also addressed in this section. Also included are the activities associated with the development flight test program, both horizontal and vertical.

The flight operations section discusses the anticipated missions and includes timelines and sequence-of-events charts. The mission operations systems, as well as mission control functions, are described, as are such activities as landing operations, aborts, and crew training. Such other operational interfaces as tracking and data relay satellite, experiments, and the scientific community are addressed in this plan.

FACILITY UTILIZATION AND MANUFACTURING PLAN
(MDC E0308-III-4)

The Facility Utilization and Manufacturing Plan:

(a) provides clear definition of the Government owned and Contractor facilities required to support the Space Shuttle Phase C/D program; and

(b) describes the manpower, material, and facilities needed to plan, manufacture, and functionally test flight hardware and (GSE).

The summary section includes a discussion of the rationale for facility site selection based on two factors:

(1) the chosen operational site for the Shuttle and

(2) the transportation problem posed by the size of the Booster and Orbiter vehicles.

Considered in the plan are evaluations of candidate launch sites, and sites for final assembly, propulsion tank fabrication and subassembly, fuselage manufacturing and assembly, and horizontal flight test.

The remainder of the facility section is devoted to discussing and defining the operations support characteristics of the KSC facility, which based on the selection rationale, was chosen as the operational site.

The appendix summarizes management and control procedures, including planning, scheduling, tooling, and control. The tooling philosophy and approach for manufacture of the Space Shuttle is, basically, to minimize construction of major fixturing, thus, minimizing costs. The assembly of the Orbiter main fuselage, which utilizes the main propulsion tank as a tooling base on which to build the main fuselage, provides a good example of the MDC philosophy. The Booster manufacturing approach employs existing major tooling and fixtures by adaptation and usage of Saturn tooling and G.S.E. The modular approach to the manufacture of vehicle major assemblies is emphasized.

FACILITY UTILIZATION AND MANUFACTURING PLAN
(MDC E0308-III-4)

Major manufacturing problems, and their proposed solutions, are presented and discussed. These problems are categorized, as applicable, by Booster and/or Orbiter.

The long lead requirements are listed and in the discussion of the respective assemblies the description of the manufacturing sequence tests, tooling and facilities requirements, schedules and cost estimates therefore as well as the rational for each of the selections and decisions made.

TEST PLAN
(MDC E0308-III-5)

The Test Plan is presented in three major sections - Space Shuttle, Booster, and Orbiter. The plan, based on the use of state-of-the-art technology and existing facilities wherever possible, addresses the definition of requirements and test approach to all levels of testing from design development, verification of requirements, predelivery acceptance, and mission demonstration. Overall testing philosophy is to minimize the extent and cost of testing, commensurate with attaining mission success and crew safety. In addition, the test plan has been carefully phased into the other related plans-management, facilities, engineering and development, operations, logistics and maintenance, and cost and schedules.

Shuttle System - This section discusses the total program summary, and reveals MDC test philosophy, including the explanation of test phases and definitions. The formal equipment qualification plan and the methods by which qualified hardware is attained along with test equipment requirements and facilities, the failure analysis routine, documentation, and safety requirements are also discussed.

Ground tests include mated and proximity wind tunnel tests, scaled model dynamic tests, and separation system tests. Wind tunnel test requirements are defined and candidate facilities and model scales identified. Test requirements are categorized as aerodynamic, thermodynamic, loads, structural dynamics, and propulsion.

The section on mated and vertical flight vehicle tests includes discussions of:

(1) electromagnetic compatibility tests, which will be conducted on the launch pad prior to the first vertical takeoff of the mated configuration

(2) low-level dynamic response tests

(3) launch site tests, which include those tests that prepare and ready vehicles and ground systems for static fire tests and the readiness tests of systems being prepared for vertical flight

TEST PLAN
(MDC E0308-III-5)

(4) vertical flight tests to evaluate and verify mission phase characteristics and subsystem operation during prelaunch, launch, and Booster ascent.

The philosophy of nonrepetitive testing is carried over from the factory acceptance test program to the launch site tests.

Participating roles of reliability, quality assurance, and safety in the test program, and the MDC approach to test management conclude the Shuttle System Section.

Booster and Orbiter - The Booster and Orbiter sections define the detailed requirements for test and the associated approach for test implementation. Flight characteristics of the vehicles are supported by wind tunnel testing, flight simulation studies, and in-flight verification.

Vehicle subsystem testing encompasses the development of the airframe structure and the thermal protection system; the propulsion group, including the main engines and fuel system, the attitude control propulsion system, the airbreathing engines and fuel system, and the auxiliary power unit; the avionics group, including the associated software validation; the auxiliary power group; and the ground support equipment.

Combined systems tests will utilize functioning setups of actual hardware components. The main integration activities include the entire avionics array, the hydraulics and avionic flight control system, and the propulsion integration test program.

The completed vehicle test program describes the utilization plan for horizontal flight testing, structural and dynamic response assurance, and installed subsystems integration. The philosophy of ground acceptance testing, and predelivery flight acceptance, completes the Booster and Orbiter test plans as individual vehicle units.

LOGISTICS AND MAINTENANCE PLAN
(MDC E0308-III-6)

This plan presents the MDC logistics and maintenance approach, which will provide an integrated support program from the design phase through the operational phase. The plan consolidates all individual logistics support elements into an interrelated, interfaced, and program-phased activity. Included in the plan is a milestone chart which provides for timely and adequate identification, development, and scheduling of the logistics support requirements.

As nearly as possible, reusable Space Shuttle logistics and maintenance functions have been related to present airline practices which have been developed through extensive operating experience.

The plan is organized (in format) by functional activity. Each function, i.e., maintenance, technical publications, etc., is presented as an identifiable entity within the Logistics and Maintenance Plan.

PROGRAM COST AND SCHEDULE ESTIMATE PLAN
(MDC E0308-III-7)

This plan provides cost and schedule planning data which can be used for making decisions vis-a-vis the development and operation of a two-stage fully reusable Space Shuttle. The required data consist both of the costs for each part of the system, and of time phasing of these costs to establish funding requirements.

This report covers the development activities starting with Phase C of Phased Project Planning (PPP) through completion of a ten-year operational cycle. The traffic model assumed for the operational cycle was specified by NASA for this project. The costs to be used for GFE items (main engines) were provided by NASA.

These data are organized as required by DRD MF003M, which defines the specific data to be included. Four data forms are required which provide a complete breakdown of cost, schedule, and technical characteristics data, organized to the work breakdown structure and reported at Level 5.

The first section provides cost information on Cost Estimate Data Form A. This data form includes cost estimates, the time phasing recommended to spread the cost estimates for funding purposes, and the data necessary to derive unit costs for recurring items. Separate cost estimates are presented for nonrecurring (RDT&E) activities, recurring production activities, and recurring operations activities; non-recurring costs through first Manned Orbital Flight (MOF) are also presented.

The next section presents Data Form B, with detailed cost estimates divided across specific subdivisions of work for each WBS item. The subdivisions of work encompass design, test, tooling, production, and materials and subcontracts.

The technical characteristics data presented in Data Form C are a concise summary of the performance, sizing, and complexity parameters used in estimating the cost of each item of the WBS. Some other vehicle parameters have also been

PROGRAM COST AND SCHEDULE ESTIMATE PLAN
(MDC E0308-III-7)

included to provide a more comprehensive description of those Shuttle technical, physical, and mission characteristics which are important in understanding the costs.

Data Form D presents the fiscal funding requirements for RDT&E, production, and operations activities.

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ABBREVIATIONS

α	Angle of Attack
ABES	Air Breathing Engine System
AC	Alignment Circle
A/C	Aircraft
(ACN/ASC)	Ascension Tracking Station
ACPS	Attitude Control Propulsion System
ACS	Attitude Control System
ADIZ	Air Defense Identification Zone
AFB	Air Force Base
AGL	Above Ground Level
ANG	Antigua Tracking Station
APU	Auxiliary Power Unit
ARTCC	Air Route Traffic Control Center
ASTU	Avionics System Test Unit
ATC	Air Traffic Control
ATS	Applications Technology Satellite
AV	Avionics
AWG	Activation Working Group
B	Booster
BDA	Bermuda Tracking Station
BGNC	Booster Guidance Navigation Communications
BIT	Built In Test
BITE	Built In Test Equipment
BOD	Beneficial Occupancy Date
CAVU	Clear and Visibility Unlimited

CCATS	Communication, Command and Telemetry System
CDDT	Countdown Demonstration Test
CH_4	Methane
CIF	Central Instrumentation Facility
CKAFS	Cape Kennedy Air Force Station
COMM	Communication
CONUS	Continental United States
CPU	Central Processing Unit
CRO	Carnarvon Tracking Station
CRT	Cathode Ray Tube
CST	Combined Systems Test
C/T	Crawler Transporter
CY	Calendar Year
CYI	Canary Island Tracking Station
ΔV	Incremental Velocity
DAC	Days After Contract
DEG	Degree
DIU	Digital Interface Unit
DME	Distance Measuring Equipment
DMS	Data Management System
DOD	Department of Defense
EAFB	Edwards Air Force Base
ECLS	Environmental Control Life Support
EC&W	Emergency Caution and Warning
ED	Energy Dissipation
EECOM	Environmental, Electrical and Communications

EMC	Electromagnetic Compatibility
ENG	Engine
ENS	Electrical Network Systems
EP	Electrical Power
EPS	Earth Physics Satellite
ERS	Earth Resource Satellite
ESSA	Environmental Science Service Agency
EVA	Extra Vehicular Activity
°F	Degrees Fahrenheit
FA	Final Approach
FAA	Federal Aviation Administration
FAR	Federal Aeronautics Regulation
FDO	Flight Dynamics Officer
FLTS	Flights
fpm	Feet per Minute
fps, FPS	Feet Per Second
FRC	Flight Research Center
FRF	Flight Readiness Firing
ft.	Feet
FT/GMOC	Flight Test Ground Mission Operations Center
FWG	Facility Working Group
g	Acceleration of Gravity
GAFSO	Ground and Flight System Optimimization
GATS	Ground Automatic Test System
GBM	Grand Bahama Island Tracking Station
GDS	Goldstone Tracking Station

GE	General Electric
G.E.T.	Ground Elapsed Time
GH_2	Gaseous Hydrogen
GMOC	Ground Missions Operations Center
GN_2	Gaseous Nitrogen
G&N	Guidance and Navigation
GNC	Guidance, Navigation and Control
GND	Ground
GO_2	Gaseous Oxygen
GOX	Gaseous Oxygen
GPM	Gallons Per Minute
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GWM	Guam Tracking Station
h	Altitude
H_2	Hydrogen
HA	Heading Alignment
HAW	Hawaii Tracking Station
H_a	Height of Apogee
HCR	High Cross Range
HEAO	Helios Astronomical Observatory
HF	High Frequency
HP	Height of Perigee
HSK	Honeysuckle Creek Tracking Station
HTO	Horizontal Take Off
HYD	Hydraulic

IBM	International Business Machines
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMU	Inertial Measuring Unit
INCO	Instrumentation and Communications Officer
INTERCOMM	Intercommunications
IOCU	Input-Output Control Unit
IRU	Inertial Reference Unit
IST	Integrated Systems Test
JP	Jet Propellant
K	Kilo = Thousand
KBPS	Kilo Bits Per Second
Kc	Kilocycle
KSC	Kennedy Space Center
KTS	Knots
Lb	Pound
LCC	Launch Control Center
LCG	Liquid Cooled Garment
LCR	Low Cross Range
L/D	Lift to Drag Ratio
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LOS	Line of Sight

LRU	Line Replacement Unit
LS	Landing System
LUT	Launcher Umbilical Tower
$\overline{M}$	Million Dollars
M	Mach Number
MAB	Maintenance and Assembly Building
MAD	Madrid Tracking Station
M/C	Mid-Course
MCAS	Marine Corp Air Station
MCC	Mission Control Center
MDAC Unit	Monitor, Display and Control Unit
MIL	Merritt Island Tracking Station
Min	Minute
ML	Mobile Launcher
MOCR	Mission Operations Control Room
MOD	Modification
MOS	Months
MPCU	Main Power Control Unit
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSL	Mean Sea Level
MSOB	Manned Spacecraft Operations Building
MSS	Mobile Service Structure
NA,N/A	Not Applicable
NASA	National Aeronautics and Space Administration

NASCOM	NASA Communications Division
N.C.	North Carolina
NC	Phasing Maneuver
NCC	Corrective Combination
NM,nm	Nautical Mile
NAVAIDS	Navigation Aids
NDT	Non Destructive Test
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Air Defense
NOTAM	Notice to Airmen
NSR	Coelliptic Sequence
NSSDC	National Space Science Data Center
O	Orbiter
O_2	Oxygen
OAO	Orbiting Astronomical Observatory
OBC	On Board Checkout
OCS	On-Board Checkout System
"O"g	Zero Gravity
OJT	On The Job Training
OMS	Orbital Maneuvering System
OOS	Orbit to Orbit Shuttle
PAN AM	Pan American
PDU	Power Distribution Unit
PIA	Pre-Installation Acceptance
PL, P/L	Payload
PLSS	Portable Life Support System

PME	Passive Meteorid Exposure Module
PSE	Propulsion System Engineer
PSF	Pounds Per Square Feet
PSI	Pounds per square inch
PSIA	Pounds per square inch atmospheric
PTU	Power Transfer Unit
Q	Dynamic Pressure
R&D	Research and Development
RCS	Reaction Control System
REV	Revolution
RF	Radio Frequency
RP	Rocket Propellant
RPC	Remote Power Controller
R&R	Rest and Relaxation
RSS	Root - Sum - Square
RTCC	Real Time Computer Complex
SAR	Sea Air Rescue
SAS	Stability Augmentation System
SAS	Small Astronomy Satellite
SATS	Space Applications Technology Satellite
SCU	System Control Unit
SEC	Second
SEF	Small End Forward
SESP	Space Experiment Support Program
SIM	Simulation
SL	Sea Level
SN	Serial Number

SSR	Staff Support Room
SS/SB	Space Station/Space Base
ST	Structural
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TEX	Texas Tracking Station
TM, T/M	Telemetry
TNT	Trinitrotoluene
TPI	Terminal Phase Initiation
TPF	Terminal Phase Finalization
TPS	Thermal Protection System
TTY	Teletype
TVC	Thrust Vector Control
UHF	Ultra High Frequency
US	United States
USB	Unified S-Band
USBS	Unified S-Band System
VAB	Vehicle Assembly Building
(VAN)	Vanguard
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Visual Omni Range
Vs	Velocity Stall
VSIA	Vehicle Systems Integration Activity
VTO	Vertical Take Off
YR	Year
WTR	Western Test Range

3.1 INTRODUCTION - The Operations Plan identifies requirements and implementation of these requirements for ground and flight operations. This plan is generally responsive to DRD MA016M (Phase B Final Reports) and specifically responsive to DRD MP010M (Operations Plan).

This plan is organized into three sections and Appendices:

3.1 Introduction

3.2 Operation Requirements

3.3 Approach

Appendix A Documentation Cross-Tie

The requirements are further categorized into those for the Shuttle System, the Booster, and the Orbiter. Our Phase C/D management baseline (described in the foreword) considers two vehicle contractors but no integration contractor; therefore, to provide the contractors with complete sets of requirements, the Shuttle System requirements would have to be distributed to one or both of them.

3.1.1 Purpose - The purpose of this document is to provide NASA with Phase C/D planning information based on the results of the Space Shuttle System Phase B Study. It is also intended to provide an aid in the development of a Phase C and D Test and Checkout Requirements Specification and Criteria Document and provide guidance in the development of test procedures. The requirements are defined so that they may be used as base material for the Phase C/D RFP. In order of precedence, it is the top level document for operations requirements.

3.1.2 Scope - This document defines and describes the requirements, rationale and the McDonnell Douglas Corporation Team approach for ground and flight operations. The ground operations section includes the requirements and activity from landing rollout through launch of the Space Shuttle Vehicles. Also included are the implementation of factory acceptance test, alternate landing site activities, and a launch site GSE/facility activation plan outline. The flight operations section includes the requirements and activities from lift-off through landing operations of the Space Shuttle Vehicles. Abort modes and operational interfaces with respect to relay satellites, experiments and the scientific community are also included.

3.1.3 Operations Objectives - A prime objective of the program is to successfully develop and operate a reliable low cost reusable Space Shuttle system. It has become quite evident that a major element of cost of such a program, centers around the ground operations phase. Our Operations Plan was structured to consider the importance of even minute cost items in a program based upon 10 missions the first year and building up to 75 missions a year in the ninth and tenth years for a total of 445 flights. The potential payload variations and mission objectives have been examined and the following operational goals and constraints established.

3.1.3.1 Goals - The following is a list of major ground and flight operations goals as presently defined:

- Low operating cost
- High launch rate flexibility
- Adaptation of airline turnaround concepts
- Maximum use of existing capabilities where cost effective
- Minimize ground turnaround time
- Reduce number of personnel required
- Vehicle interchangeability
- All weather launch capability
- Reduce documentation
- All azimuth launch capability
- Minimize inflight ground support
- Versatile payload carrying capability

3.1.3.2 Constraints - The following is a list of major ground and flight operations constraints as presently defined:

- Mission Duration
  - 7 days limitation with no payload impact
  - 30 days or longer with payload impact
- Extensive unscheduled maintenance/refurbishment
  - Impact on high launch rate capability
- Unknown Cargo/DoD configuration
  - Handling could impact turnaround timeline
  - Interface testing could impact turnaround timeline
- Launch window
  - Propellant utilization limitations impacts launch window
- Weather
  - Category II
  - Extreme weather (severe turbulence, heavy icing, visibility, etc.)
  - Launch abort due to severe weather
- Flight crew performance limits
  - Crew rest periods must be provided
  - Crew radiation exposure must be limited
  - Crew workload must be reasonable
- On orbit ΔV
  - Approximately 2,000 feet per second limited by tank size
- Navigation accuracy
  - One sigma RSS steady state star-horizon navigation accuracy is approximately one nautical mile
- Payload weight limit
  - 69.5K lbs. due east, KSC launch, ABES out, Booster cruiseback to launch site, OMS abort to orbit capability

  - Reduced capability for other azimuths
  - Reduced capability with ABES in
  - Additional capability with downrange landing
- Overflight
  - Booster cruiseback over foreign territory undesirable
  - Launch over heavily populated areas undesirable
- Propellant dump
  - Orbiter OMS and main propellant must be dumped prior to landing
  - Booster main and secondary propellant systems must be dumped prior to landing
- Downrange landing sites
  - Availability of sites limits ability to take advantage of downrange landing to increase payload
- Yaw steering capability
  - TBD degrees nominally yaw steering
  - TBD degrees yaw steering with payload impact

3.2 OPERATIONS REQUIREMENTS - This section identifies the contractor ground and flight operations requirements. These requirements are based on the implementation of the Space Shuttle Requirements Document issued in support of the Phase B Study. Some of the requirements noted have not been satisfied by the Phase B baseline. Further trade studies will determine whether these requirements will be included in the Phase C and D Statement of Work or deleted. The requirements in this category are identified by an asterisk (*) mark. The reference indicates the section in the approach that addresses the requirement.

3.2.1 Space Shuttle Requirements - The requirements noted in this section are those that are applicable to the mated vehicle activities. They are divided into ground and flight requirements.

3.2.1.1 Ground - These requirements are applicable to the ground operation activities.

A. The vehicles will be transported to the pad in a vertically mated configuration.

Rationale - Cost effective to utilize existing equipment and this allows vehicle umbilical installation, other vehicle to launcher interfaces, and checkout in an enclosed area.

Reference: Section 3.3.1.5.1.3 and 3.3.1.11.1

B. Post launch pad operations will be accomplished within 4 days for the operational Shuttle.

Rationale: Insure high launch rate capability.

Reference: Section 3.3.1.6.2 and 3.3.1.6.5.2

C. Existing government facilities and GSE will be utilized where possible.

Rationale: Cost and schedule effective.

Reference: Section 3.3.1.11 and 3.3.1.13

D. Loading of cryogenic propellants will be a simultaneous operation. Cryogens will also be loaded into both vehicles simultaneously.

Rationale: Minimize pad operations time which in turn minimizes exposure of vehicles to weather.

Reference: Section 3.3.1.6.1.2 and 3.3.1.12.3.4

E. The vehicles will be erected individually, not mated.

Rationale: Provide flexibility in operational schedules and activities.

Reference: Section 3.3.1.5.1.3 and 3.3.1.11

F. Vehicle main propellant loading will be remotely controlled.

Rationale: Insure safety of personnel.

Reference: Section 3.3.1.6.1.2 and 3.3.1.12.3.4

G. 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.

Rationale: Insure continuity between the development and operational phases. Also a method by which the operational personnel can gain experience with the vehicles and subsystems.

Reference: Section 3.3.1.2.2

H. Standby to launch with vehicles in an unfueled status will not occur in less than T-2 1/2 hours.

Rationale: Permits utilization of existing fueling capabilities. Provides more time from crew ingress to launch.

Reference: Section 3.3.1.6.1

I. Crew will have final checkout and launch commit capability.

Rationale: Minimize launch crew support.

Reference: Section 3.3.1.6.1.3

J. Vehicle shall have capability of holding for 10 hours in a launch ready configuration.

Rationale: Gain opportunity to reach the next launch window without deservicing and reservicing.

Reference: Section 3.3.1.6.3.1

3.2.1.2 Flight - These requirements are applicable to the flight operations activities.

A. The Space Shuttle shall have the capability to launch day or night.

Rationale: Certain missions will require night launch. Both launch windows for the Space Station resupply mission are in darkness about 13% of the time. At least one window is in darkness about 74% of the time.

Reference: Section 3.3.2.1.6

* B. At least one of the redundant means of control for any mission phases critical to crew safety shall be insensitive to errors in the primary software.

Rationale: Decreases the probability of a catastrophic failure due to software errors which are duplicated in all redundant software.

3.2.2 Booster Requirements - The requirements noted in this section are those that are applicable to the Booster vehicle activities. They are divided into ground and flight requirements, respectively.

3.2.2.1 Ground - These requirements are applicable to the ground operation activities.

A. Emergency egress timeline for unaided crew, during pad operations, shall not exceed 4 minutes from emergency warning indication to arrival at protective area.

Rationale: Insure safety of crew and passengers.

Reference: Section 3.3.1.6.4.2

B. Propellant tanks will be purged to an acceptable safe level prior to moving the vehicle into the maintenance area.

Rationale: Personnel safety and minimize moisture content in tanks.

Reference: Section 3.3.1.7

C. Vehicle must be towable on its landing gear.

Rationale: Reduce GSE handling requirements for post landing activities.

Reference: Section 3.3.1.7 and 3.3.1.5.1.3

D. The vehicle shall have maintenance and testing accessibility in both the horizontal and vertical position.

Rationale: Minimize possibility of returning to maintenance area for replacement of hardware.

Reference: Section 3.3.1.6.1 and 3.3.1.8

E. Emergency egress for unaided crew shall be provided when vehicle is in horizontal position.

Rationale: Insure safety of crew.

Reference: Section 3.3.1.6.4.2

F. Equipment that will be used for development testing only, will not be integral with operational hardware where possible and will be accessible for ease of removal.

Rationale: Ease of removal of superfluous equipment. Reduction in vehicle weight and elimination of monitoring capability of parameters that are not required operationally.

Reference: Section 3.3.1.3

G. Any Booster must be capable of mating and interfacing with any Orbiter.

Rationale: Permit flexibility in selection of vehicles.

Reference: Section 3.3.1.6.5

H. Post-landing deservicing activities will be performed with ground personnel onboard.

Rationale: Reduces postlanding activities by a significant amount, specifically in the propulsion system. Also reduces GSE requirements.

Reference: Section 3.3.1.7

I. The vehicle shall have the capability of servicing and deservicing the JP fuel tankage system in both the vertical (launch pad) and the horizontal position.

Rationale: Minimize vehicle handling weight during erection. Provide servicing for both vertical and horizontal flights.

Reference: Section 3.3.1.2.1, 3.3.1.2.2 and 3.3.1.6.1.1

* J. GSE will not be required to prevent damage to the vehicle, its subsystems and equipment for two hours after landing.

Rationale: Prevent major damage to a vehicle if landing site is other than the prime landing site or if safing/deservicing operations are inadvertently delayed.

K. The vehicle shall be capable of being lifted without load distribution GSE which requires large numbers of fasteners.

Rationale: Reduce time and effort in vehicle lifting preparations and to reduce GSE.

Reference: Section 3.3.1.5.1.3

L. The vehicle shall be capable of taxiing.

Rationale: Reduce the handling effort associated with towing the vehicle and to eliminate closing the runway for towing the vehicle.

Reference: Section 3.3.1.7

3.2.2.2 Flight - These requirements are applicable to the flight operations activities.

A. A communications capability between booster and landing site shall be provided during entire cruiseback phase.

Rationale: Provides means of notification of emergencies, either on the vehicle or at the site.

Reference: Section 3.3.2.1.8 and 3.3.2.4.3

B. The capability to identify and fly around weather problem areas is required.

Rationale: Enhances safety and comfort.

Reference: Section 3.3.2.1.8 and 3.3.2.4.3

C. The Booster shall be capable of landing in darkness.

Rationale: Night launch typically results in night landing.

Reference: Section 3.3.2.4.3

D. The Booster shall be capable of landing downrange.

Rationale: Provides payload increase for missions requiring heavy payloads.

Reference: Section 3.3.2.1.8 and 3.3.2.4.1

3.2.3 Orbiter Requirements - The requirements noted in this section are those that are applicable to the Orbiter vehicle activities. They are divided into ground and flight requirements, respectively.

3.2.3.1 Ground - The requirements are applicable to the ground operation activities.

A. The vehicle, in the vertical configuration shall have the capability of cargo module replacement at both pre-pad and on-pad facilities.

Rationale: To support time limited rescue requirements

Reference: Section 3.3.1.5.1.3 and 3.3.1.6.1

B. Cargo module will normally be installed and removed while vehicle is in horizontal position.

Rationale: Ease of installation and removal.

Reference: Section 3.3.1.8

C. Vehicle must have capability of cargo module removal at the safing area.

Rationale: Expedite processing of critical and hazardous payloads.

Reference: Section 3.3.1.7

D. Emergency egress timeline for unaided crew/passengers, during pad operations, shall not exceed 4 minutes from emergency warning indication to arrival at the safe area.

Rationale: Insure safety of crew and passengers.

Reference: Section 3.3.1.6.4.2

E. Propellant tanks will be purged to an acceptable safe level prior to moving the vehicle into the maintenance area.

Rationale: Personnel safety and minimize moisture content in tanks.

Reference: Section 3.3.1.7

F. Vehicle must be towable on its landing gear.

Rationale: Reduce GSE handling requirements for post landing activities.

Reference: Section 3.3.1.7 and 3.3.1.5.1.3

G. The vehicle shall have maintenance and testing accessibility in both the horizontal and vertical postition.

Rationale: Minimize possibility of returning to maintenance area for replacement of hardware.

Reference: Section 3.3.1.6.1 and 3.3.1.8

H. Emergency egress for unaided crew shall be provided when vehicle is in horizontal position.

Rationale: Insure crew safety.

Reference: Section 3.3.1.6.4.2

I. Equipment that will be used for development testing only, will not be integral with operational hardware where possible and will be accessible for ease of removal.

Rationale: Ease of removal of superfluous equipment. Reduction in vehicle weight and elimination of monitoring capability of parameters that are not required operationally.

Reference: Section 3.3.1.3

J. Postlanding deservicing activities will be performed with ground personnel onboard.

Rationale: Reduces postlanding activities by a significant amount, specifically in the propulsion system. Also reduces GSE requirements.

Reference: Section 3.3.1.7

K. Any Orbiter must be capable of mating and interfacing with any Booster.

Rationale: Permit flexibility in selection of vehicles.

Reference: Section 3.3.1.6.5

* L. GSE will not be required to prevent damage to the vehicle, its subsystems and equipment for two hours after landing.

Rationale: Prevent major damage to a vehicle if landing site is other than the prime landing site or if safing/deservicing operations are inadvertently delayed.

M. The vehicle shall have the capability of servicing and deservicing the JP fuel tankage systems in both the vertical (launch pad) and the horizontal position.

Rationale: Minimize vehicle handling weight during erection. Provide servicing for both vertical and horizontal flights.

Reference: Section 3.3.1.2.1, 3.3.1.2.2 and 3.3.1.6.1.1

N. The vehicle shall have the capability of servicing and deservicing the ACPS LO_2 and LH_2 tankage system in both the vertical (launch pad) and horizontal position.

Rationale: Horizontal servicing required for the ferry flights. LO_2 and LH_2 cannot be serviced inside checkout building. Therefore, it will be serviced at the launch pad.

Reference: Section 3.3.1.2.1, 3.3.1.2.2 and 3.3.1.6.1.2

O. The vehicle shall be capable of being lifted without load distribution GSE which requires large numbers of fasteners.

Rationale: Reduce time and effort in vehicle lifting preparations and to reduce GSE.

Reference: Section 3.3.1.5.1.3

P. The vehicle shall be capable of taxiing.

Rationale: Reduce the handling effort associated with towing the vehicle and to eliminate closing the runway for towing the vehicle.

Reference: Section 3.3.1.7

3.2.3.2 Flight - These requirements are applicable to the flight operations activities.

A. The Orbiter shall have the capability to land at night.

Rationale: Ascent abort with return to launch site following night launch requires this capability. Also, it enhances operational flexibility for end of mission returns.

Reference: Section 3.3.2.4.2

B. The Orbiter shall have a voice link between crew and passengers.

Rationale: Allows crew to monitor status of passengers.

Reference: Section 3.3.2.3.5

C. The Orbiter on-orbit acceleration level along $-Z_B$ axis must be greater than or equal to 0.4 ft/sec^2.

Rationale: Needed for rendezvous braking maneuvers for typical rendezvous profiles.

* D. Range and range-rate data shall be displayed to the flight crew during docking.

Rationale: Early docking simulations indicate need for these displays to achieve acceptable docking and conditions.

E. The Orbiter shall provide the capability for the flight crew to monitor and communicate with an EVA crewman.

Rationale: Improves EVA flexibility while reducing attendant risk.

Reference: Section 3.3.2.3.8

F. The Orbiter shall have the capability for installation of an ATC transponder for ferry flights.

Rationale: Anticipated FAA requirement by the time the Shuttle is operational.

Reference: Section 3.3.2.4.4

G. The Orbiter shall be capable of returning to alternate landing sites.

Rationale: Provides capability for return in event of weather problems at the prime landing site and enhances emergency return capability.

Reference: Section 3.3.2.2.3 and 3.3.2.4.2

H. The Orbiter shall have the capability for making both range and angle measurements for rendezvous with an active cooperative target vehicle.

Rationale: Rendezvous techniques not utilizing these measurements lead to excessive propellant expenditures.

Reference: Section 3.3.2.2.1

I. The Orbiter shall have the capability for data downlink and voice.

Rationale: Data is required for contingency ground support in event of abnormal systems problems. Voice required for interface with Ground Mission Operations Center (landing site, weather data, medical support, solar flare advisories, etc.).

Reference: Section 3.3.2.2.2 and 3.3.2.2.3

J. The Orbiter shall be designed such that minimal modifications are required for operational transition from MSFN to a Tracking and Data Relay Satellite System (TDRS) when such a system is available.

Rationale: Use of the TDRS provides more communications coverage at lower cost.

Reference: Section 3.3.2.2.1 and 3.3.2.2.2

3.3 APPROACH -This section describes the approach the contractor will employ to meet the ground and flight requirements in a way consistent with overall program objectives. The approaches cover the operational support of acceptance and developmental tests and the conduct of launch and alternate site operations, flight operations and the handling of operational interfaces with other programs.

3.3.1 Ground Operations Approach - The ground operations begin with the support of the different levels of acceptance tests which focus on progressively developing confidence in the operational integrity of components, subassemblies, combined systems and finally in the flight ready vehicle. Operations activity continues with support of the developmental program and operational launch site activities.

3.3.1.1 Acceptance Test Implementation - The operations plan is integrated with the vehicle acceptance test program to ensure a more efficient transition from the pre-operational to operational phases. The acceptance test program starts with detailed component tests performed at the vendor and proceeds through factory build-up of the vehicles, post manufacturing checkout, tests performed as an integral part of the development flight test phase and culminates with predelivery flight acceptance tests performed prior to the turnover of operational vehicles. Figure 3.3-1 outlines the acceptance test program.

3.3.1.1.1 Component/Module Pre-Installation Acceptance - Pre-installation acceptance testing (PIA) will be performed on all components prior to installation in the vehicle. PIA will primarily be performed at the vendors' facilities. Receiving inspection, at the assembly facility, will essentially be for the accountability of purchased items and associated data and for detecting damage incurred in transit. Those components requiring a factory PIA test will be treated as exceptions with proof of cost effectiveness required before this approach is taken.

Contractor personnel will participate in the vendor tests to insure that the

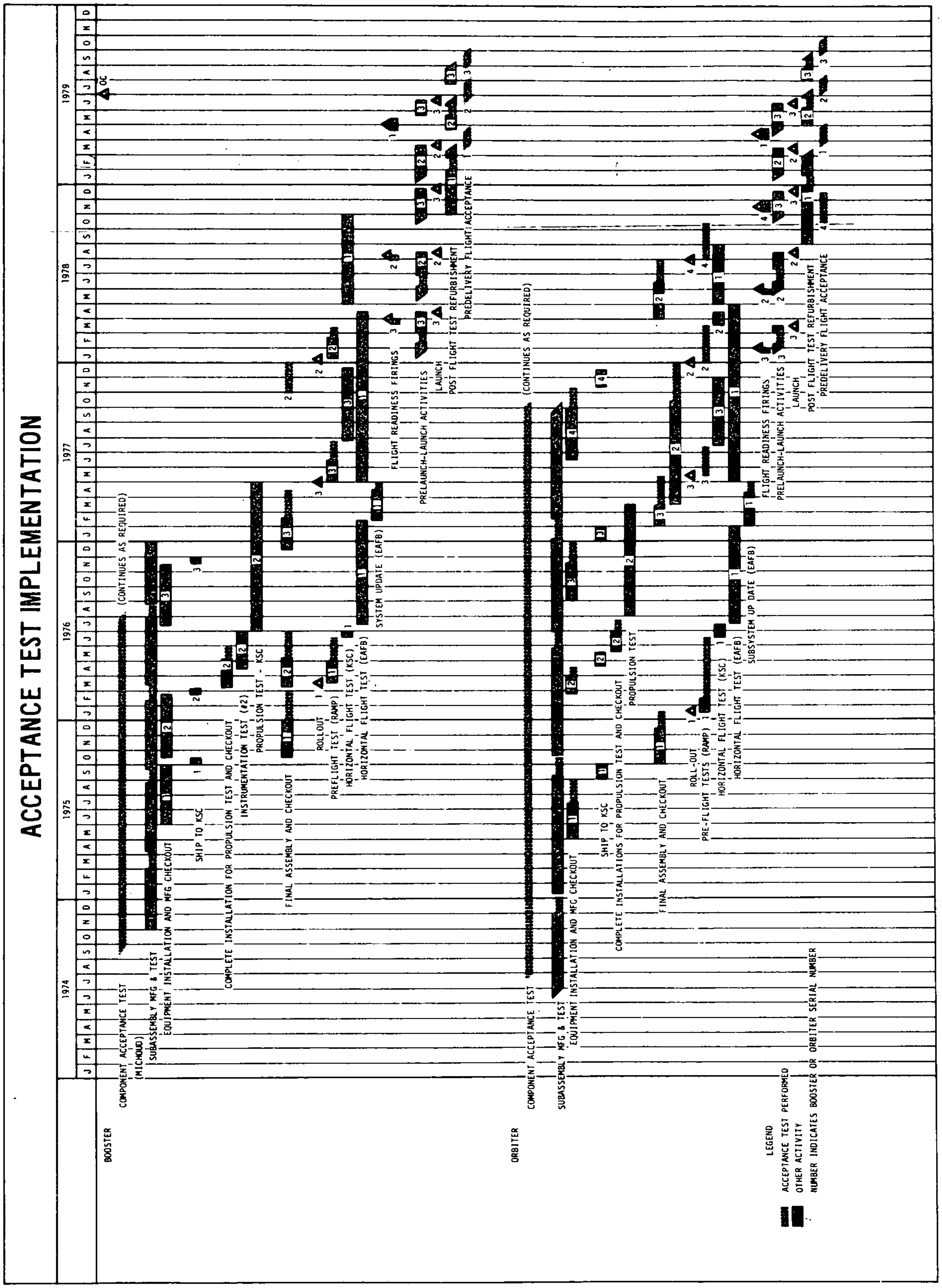

ACCEPTANCE TEST IMPLEMENTATION

FIGURE 3.3-1

tests are performed as required. This participation will permit early recognition of potential operational problems and develop familiarity with basic elements of each system.

It should be noted that after all the components are delivered, retention of PIA capabilities at some or any of the vendors will not be cost effective. The philosophy and approach as to where refurbishment and retest of components is performed, is discussed in Section 3.3.1.5.2 LRU management system.

3.3.1.1.2 Subassembly Acceptance Tests - These tests will be performed on subassemblies during the manufacturing phase to verify proper assembly and that integrity, operation and performance are within design specifications. Examples of subassemblies and of how they are tested are as follows:

A. Cabling - Continuity, insulation breakdown, shielding and grounding tests will be performed.

B. Fluid Lines, Manifolds, Tanks - Fabricated assemblies will be hydrostatically or pneumostatically proof pressure tested and leak tested. Jacketed cryogenic lines will be cold shocked using a cryogenic fluid and leak-tested using a mass spectrometer.

C. Modules - Applicable cabling, line and tank tests, as above, will be performed on modules during and/or after manufacturing buildup. Modules tested will vary from relatively small pneumatic units to major assemblies consisting of a complete cabin-nose section. Module testing is designed so that upon final assembly, there will be no requirements to repeat the tests to the same level. Next assembly testing is to be mainly concerned with the validation of interfaces. Tests of modularized components will be deferred until the subsystem is completed on the next assembly for cases where complex and expensive simulators are required to accomplish the test in a module level.

3.3.1.1.3 Subsystem Acceptance Tests will be performed on the completed vehicle at KSC in the final assembly facilities. Functional tests will be conducted to check proper installation integrity, performance specification compliance, function and operation of each subsystem. These tests will be performed on the assembled vehicle in the final assembly facility immediately prior to rollout to the preflight test area. The onboard checkout system and DMS will be used to conduct these tests. The integrated Avionics System, Crew Station-ECLS/Crew Systems, propulsion system, power system (electrical and hydraulic) and airframe-structural/mechanical subsystems are typical of the levels of test involved in this operational phase. These tests determine the readiness of the subsystem to operate in a combined subsystem test. Certain subsystem acceptance tests are deferred until the vehicle is in the proper test configuration. For example, the main propulsion subsystems are validated during preparations for, the run of, and tests performed subsequent to the Flight Readiness Firing tests. The Flight Readiness Firings of vertical flight test vehicles satisfy both acceptance and development test requirements. Flight Readiness Firings of other vehicles are for acceptance test purposes only.

3.3.1.1.4 Combined Subsystems Acceptance Tests will be performed on the completed vehicle at KSC in the final assembly facilities. Upon completion of the individual subsystem tests, an all-up systems test will be performed in which all subsystem interfaces with the vehicle and other subsystems are validated and checked out. All subsystems are tested in sequence (as controlled by the onboard Data Management System) to establish operational readiness and check that all elements under test will function in the proper sequence of flight.

An electromagnetic compatibility test will be conducted on each vehicle, with all systems as nearly as possible in flight configuration, in order to determine that any manual switch operation, data bus sequences, or mechanical sequences that might be performed in flight will not generate spurious signals on the data bus or cause dropouts of data on this system that would affect the overall operation of the vehicle.

Preflight Tests - A series of ground tests will be performed to check proper operation of all subsystems that will operate, or be called upon to operate, during a horizontal flight. Airbreathing propulsion engines will be run up and their performance checked. The DMS will be used for onboard control and monitoring during test. For early development vehicles, emphasis will be placed on the proper operation of the DMS and flight test instrumentation. APU's will be started and operations checks of the APU's, hydraulic and electrical subsystems made. Fuel cells will be activated and checked out. An overall avionics systems test using the onboard computer will be made either on an end-to-end and/or open loop basis (in the case of comm-navaids). The development flight test equipment will be calibrated and open loop operation to the site telemetry facility will be verified as applicable.

After all subsystems have been checked with the vehicle in a stationary position, taxi tests will be performed to demonstrate ground handling characteristics and the braking and steering systems. Vehicles then enter the flight test program, or in the case of Orbiter S/N 4, undergo predelivery flight acceptance testing.

3.3.1.1.5 Pre-Delivery Flight Acceptance Tests - Prior to turnover of vehicles for operational use, each vehicle will undergo predelivery flight acceptance test. For development flight test vehicles, the tests are performed subsequent to the refurbishment following completion of it's portion of the development flight test program. These tests include those subsystem, combined subsystem, and horizontal check flight tests that are necessary to verify readiness for operational use. Applicable factory acceptance tests will be performed to verify readiness for horizontal flight. In addition, certain deferred subsystem tests, such as Flight Readiness Firing tests will be performed at this time on Booster S/N 1 and Orbiters S/N 1 and 4.

Acceptance Test Flights - A series of acceptance test flights will be flown to check horizontal flight characteristics. These flights will check the horizontal flight operation of the navigational system, the guidance system (area navigation and automated landing), and other subsystems. Discrepancies noted will be corrected, revalidated by ground test and flight tested on another check flight, if necessary. Information obtained from the development and verification flight test program will be utilized for test criteria.

3.3.1.1.6 Software Verification - The requirement for a high degree of autonomous onboard checkout and rapid vehicle turnaround dictates that a high degree of confidence in the reliability and repeatability of software programs be developed early in the acceptance test program. Smooth operational flow requires that the software be largely self documenting and flexible enough to accommodate special tests that may be required in the developmental phase as well as the more routine tests associated with the pre-operational and operational phases. Two major categories of software are involved, that associated with the Onboard Checkout System (OCS) and that of the Ground Automatic Test System (GATS). The fact that the software will be written in a new higher order test language, which will be developed concurrently with the hardware, makes verification more time critical. The early need for software in the test program may require the use of computer simulation techniques to verify critical modules in advance of the availability of hardware.

At least fourteen major software modules for the operation and checkout of the vehicle have been identified. OCS support of subsystem acceptance tests requires that the critical modules for executive control, data bus control, sensor processing, display and control, sequence and control, and subsystem checkout be developed and checked in advance of the need date for equipment subsystem and combined systems acceptance tests. Software will be acceptance tested on prototype DMS and subsystem hardware for subsystem modules and on the ASTU for subsystem and the overall systems test. These verified modules will be used in component acceptance tests to verify the repeatability of results.

Acceptance testing of the flight software will be conducted on the central computer units delivered to the vehicle final assembly point. The OCS and GSE interface modules, which have been checked out on the ASTU, will be loaded into the installed central computers. The system will be initialized by manual operation of switches on the System Control Unit (SCU) and the checkout program started. In the course of the test, simulated computer malfunctions will be introduced to demonstrate the malfunction detection and switching logic of the SCU and IOCU. At the end of the test, the portion of the memory core dedicated to recording malfunctions and out of limit data bus conditions will be dumped for ground evaluation. All four central computers will be cycled into the lead computer function to demonstrate hardware-software compatibility. The capability of reloading the flight program from mass memory will be verified and the onboard system will be left in that configuration for flight test.

The GATS software includes three categories: on-line, for real time support of automatic checkout and operations related to both vehicle and GSE; off-line, not directly used in checkout, but required to support the on-line system and R&D only, software including both on- and off-line programs unique to the pre-operational test phase. Figure 3.3-2 gives a more complete breakdown of the GATS software.

GATS software will be generated and documented by using graphic terminals time-sharing a central computer. The operator at the terminal defines the mode of operation desired, selects functions from the computer initiated displayed list and modifies existing test sequences or creates new ones as desired. When he has completed the program, he can elect to store in bulk memory, and/or hardcopy via the

GATS SOFTWARE

On-Line

- Executive
- Dictionary
- Applications
    - Vehicle Subsystems
    - Vehicle System
    - Interface Compatibility
    - Countdown
    - GSE Self Test

Off-Line

- Compiler/Assembler
- Test Results Processor
- Maintenance Recorder Processor
- Files and File Generation
- Library Tape and File Maintenance
- Diagnostics
- Utility
    - Tape Edit
    - Card to tape
    - Debug and trace, etc.

R&D Only

- Vehicle Subsystems
    - DFI and TM System
    - Range Safety, etc.
- Vehicle Post Manufacturing Acceptance
    - Subsystem and Systems
- GSE Post Manufacturing Acceptance
- GSE Development

FIGURE 3.3-2

plotter or printer. When a test program is finished and ready for release, all items required for that release are output from the master file stored in bulk memory. This includes the program magnetic tape, the test buy-off sheets, listing of other files used, and "Engineering Reference Only" sorts. The test program can be transmitted to the test area via a data line and entered directly into the test computer, or it can be transported in the form of a magnetic tape.

The vehicle subsystem interface between GATS and OCS software will be verified by exercising it on the ASTU. The capability of GATS to control various GSE and ground facility functions will be demonstrated by connecting to the launch site interfaces and conducting simulated test and launch operations.

The operation of the combined OCS and GATS software will be verified during combined systems tests and preflight servicing tests. The capability of operational software to put the ground equipment in a safe condition in the event of servicing malfunctions, and to provide minor changes in automatic programming will be demonstrated. The GATS will provide automatic self test of a gross nature with the vehicle connected, and extensive self test with the vehicle not connected.

3.3.1.2 Operations in Support of Development Flights - Space Shuttle flight development testing will be employed to satisfy the flight test objectives. The primary objective of the mated vertical flight test program is to evaluate and verify mission phase characteristics and subsystem operation during prelaunch, launch, ascent, on-orbit, entry, cruiseback, landing, and postlanding Booster and Orbiter operations.

The Booster and Orbiter horizontal takeoff, airplane flight modes will be utilized to evaluate and verify their performance for the cruiseback, landing, and ferry mission phases. This mode of testing these flight regimes, described in detail in the test plan, will verify subsystems and vehicle performance and will remove most of the unknown factors from the post-transition flight regimes prior to the first vertical flight. Most of the horizontal flight testing will be performed at Edwards AFB, California.

The vertical flight development test program will consist of five vertical mated orbital flights. The vertical flight testing will take place at the final assembly/operational site, Kennedy Space Center (KSC).

Two major vertical test program milestones have been identified: Manned Orbital Mission (first vertical launch), and operational capability (OC). The Space Shuttle will have demonstrated by performance and analysis the capability of performing the design mission, including full payload capability, at OC. It is planned to carry some operational payload supplied by NASA to orbit on all vertical test flights after the first mission. The vertical development flight test program will be complete at OC.

3.3.1.2.1 Horizontal Development Flight Operations - The horizontal flight test plan as shown in Figures 3.3-3 (Orbiter) and 3.3-4 (Booster), includes ferrying the vehicles from the assembly site to the horizontal test site. This task consists of servicing the vehicle at the assembly site and deservicing/servicing the vehicle at intermediate stops. In support of ferrying, it is necessary to fly servicing GSE to the ferry stops in advance of the flight vehicle.

The quantity of servicing GSE has been greatly reduced by elimination of liquid oxygen and liquid hydrogen from the horizontal flight mode. The Booster H_2/O_2 APU was replaced by a dual mode APU -- one that burns H_2/O_2 during vertical flight and JP-4/air during horizontal cruise. The Orbiter will have hydraulic pumps added to the air breathing engines. This source of hydraulic power and utilization of the fuel cells for electrical power eliminates the need for LOX and LH_2. The Orbiter accumulators will have to be pressurized with GOX and GH_2 to operate the fuel cells. The liquid hydrogen used for the Orbiter ECLS will be replaced by a freon refrigeration kit for horizontal flights. This new plan greatly reduces the

ORBITER FLIGHT TEST PLAN

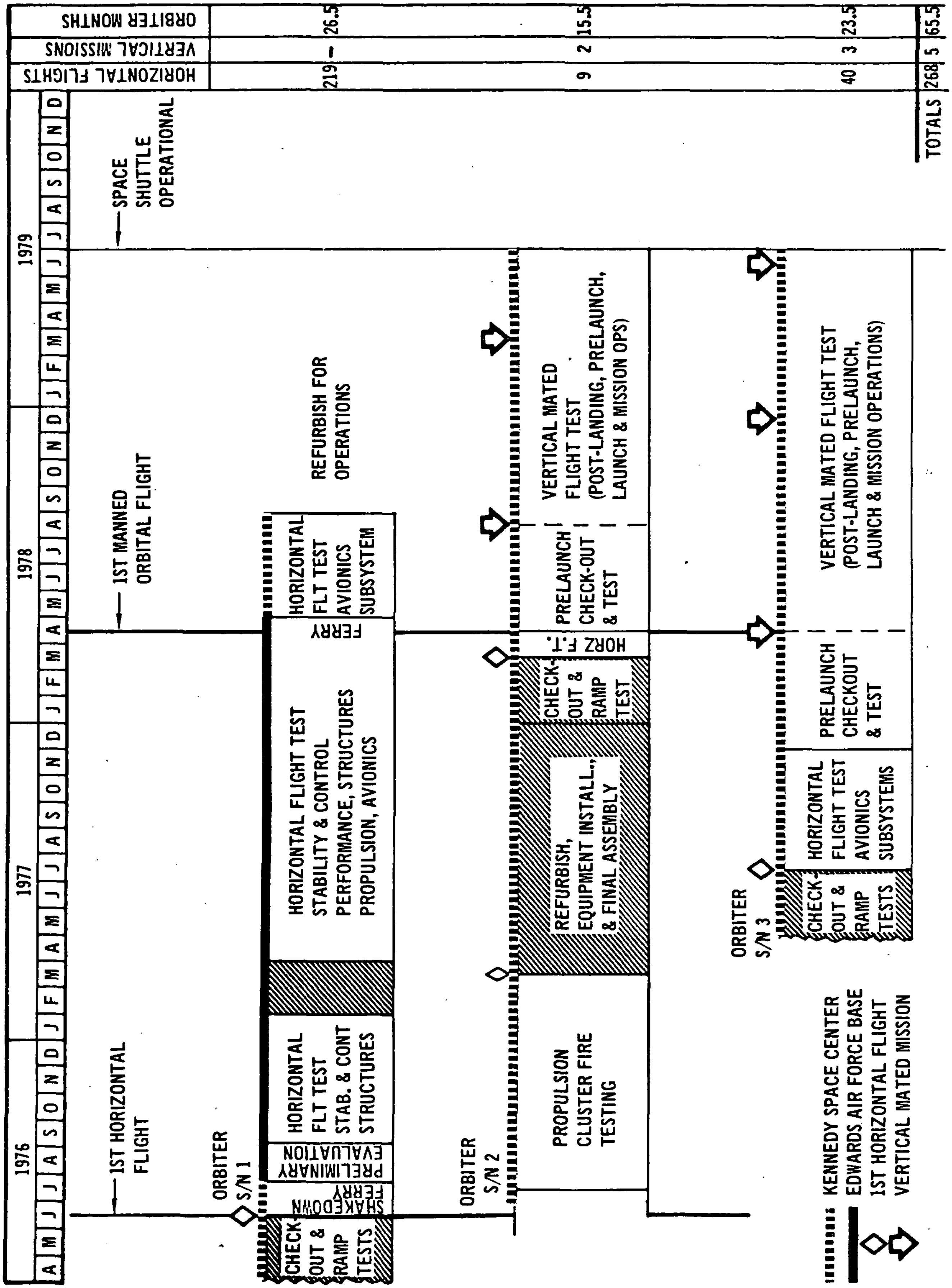
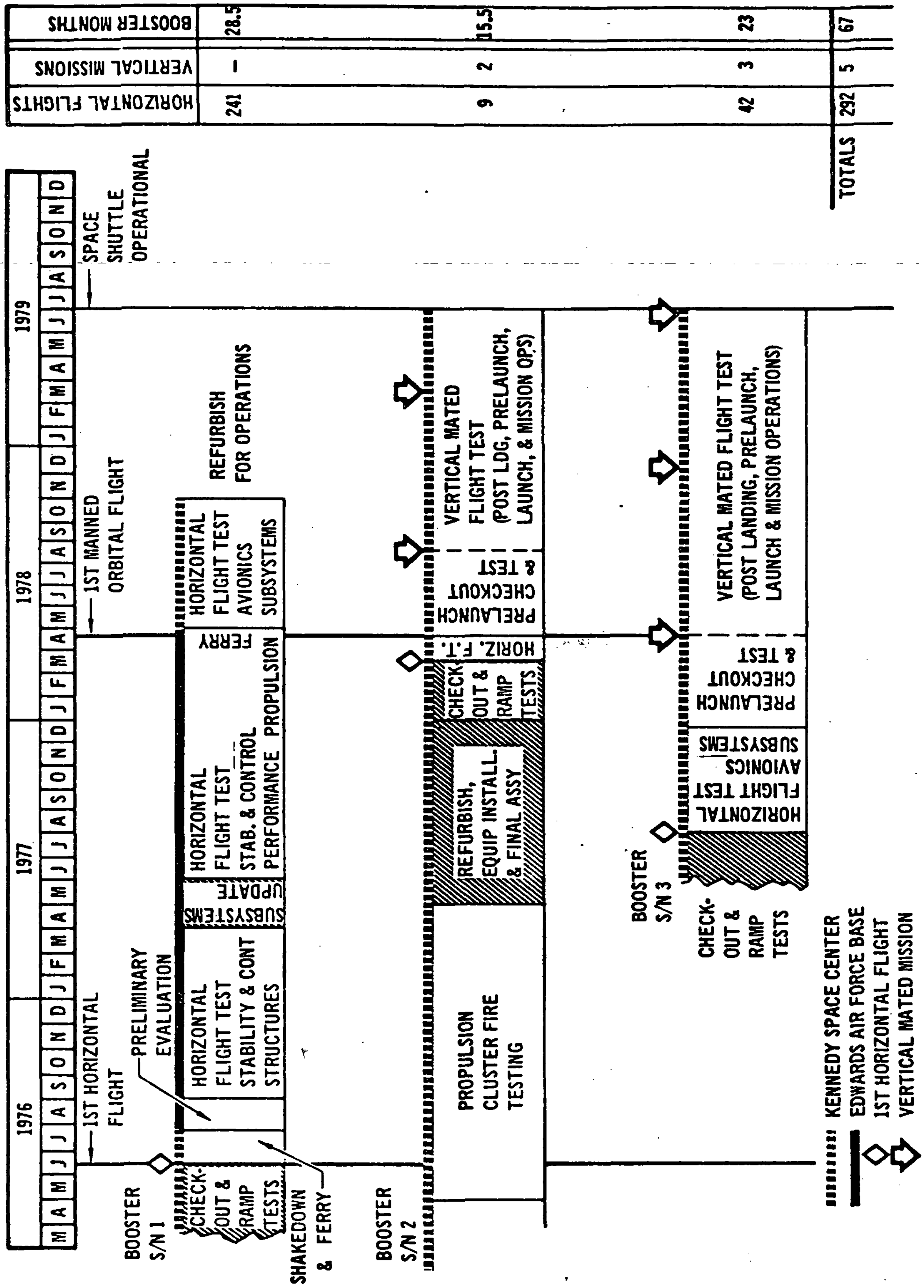


FIGURE 3.3-3

BOOSTER FLIGHT TEST PLAN



	HORIZONTAL FLIGHTS	VERTICAL MISSIONS	BOOSTER MONTHS
BOOSTER S/N 1	241	–	28.5
BOOSTER S/N 2	9	2	15.5
BOOSTER S/N 3	42	3	23
TOTALS	292	5	67

FIGURE 3.3-4

need for complex GSE and cryogenic facilities at the servicing locations for ferry and horizontal flight testing.

The Orbiter will require the four primary airbreathing engines be installed plus an additional one installed underneath the vehicle fuselage for ferrying and horizontal flight test. In addition, the cargo bay will be utilized for additional JP-4 tankage as well as for storage of other horizontal flight peculiar hardware. The Booster will be essentially configurated as it is operationally with the exception that a drag chute and its associated equipment will be required.

Activities during servicing of the vehicle between ferry flights are shown in Figure 3.3-5 and consist of the following operations: taxiing the vehicle to the servicing area which will be allocated at the intermediate stop,connecting umbilicals and GSE to the vehicle, deservicing the Orbiter GOX and GH_2 systems and loading the JP-4 tanks. The vehicle is then put into standby overnight if another flight cannot be made during daylight hours since the vehicle will only be flown under daylight VFR conditions prior to qualification. Just prior to the next flight, the Orbiter GOX and GH_2 accumulators are pressurized and the GSE is disconnected. The engines are started, the engine starting equipment removed, the chocks removed and then it leaves for the next leg of the ferry flight.

The ground crew then inerts the GSE, secures the GSE and then loads the GSE aboard a logistics aircraft. The GSE is flown to another ferry landing site where it is unloaded, set-up, tested and put into standby waiting for the Shuttle Vehicle. Two sets of GSE will be used at alternating landing sites.

Part of the horizontal flight test program is baselined to take place at Edwards AFB, California. The planning and scheduling effort begins with facility planning and activation. Facilities required will include freon, JP-4, 1500 psi GOX, 1500 psi GH_2, 3000 psi Helium and GN_2 supplies in addition to electrical power, maintenance buildings, office buildings, telemetry and instrumentation facilities,

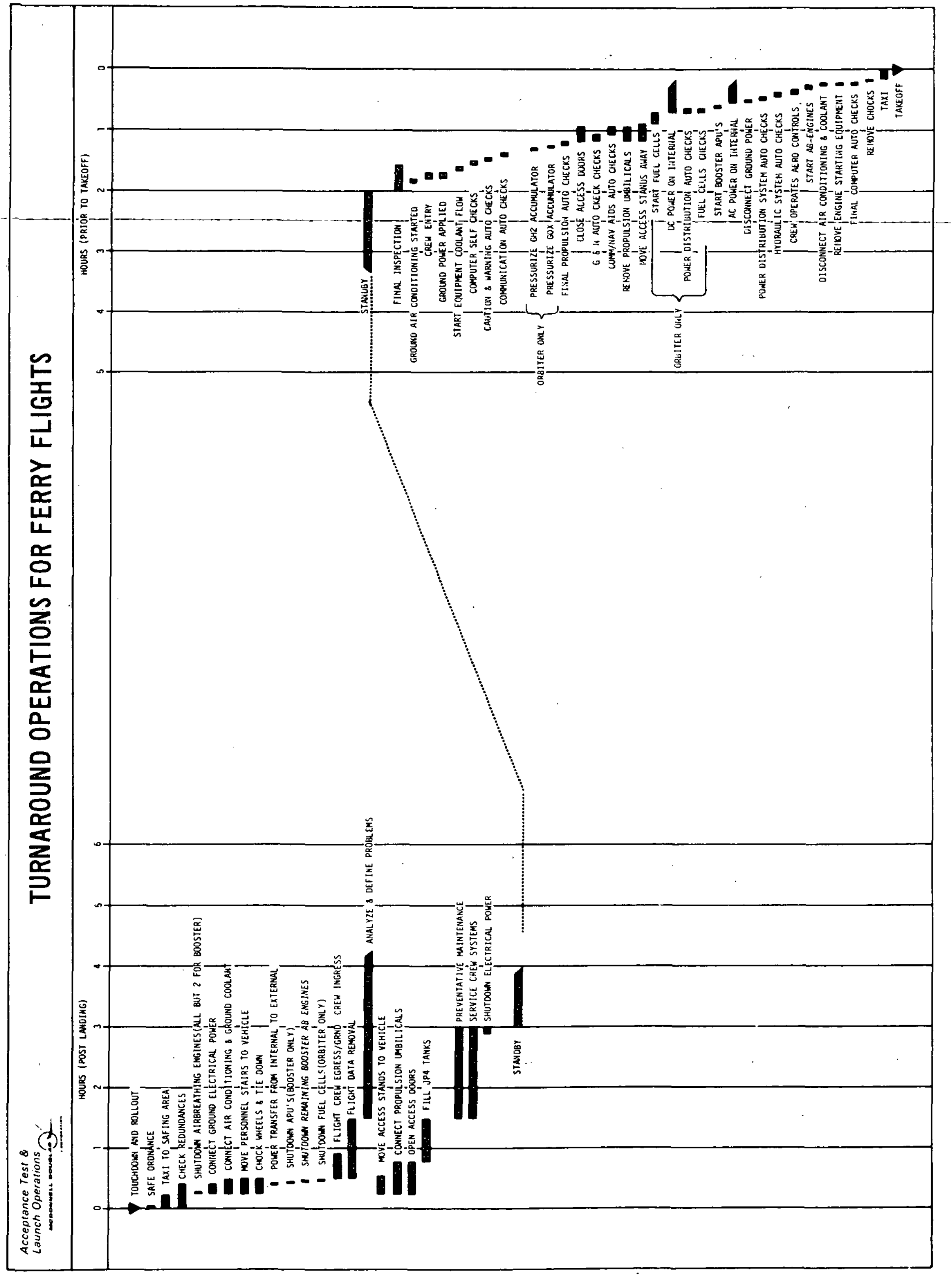

TURNAROUND OPERATIONS FOR FERRY FLIGHTS

FIGURE 3.3-5

telemetry relay stations and other base support items.

Ground Support Equipment will be flown in aboard logistics aircraft. The GSE will be allocated to the main stream of activities and can be used for remote site servicing after the completion of the horizontal test program. All necessary GSE will be connected to the facility equipment and then functionally tested. All fluid systems will be leak checked.

Only one Booster and one Orbiter, each being S/N 1, will be exclusively assigned as horizontal flight test vehicles and will be ferried to the horizontal flight test site. These vehicles will be refurbished for operational flights after the completion of horizontal flight testing. The remaining vehicles will undergo limited horizontal flight test at the launch site. Between each horizontal flight, the vehicle must go through deservicing, maintenance, checkout and servicing. A typical schedule is shown in Figure 3.3-6. The deservicing consists of removing residual GOX and GH_2 pressurants from the Orbiter and then purging prior to allowing normal work to be performed. The JP-4 tanks will be filled and the ullage purged with an inert gas so that the vehicle will be safe for operations inside the maintenance hangar.

3.3.1.2.2 Vertical Development Flight Operations - The Space Shuttle vertical development flight schedule is shown in Figure 3.3-7 and Figure 3.3-8. Two Space Shuttle vehicles, (comprising Booster S/N 3, Orbiter S/N 3; and Booster S/N 2, Orbiter S/N 2), will be utilized. These vehicles will proceed through ground checkout, ramp, and acceptance testing with a complete complement of production subsystems. Vehicles S/N 2 will have been utilized as ground propulsion cluster fire test articles, prior to final manufacturing.

Following a short period of horizontal flight testing, the vehicles will be committed to a period of preparation and prelaunch checkout and testing prior to vertical flight, with the first vertical mated launch occurring in April 1978. A

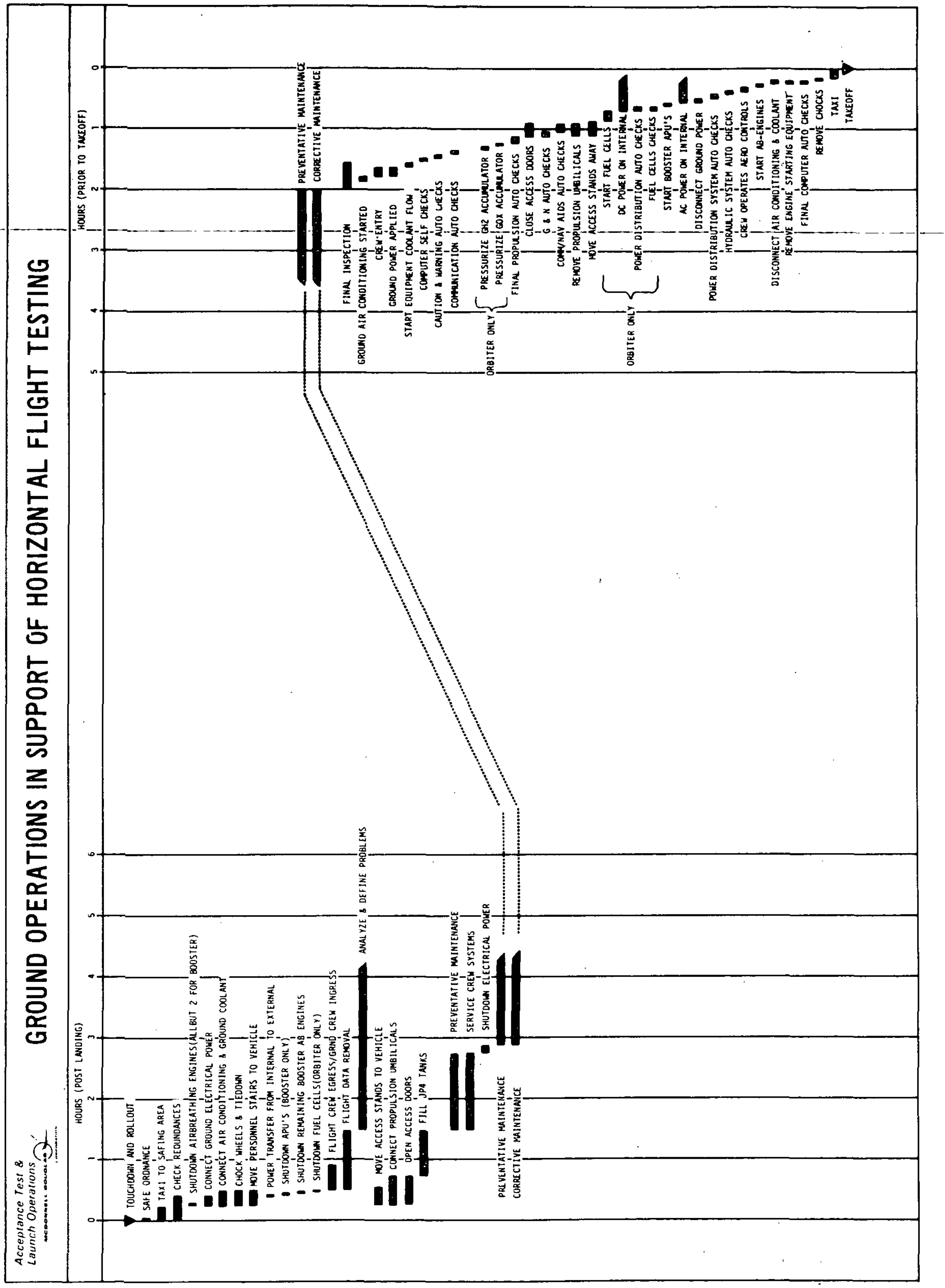

GROUND OPERATIONS IN SUPPORT OF HORIZONTAL FLIGHT TESTING
Acceptance Test & Launch Operations
MCDONNELL DOUGLAS
HOURS (POST LANDING)
0
1
2
3
4
5
6
TOUCHDOWN AND ROLLOUT
SAFE ORDNANCE
TAXI TO SAFING AREA
CHECK REDUNDANCES
SHUTDOWN AIRBREATHING ENGINES(ALLBUT 2 FOR BOOSTER)
CONNECT GROUND ELECTRICAL POWER
CONNECT AIR CONDITIONING & GROUND COOLANT
CHOCK WHEELS & TIEDOWN
MOVE PERSONNEL STAIRS TO VEHICLE
POWER TRANSFER FROM INTERNAL TO EXTERNAL
SHUTDOWN APU'S (BOOSTER ONLY)
SHUTDOWN REMAINING BOOSTER AB ENGINES
SHUTDOWN FUEL CELLS(ORBITER ONLY)
FLIGHT CREW EGRESS/GRND CREW INGRESS
FLIGHT DATA REMOVAL
ANALYZE & DEFINE PROBLEMS
MOVE ACCESS STANDS TO VEHICLE
CONNECT PROPULSION UMBILICALS
OPEN ACCESS DOORS
FILL JP4 TANKS
PREVENTATIVE MAINTENANCE
SERVICE CREW SYSTEMS
SHUTDOWN ELECTRICAL POWER
PREVENTATIVE MAINTENANCE
CORRECTIVE MAINTENANCE
HOURS (PRIOR TO TAKEOFF)
5
4
3
2
1
0
PREVENTATIVE MAINTENANCE
CORRECTIVE MAINTENANCE
FINAL INSPECTION
GROUND AIR CONDITIONING STARTED
CREW ENTRY
GROUND POWER APPLIED
START EQUIPMENT COOLANT FLOW
COMPUTER SELF CHECKS
CAUTION & WARNING AUTO CHECKS
COMMUNICATION AUTO CHECKS
PRESSURIZE GH2 ACCUMULATOR
PRESSURIZE GOX ACCUMULATOR
ORBITER ONLY
FINAL PROPULSION AUTO CHECKS
CLOSE ACCESS DOORS
G & N AUTO CHECKS
COMM/NAV AIDS AUTO CHECKS
REMOVE PROPULSION UMBILICALS
MOVE ACCESS STANDS AWAY
START FUEL CELLS
DC POWER ON INTERNAL
POWER DISTRIBUTION AUTO CHECKS
FUEL CELLS CHECKS
ORBITER ONLY
START BOOSTER APU'S
AC POWER ON INTERNAL
DISCONNECT GROUND POWER
POWER DISTRIBUTION SYSTEM AUTO CHECKS
HYDRAULIC SYSTEM AUTO CHECKS
CREW OPERATES AERO CONTROLS
START AB-ENGINES
DISCONNECT AIR CONDITIONING & COOLANT
REMOVE ENGINE STARTING EQUIPMENT
FINAL COMPUTER AUTO CHECKS
REMOVE CHOCKS
TAXI
TAKEOFF

FIGURE 3.3-6

VERTICAL FLIGHT TEST PLAN

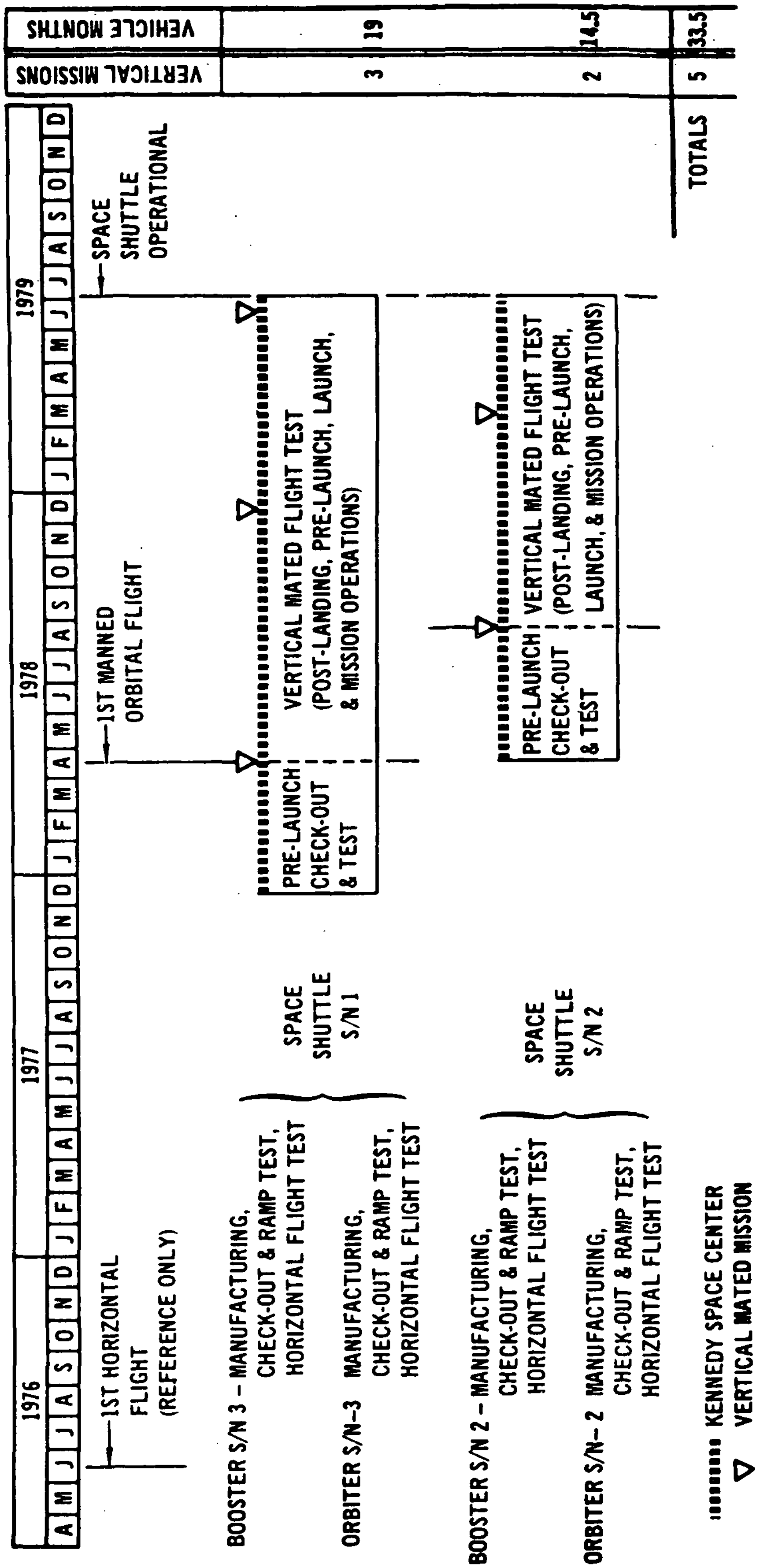


FIGURE 3.3-7

total of five vertical mated manned orbital launches are planned with operational capability scheduled for July 1979. All test vehicles will be refurbished and utilized as operational Space Shuttles upon completion of the flight test program. The vertical flight test plan will require very similar ground operations effort as that performed after the Shuttle becomes operational. The time required to perform the required tasks will be greater until experience and confidence is gained and the operation becomes routine. The turnaround cycle will consist of post landing, maintenance, prelaunch, and launch operations.

Prelaunch operations will consist of subsystems tests in the horizontal position in the hangar. The level of test in the beginning will be to the same level as factory acceptance tests.

The initial flights will be used to establish procedures and train the ground crew to operate in a cost-effective manner. The goal of the Shuttle program is to reduce costs and one of the most effective means of achieving this goal is by reducing personnel required as a result of reduced testing.

The level of test cannot be arbitrarily reduced without a resulting loss of confidence in the probable success of each mission. As pointed out in other sections of this plan, the first launch vehicles will undergo extensive checkout. These tests will be near the level that is planned for post-manufacturing acceptance testing. As the reliability of the Shuttle system is proven, the testing will be reduced and the confidence will be maintained by detailed computer analysis of the operations as shown in figure 3.3-9.

The first launch will consist of the following operations. Following receipt of each Orbiter and Booster from the horizontal flight test program, maintenance is performed, special test instrumentation installed and a pre-FRF checkout performed while the vehicles are in the horizontal position. This checkout will validate each vehicle's subsystems and test instrumentation required to support the FRF.

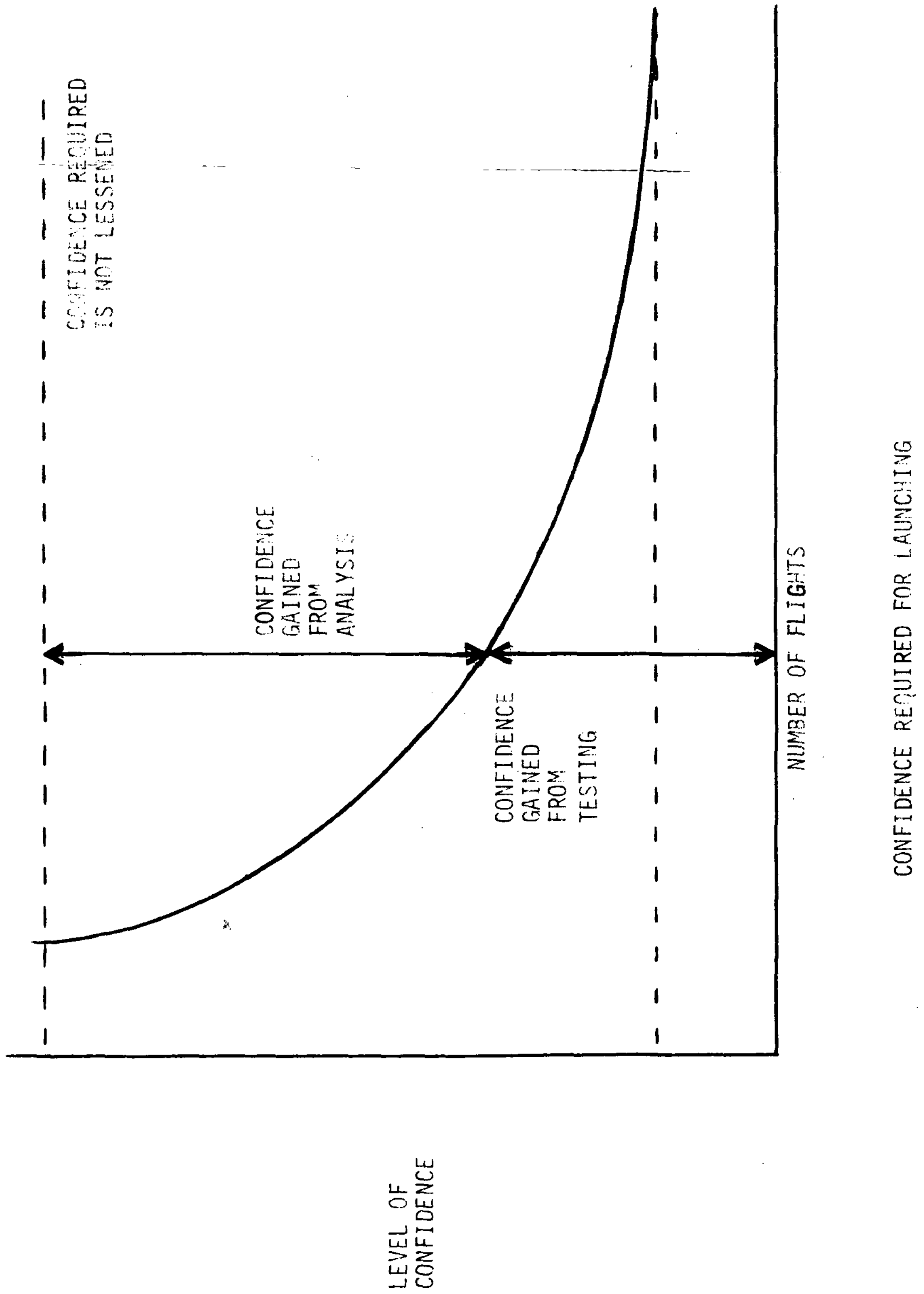

CONFIDENCE REQUIRED IS NOT LESSENED
CONFIDENCE GAINED FROM ANALYSIS
CONFIDENCE GAINED FROM TESTING
NUMBER OF FLIGHTS
CONFIDENCE REQUIRED FOR LAUNCHING
LEVEL OF CONFIDENCE

FIGURE 3.3-9

In the case of the Booster, this checkout is expanded to include prelaunch testing as well, because the Booster FRF is performed with the Orbiter installed in a launch configuration.

The Orbiter is then erected on a modified mobile launcher in the VAB. Vehicle subsystems, test instrumentation and equipment, and ML GSE are checked out. These tests will include EMC testing to verify no problem areas among the vehicle, test equipment, instrumentation, and GSE. The mobile launcher is transported to the pad. Facility connections to the ML are connected and verified. On pad preparations and checkout for the FRF are then performed. The FRF test will be conducted as defined in detail in the test plan. Subsequent to the FRF test the ML is returned to the VAB where the Orbiter is removed. Inspection and maintenance activities will be performed as necessary.

Prelaunch checkout for vertical flight will be performed on each Booster and Orbiter prior to mate to verify each vehicle's flight readiness. Subsystem tests will be performed as follows:

A. Avionics - Following such verification as may be dictated by maintenance operation, the vehicle will be powered by external power, and the avionics systems (DMS, crew station and display, G&N, Comm-navaids and flight controls) will be turned on. The crew will operate the systems through all modes and observe the display and caution and warning system for out-of-limit conditions, dropouts, or other indications of system anomalies. Voting and automatic redundancy switching logic will be exercised by selective power switching. Interfaces to the other vehicle will be verified by the use of GSE simulators for the interfaced component. Special flight test instrumentation operation and calibration will be verified by the telemetry link. The ability to load flight software programs from mass memory will be verified by loading, making parity checks, and running test problems, with computer comparison of the results.

B. Environmental Control and Life Support - Equipment cooling loops will be functionally checked as early as possible so that cooling support can be provided for the DMS. Cooling on the ground is provided by GSE. After the checkout of the DMS, other ECLS subsystems will be functionally checked and leak tested and serviced, as applicable. Redundancies will be checked. Checkout will be accomplished using portable GSE, external fluid supplies, and computer monitoring (onboard).

C. Propulsion - Leakage and functional tests of the propulsion subsystems - Main, ACPS, OMS, APU, ABES - will be performed to check the integrity and to establish that leakage (both internal and external) and component functioning (including all redundancies) are within established limits. Component functional checks will include internal valve leakage, valve response, regulation band, relief band, and pressure switch operating bands. The vehicle functions will be controlled via onboard computer subroutines while executive control and the fluid servicing required to support the testing will be performed by the GSE. Sequence checks on all engines and supporting systems will be performed to verify operational readiness.

D. Electrical Power - Control and monitoring functions of the power distribution system will be performed onboard, using both crew and DMS. With the exceptions of testing to isolate a power problem to an LRU and revalidate LRU operation and cases requiring special development test instrumentation, testing capability is onboard. Capability for checkout of the Orbiter alternator systems will be provided by spinning the APU gearbox with hot gas. The Booster will require running the APU on JP-4/air for this purpose.

E. Hydraulic Power - Checkout of the hydraulic systems is controlled and monitored onboard. Pumps, reservoirs, actuators, et cetera, will be checked out using onboard controls and computer monitoring. After maintenance actions requiring a component change, GSE is required to service, bleed and power the hydraulic systems. Upon completion of hydraulic systems checkout, the hydraulic systems provide support for checkout of landing subsystems, flight control surfaces and main engine actuators.

F. Mechanical Subsystems - Mechanical subsystems will be verified as soon as practicable; however, these activities will be scheduled around other subsystem testing. Control surface checkout and separation system checkout will be performed at this time.

G. Landing Subsystems - The landing subsystems consist of the landing gear, brakes/antiskid, nose gear steering and drag chute. Checkout of these subsystems is performed primarily from onboard, using crew procedures and computer monitoring.

Upon completion of individual subsystems tests, an all-up system test will be performed, where all subsystems interfaces with the vehicle, subsystems, test instrumentation, and GSE are validated and checked out. All subsystems are tested in sequence to establish operational readiness and check that all elements will function in the proper sequence for vertical flight.

Although not specifically planned, capability is provided to perform other tests to verify vehicle readiness. These include ABES run-up tests, taxi tests, and horizontal check flights as well as Booster JP-4/air APU run-up tests.

Following verification of electrical and mechanical tests performed in the hangar, the individual elements will be moved to the erection area. Prior to this move, however, the mobile launcher and its umbilicals, GSE, and test equipment will have been validated. The Booster and Orbiter are erected and mated on the mobile launcher, and interfaces to each other and to the mobile launcher are connected and verified. For the case of the first launch of the Booster, the Booster is erected and its interface with the ML checked out prior to the mating to the Orbiter.

Following verification of electrical and mechanical mating interfaces, an integrated systems test will be conducted, using external power and the onboard computer to sequence, control, and evaluate the system performance as applicable. The INS will perform a self alignment and verify the voting logic. Appropriate to the particular test, checks will be made of the interface between Orbiter/ Booster, Orbiter/cargo module and Shuttle/ground.

Electromagnetic compatibility tests will be conducted to verify that onboard switching operations and GSE switching operations cause no dropouts or spurious systems operations.

The mobile launcher, with the test vehicle, will be moved to the launch pad, the mobile launcher transferred to the pedestals, and the crawler removed. Prior to this move, the facility, GSE, and servicing systems will have been validated. Interfaces from the mobile launcher to the ground will be connected and verified. The DMS and test equipment will perform a check of the elements involved in the propellant loading operation, including hazardous condition detection and command inhibit routines associated with propellant loading. An EMC test involving the Shuttle, and mobile launcher in the launch RF environment will be made to check the compatibility of Shuttle operation with the launch facility. Additional operations preparatory for propellant loading and final systems readiness will be completed at this time, using the Monitor Display and Control (MDAC) unit.

A Countdown Demonstration Test (CDDT) will be performed to verify and demonstrate that all elements, Orbiter, Booster, GSE, facility, and test equipment perform properly through a count down up to the point of a simulated engine start and safely off-load propellants.

Upon completion of the CDDT, and prior to detanking cryogenics, the Booster FRF is performed as described in detail in the test plan. Inspections, maintenance and revalidations as required to verify launch readiness will be performed. Final preparations for launch are completed, propellants are loaded, flight crews ingress, final checks are completed, and the Shuttle is launched.

At the completion of the vertical flight, the Booster will land at Seymour Johnson AFB, North Carolina and the Orbiter will land at the landing strip adjacent to the launch facilities. Each will undergo post landing operations where propellant tankage systems are inerted. The Booster will be flown back to the launch site in the airplane mode. The vehicles will be inspected and tested to determine whether any defects or degradations occurred as a result of the vertical and horizontal flight modes. Corrective and preventive maintenance and revalidation tests will be performed as required. Due to the relatively long spacing between launches of any particular set of vehicles, the Orbiters and Boosters will be placed in a dormant storage condition until a short time prior to their next launch.

It is anticipated that prelaunch and launch activities for subsequent launches will not require extensive EMC tests nor will they require an FRF or CDDT. Subsystem, combined subsystem, and integrated systems tests will still be necessary, however.

The prelaunch activities for the third successive launch of Space Shuttle S/N 1 should be greatly reduced in intensity from that of the initial launch. With the exception of flight test instrumentation and special test equipment, activities should closely parallel those as anticipated for the operational launch through re-launch turnaround cycle.

3.3.1.3 Refurbishment of Development Test Vehicles - The Orbiter configuration modification for the flight test program consists of a crew escape system, flight test instrumentation, additional JP-4 fuel tanks for the cruise engines, one ABE and rocket engine simulators. The flight test instrumentation equipment will be located in an easily accessible area so that it can be serviced and easily removed after the flight test program. An additional JP-4 fuel tank will be added in the cargo bay. Rocket engine simulators will be installed in place of the flight rocket engines and an ABE will be added to the underside of the fuselage. The Orbiter that will be used for the major horizontal flight test program, will be refurbished to the vertical flight operational status. The refurbishment of this vehicle will consist of the following general activities:

- Remove rocket engine simulators and install flight rocket engines
- Remove ABE from underside of fuselage
- Remove escape system
- Modify explosive hatches to production configuration
- Remove JP-4 fuel tank from cargo bay
- Refurbish JP-4 fuel system
- Remove all accessible flight test equipment
- Remove flight test wire bundles where practical
- Complete inspection for structural and thermal damage
- Repair and refurbish any of the discrepancies noted by inspection
- Incorporate all outstanding engineering modifications
- Perform maintenance and replace time critical units

The Booster configuration modifications for flight testing are similar to the Orbiter except that additional JP-4 fuel tanks are not required. The Booster that will be used for the major horizontal flight test program, will be refurbished to the vertical flight operational status.

The Booster refurbishment activities will be much the same as for the Orbiter with the exception that the cruise engine fuel system would not have to be reconfigured.

The remaining Boosters and Orbiters will be similar to the above noted Orbiter and Booster flight test configurations. The main difference is that the flight instrumentation will be for the vertical flights primarily and flight rocket engines will be installed. Both the Orbiters and Boosters will engage in a short horizontal flight test program prior to the vertical flight test program thereby making it necessary to have a two step refurbishment activity prior to the vehicles being operational.

The basic refurbishment prior to the vertical flights will consist of the following general activities:

- Remove ABE from underside of fuselage
- Modify explosive hatches to production configuration
- Complete inspection for structural and thermal damage
- Repair and refurbish of discrepancies noted by inspection
- Perform maintenance and replace time critical units

At the completion of the vertical development flights, these vehicles will require additional refurbishment in order to meet the operational vehicle configuration requirements. This refurbishment will consist of the following:

- Remove JP-4 fuel tank from cargo bay (Orbiter only)
- Remove escape system
- Refurbish JP-4 fuel system
- Remove all accessible flight test equipment
- Remove flight test wire bundles where practical
- Inspect rocket engines

- Complete inspection for structural and thermal damage
- Repair and refurbishment of discrepancies noted by inspection
- Incorporate all outstanding engineering modifications
- Perform maintenance and replace time critical units

The retest requirements for all the vehicles after a refurbishment cycle will be to a level consistent with post manufacturing checkout and be consistent with the test requirements during the prelaunch and launch operational activities. These activities are identified in detail in Sections 3.3.1.1, 3.3.1.5 and 3.3.1.6.1. Test requirements are identified in the Test Plan.

3.3.1.4 Turnaround Cycle - The prime operational objective is to be able to launch each vehicle within 10 working days from the start of turnaround activities. Turnaround cycle includes the activities that occur from landing through re-launch of the Space Shuttle Vehicles. This cycle has been subdivided into four distinct phases of operations. (1) Postlanding (ref. section 3.3.1.7); (2) Maintenance (ref. section 3.3.1.8); (3) Prelaunch (ref. section 3.3.1.5); and (4) Launch (ref. section 3.3.1.6). Figure 3.3-10 identifies the key activities that occur during each phase of operations.

Included in this section is the checkout philosophy and redundancy testing approach we feel necessary to obtain the 10 day turnaround. Also included is our philosophy in obtaining operational status and a description on initialization of a dormant vehicle prior to test or checkout.

3.3.1.4.1 Checkout Philosophy and Redundancy Testing - The following definition of checkout is intended for the operational phase. This philosophy is quite different from that planned for the development phase. Certain assumptions must be made: first, that each vehicle has already proven that it can be operated as intended, and second, that the viability of the operational test plan was proven during the development testing.

Previous programs to the Shuttle Program were different in that they utilized vehicles which had not previously flown. Tests were performed at the manufacturing site and at the acceptance test site (static firing) followed by repetitive testing at the launch site. It was believed that the many tests would, first, locate all of the components which may fail during flight and second, give the launch crew confidence that the vehicle would be successful during the mission operations. It is doubtful if either of these objectives were achieved because the test conditions were, in most cases, far from the extreme conditions which the vehicle would experience during flight. Too often, the test conditions were established either

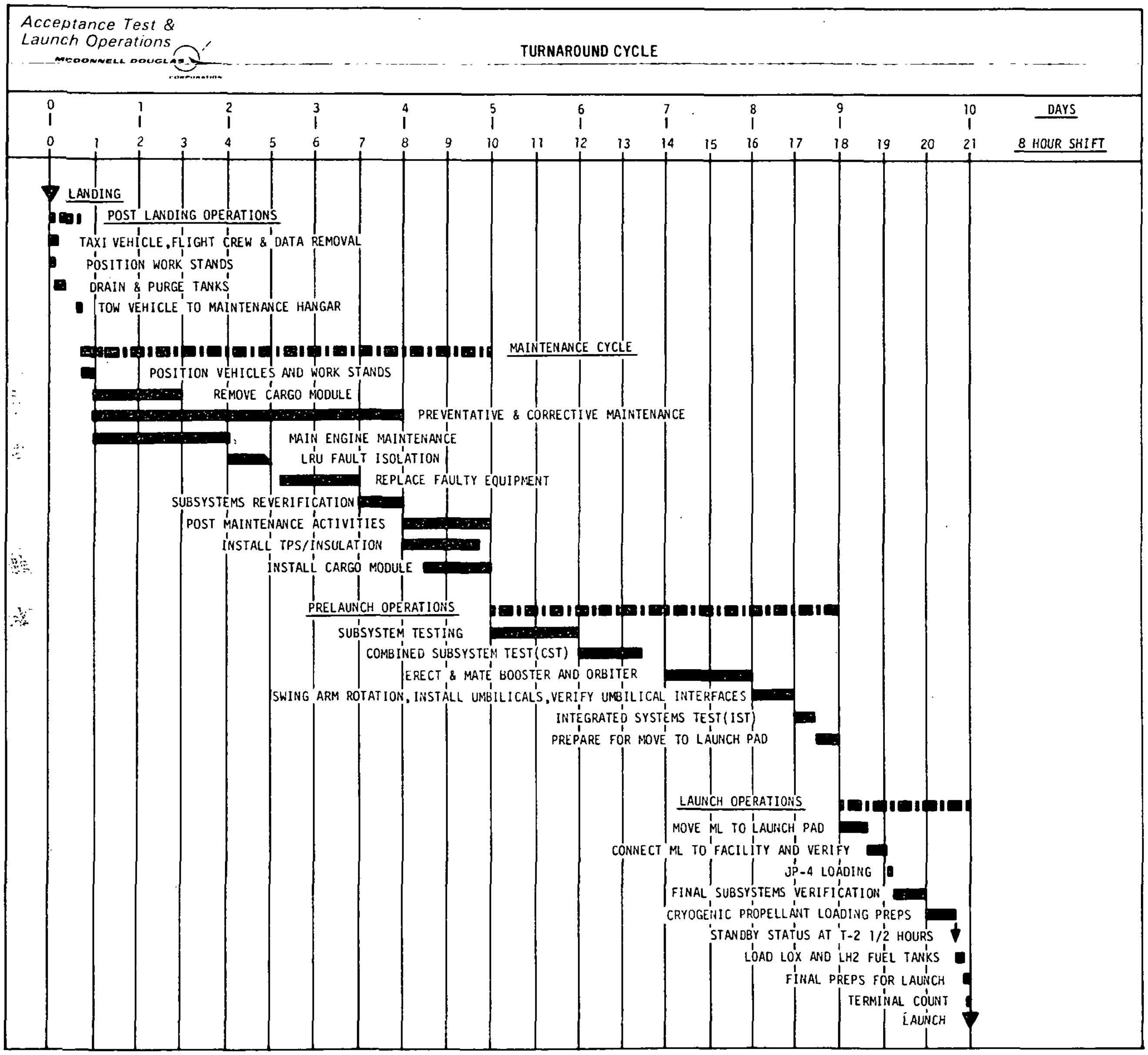

Acceptance Test & Launch Operations
McDONNELL DOUGLAS CORPORATION
TURNAROUND CYCLE
DAYS
0 1 2 3 4 5 6 7 8 9 10
8 HOUR SHIFT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
LANDING
POST LANDING OPERATIONS
TAXI VEHICLE, FLIGHT CREW & DATA REMOVAL
POSITION WORK STANDS
DRAIN & PURGE TANKS
TOW VEHICLE TO MAINTENANCE HANGAR
MAINTENANCE CYCLE
POSITION VEHICLES AND WORK STANDS
REMOVE CARGO MODULE
PREVENTATIVE & CORRECTIVE MAINTENANCE
MAIN ENGINE MAINTENANCE
LRU FAULT ISOLATION
REPLACE FAULTY EQUIPMENT
SUBSYSTEMS REVERIFICATION
POST MAINTENANCE ACTIVITIES
INSTALL TPS/INSULATION
INSTALL CARGO MODULE
PRELAUNCH OPERATIONS
SUBSYSTEM TESTING
COMBINED SUBSYSTEM TEST (CST)
ERECT & MATE BOOSTER AND ORBITER
SWING ARM ROTATION, INSTALL UMBILICALS, VERIFY UMBILICAL INTERFACES
INTEGRATED SYSTEMS TEST (IST)
PREPARE FOR MOVE TO LAUNCH PAD
LAUNCH OPERATIONS
MOVE ML TO LAUNCH PAD
CONNECT ML TO FACILITY AND VERIFY
JP-4 LOADING
FINAL SUBSYSTEMS VERIFICATION
CRYOGENIC PROPELLANT LOADING PREPS
STANDBY STATUS AT T-2 1/2 HOURS
LOAD LOX AND LH2 FUEL TANKS
FINAL PREPS FOR LAUNCH
TERMINAL COUNT
LAUNCH

FIGURE 3.3-10

by safety limitations (such as the 4:1 burst requirement) or by hardware limitations (the throat plug of an engine allows checking the hot gas system at about 5% of systems operating pressure). What does a leak check of a system which operates at -423 °F and at 6,000 PSI prove if checked at 10 PSI and at 70°F? It is obvious that testing at anything less than operating conditions really only provides a low level of confidence.

The level of confidence that is required for launch of the Shuttle should not be lessened by abbreviation of checkout, and should be just as high as that required for any other kind of launch vehicle. The difference between the Shuttle Program and other programs is in the method of achieving the required confidence level. The Shuttle vehicle is a reusable vehicle which means that certain knowledge is gained from the multiple usage of the vehicle and knowing that it has successfully performed its previous missions with success which results in establishing a known baseline. The level of confidence in the Shuttle program is based on having this known baseline and then analyzing the performance of each flight to update that baseline. In other words, baseline plus previous flight analysis gives confidence required for the next flight. This method of gaining confidence will probably prove to be more effective than methods which were utilized by previous programs.

Operational data will be analyzed to verify that the various systems are ready for flight. For example, the flight sequence will be checked to verify that the sequence was exactly as intended and the engine start transients will be checked to verify that they were in limits and have not changed greatly from the previous flights. The plan is for maximum utilization of flight data to verify that the vehicle is ready for the next flight. In other words, the best method for determining the health of the vehicle is by analyzing the data from the previous flight. See Figure 3.3-11 for the types of parameters that will be analyzed.

Obviously, certain data cannot be obtained from analyzing the previous flight. Ground testing must be used to supplement the operations analysis. Ground testing

TYPES OF PARAMETERS THAT WILL BE ANALYZED

- PRESSURE DATA
  - TO INDICATE LEAKAGE BY PRESSURE DECAY OR CONSUMABLES USAGE
  - CONFIRM CORRECT OPERATION OF VALVE
  - ~~CONFIRM MALFUNCTIONS INDICATED BY VALVE POSITION~~
  - VERIFY CORRECT SYSTEM OPERATION AS COMPARED WITH EXPECTED PRESSURE PROFILE
- TEMPERATURE DATA
  - VERIFY THAT INSULATION IS INTACT
  - ASSIST IN PRESSURE DECAY EVALUATION
  - VERIFY CORRECT SYSTEM OPERATION AS COMPARED WITH EXPECTED TEMPERATURE PROFILE
- DISCRETES DATA
  - VERIFY THAT ALL VALVES OPERATE
  - VERIFY CORRECT OPERATION AS COMPARED TO EXPECTED OPERATING TIME
  - VERIFY THAT ALL SYSTEMS OPERATE IN THE PROPER SEQUENCE
- VOLTAGE/CURRENT/FREQUENCY DATA
  - TO INDICATE PROPER OPERATION OF FUEL CELLS AND APU'S
  - CONFIRM CORRECT LOADS
  - DETECT SHORTS AND INTERMITTENT CONDITIONS
  - VERIFY CORRECT SYSTEM OPERATION AS COMPARED WITH EXPECTED OPERATIONS
- OTHER DATA
  - VERIFY THAT AREA SENSORS SUCH AS SPECTROMETER OR ULTRA-SONIC RECORD LEVELS EXPECTED
  - ACOUSTICAL/VIBRATION DATA WILL INDICATE IMPROPER TURBO-MACHINERY OPERATION
  - FLOW DATA WILL BE COMPARED TO EXPECTED FLOWS
  - MASS DATA TO DETERMINE PROPER CONSUMABLE USAGE

FIGURE 3.3-11

should be minimized and should include only that testing necessary to satisfy the launch team that the vehicle is ready for the next mission after the analysis of the previous flight is completed. This type of testing essentially falls into two categories: (1) testing that is necessary because the analysis of previous flights' data does not completely satisfy certain safety or flight critical functions, and (2) testing that is necessary to verify that redundancies were operating properly although the flight analysis could not verify same. Such examples of the foregoing are a hazardous condition that would exist if certain external leakages were not checked or the primary redundant hydraulic pumps which operate at the same time and cannot be verified that each operate in flight; therefore, the pumps must be verified individually on the ground.

In addition, certain tests must be performed after the maintenance functions have been completed to verify that the maintenance functions have been successfully completed, and that the maintenance activities did not lessen the reliability of the vehicle. In the first case, all interfaces which were invalidated due to maintenance operations must be revalidated. In the second case, an electro-mechanical test must be performed to verify that no control or monitor wires were inadvertently disturbed during maintenance operations.

Testing of all redundancies should not be laid down as a firm requirement. Other aspects must be analyzed. One must question the effects of loss of the redundant component - does it lessen the probability of success of the next mission? If the answer is no, then there is not a requirement to check that redundancy between flights. Several factors must be analyzed to determine whether a redundant item must be tested between flights. First, the failure effects must be analyzed to determine if the failure results in loss of mission or a major disaster, then obviously, the redundancy must be checked. If the redundancy checks, in themselves, render the vehicle less reliable, then checking of the redundancy must be questioned. For example, if it is necessary to break into a system to check redundancy such as a check valve, then the system may become less reliable due to injection of contaminants. The total reliability must be assessed.

In summary, the only tests that will be required during turnaround operations will be those that are necessary to supplement the analysis of operations to verify that the vehicle is ready for the next mission.

3.3.1.4.2 Operational Status - During vertical flight test operations, the turnaround cycle is planned to be 3 months. A total of 5 vertical launches are now baselined. These launches will include tests, such as EMC, engine static firing, etc., which will not be applicable to the operational launches. With the elimination of these special tests, and even though we have verified fuel loading techniques, demonstrated subsystems performance, and ground support equipment operation, it is still believed that operational status will not be obtainable until the twentieth flight. By then, a sufficient confidence level in operational, maintenance, and control procedures to support a routine 10 day turnaround cycle will have been attained.

3.3.1.4.3 Dormant Vehicle Initialization - Dormant Shuttle Vehicles will be initialized prior to launch at various times within the turnaround cycle in support of test/checkout. After initialization of a Shuttle Vehicle, it is a requirement that the vehicle configuration control software will always return the vehicles to a safe powered down known configuration.

The baseline operational sequence to activate a passive vehicle is as follows:

A. Connect or verify the following umbilicals/GSE connections

- ECLS ground cooling
- Ground power
- Data bus and audio interfaces
- Propulsion, pneumatics, purge lines, etc.

Instrumentation or electrical power is not required for fluid umbilical connections because pneumatics will not be applied during that time frame.

B. Ground Cooling Flow - Parameters for monitoring the onboard ECLS functions require that the data management system be operational. This is not a constraint since the initial activation of the data management and display system does not require coolant flow.

C. Electrical Power - The electrical power distribution startup requires GSE power to main power control units via umbilicals. The presence of power will be verified on dedicated displays (volt meters) on the instrument panel. Feeder power controls the PDU's for power distribution.

D. After activation of the power bus the data management subsystem power is provided using panel mounted switches. In addition, the display power control is activated. After vehicle warmup the operation is verified by internal BITE. All four computers are turned on in sequence. The keyboard is then used to initiate computer self test. The computer always has a boot strap program for initialization and self test. Upon completion of the self test the computer indicates a Ready Status. At this point the desired test sequence can be called up via the keyboard. The program residing within the computers is capable of maintaining a safe vehicle configuration including the Emergency Caution and Warning (EC&W) functions.

E. The coolant pumps are now brought on line and monitoring of the system performance monitored by the data management system and EC&W functions.

F. At this point the system is in a ready condition for any desired test sequence.

G. Vehicle shut down will essentially reverse the procedure outline for start up.

H. The vehicle configuration control software will be setup to return to a specific configuration for either a "test complete" command from the keyboard or from an "emergency shut down" command. An emergency could occur external to the vehicle associated with propellant loading which would require the vehicle to go to a safe condition. This routine is part of the software required for safe operation.

I. With the above provisions for shut down the passive vehicle would always be returned to a predetermined configuration in a ready condition for power up.

3.3.1.5 Prelaunch Operations (Operational Vehicles) - Prelaunch operations consist of the activities occurring during buildup and checkout of the operational Space Shuttle Vehicles. The system used to manage the handling of Line Replaceable Units (LRU), assembling and checkout of the cargo modules, and mission peculiar activities that effect ground operations are also covered in this section.

3.3.1.5.1 Orbiter/Booster - Prelaunch activities for the Orbiter and Booster consists of subsystems testing, Combined Subsystems Test (CST), erection and mate, and Integrated Systems Tests (IST). Figure 3.3-12 identifies the flow and schedule for these activities.

3.3.1.5.1.1 Subsystems Testing - Subsystems testing and CST will be conducted with the vehicles horizontal utilizing the onboard Data Management Subsystem (DMS) to the maximum extent possible to verify subsystems redundancies, and end-to-end subsystems operation to the degree required to show flight readiness prior to mate. The DMS will be used to power up (using external power) the onboard subsystems and will interface with the Monitor Display and Control (MDAC) unit which is used to control GSE and the Ground Automatic Test System (GATS). The onboard computer will control the test sequence, subsystem configuration and inhibit improper commands. The GATS will monitor the test commands and responses on the data bus and compare

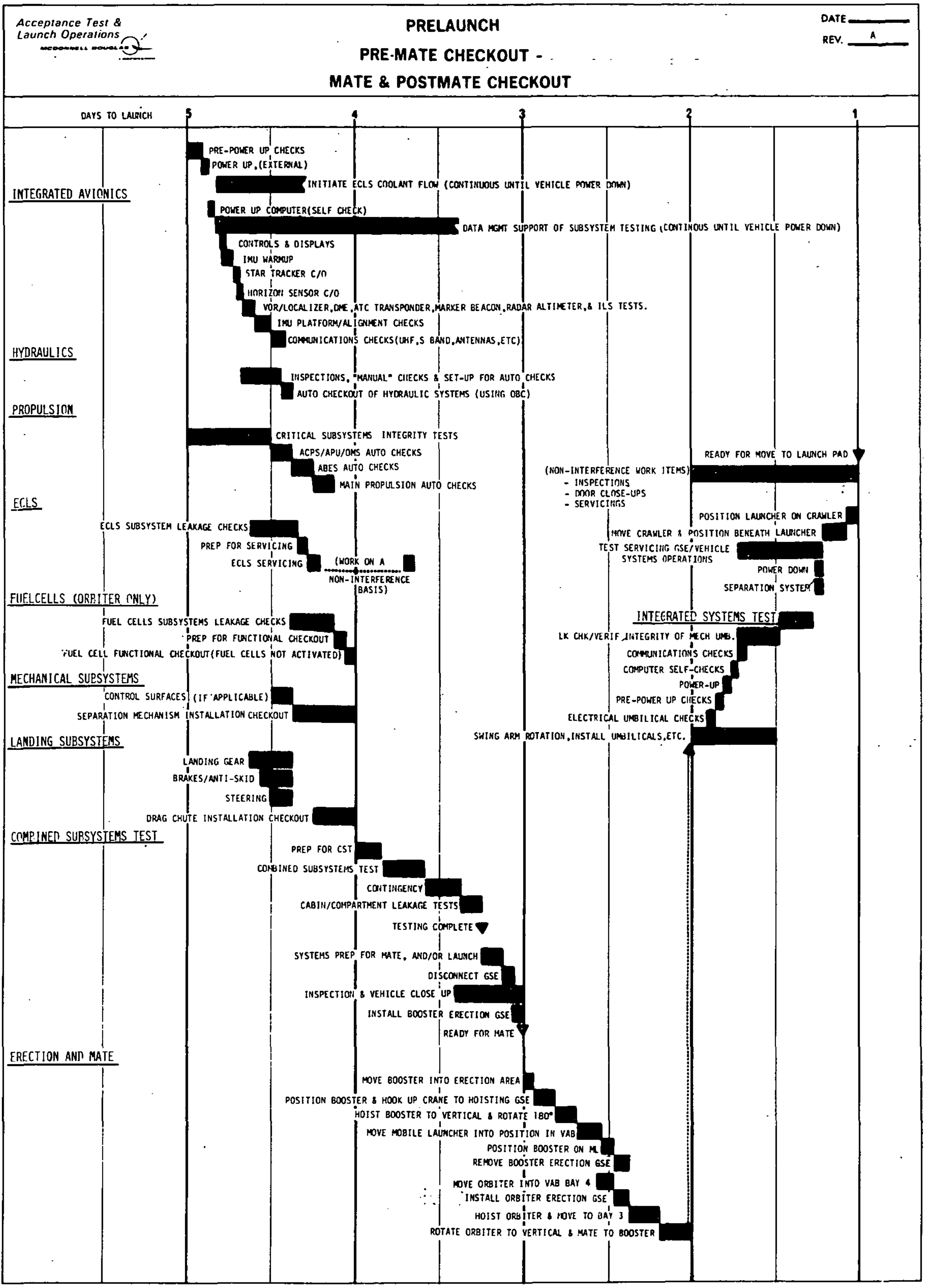

Acceptance Test & Launch Operations
MCDONNELL DOUGLAS
PRELAUNCH
PRE-MATE CHECKOUT -
MATE & POSTMATE CHECKOUT
DATE
REV. A
DAYS TO LAUNCH
5
4
3
2
1
INTEGRATED AVIONICS
PRE-POWER UP CHECKS
POWER UP,(EXTERNAL)
INITIATE ECLS COOLANT FLOW (CONTINUOUS UNTIL VEHICLE POWER DOWN)
POWER UP COMPUTER(SELF CHECK)
DATA MGMT SUPPORT OF SUBSYSTEM TESTING (CONTINOUS UNTIL VEHICLE POWER DOWN)
CONTROLS & DISPLAYS
IMU WARMUP
STAR TRACKER C/O
HORIZON SENSOR C/O
VOR/LOCALIZER,DME,ATC TRANSPONDER,MARKER BEACON,RADAR ALTIMETER,& ILS TESTS.
IMU PLATFORM/ALIGNMENT CHECKS
COMMUNICATIONS CHECKS(UHF,S BAND,ANTENNAS,ETC)
HYDRAULICS
INSPECTIONS, "MANUAL" CHECKS & SET-UP FOR AUTO CHECKS
AUTO CHECKOUT OF HYDRAULIC SYSTEMS (USING OBC)
PROPULSION
CRITICAL SUBSYSTEMS INTEGRITY TESTS
ACPS/APU/OMS AUTO CHECKS
ABES AUTO CHECKS
MAIN PROPULSION AUTO CHECKS
ECLS
ECLS SUBSYSTEM LEAKAGE CHECKS
PREP FOR SERVICING
ECLS SERVICING
(WORK ON A NON-INTERFERENCE BASIS)
FUELCELLS (ORBITER ONLY)
FUEL CELLS SUBSYSTEMS LEAKAGE CHECKS
PREP FOR FUNCTIONAL CHECKOUT
FUEL CELL FUNCTIONAL CHECKOUT(FUEL CELLS NOT ACTIVATED)
MECHANICAL SUBSYSTEMS
CONTROL SURFACES (IF APPLICABLE)
SEPARATION MECHANISM INSTALLATION CHECKOUT
LANDING SUBSYSTEMS
LANDING GEAR
BRAKES/ANTI-SKID
STEERING
DRAG CHUTE INSTALLATION CHECKOUT
COMBINED SUBSYSTEMS TEST
PREP FOR CST
COMBINED SUBSYSTEMS TEST
CONTINGENCY
CABIN/COMPARTMENT LEAKAGE TESTS
TESTING COMPLETE
SYSTEMS PREP FOR MATE, AND/OR LAUNCH
DISCONNECT GSE
INSPECTION & VEHICLE CLOSE UP
INSTALL BOOSTER ERECTION GSE
READY FOR MATE
ERECTION AND MATE
MOVE BOOSTER INTO ERECTION AREA
POSITION BOOSTER & HOOK UP CRANE TO HOISTING GSE
HOIST BOOSTER TO VERTICAL & ROTATE 180°
MOVE MOBILE LAUNCHER INTO POSITION IN VAB
POSITION BOOSTER ON ML
REMOVE BOOSTER ERECTION GSE
MOVE ORBITER INTO VAB BAY 4
INSTALL ORBITER ERECTION GSE
HOIST ORBITER & MOVE TO BAY 3
ROTATE ORBITER TO VERTICAL & MATE TO BOOSTER
INTEGRATED SYSTEMS TEST
SWING ARM ROTATION,INSTALL UMBILICALS,ETC.
ELECTRICAL UMBILICAL CHECKS
PRE-POWER UP CHECKS
POWER-UP
COMPUTER SELF-CHECKS
COMMUNICATIONS CHECKS
LK CHK/VERIF INTEGRITY OF MECH UMB.
SEPARATION SYSTEM
POWER DOWN
TEST SERVICING GSE/VEHICLE SYSTEMS OPERATIONS
MOVE CRAWLER & POSITION BENEATH LAUNCHER
POSITION LAUNCHER ON CRAWLER
(NON-INTERFERENCE WORK ITEMS)
- INSPECTIONS
- DOOR CLOSE-UPS
- SERVICINGS
READY FOR MOVE TO LAUNCH PAD

FIGURE 3.3-12

them with a reference program and previous test results to evaluate the particular subsystem. Print-outs of limit conditions will be provided via the MDAC unit. Proven software and procedures, verified during subsystem testing at the contractor's facility and during the development test program, will be utilized. Checkout or tests performed during the maintenance cycle due to fault isolation activities or component replacement will not be repeated during the prelaunch phase.

All GSE connections will be made prior to the start of this phase. The integrity of the GSE/vehicle interface will be checked by operating the GATS and MDAC in the self test mode. The following is a description of the Orbiter and Booster prelaunch activity during subsystem testing.

Integrated Avionics Subsystems - The following subsystems make up the integrated avionics:

A. Data Management
B. Guidance and Navigation
C. Communications and Navaids
D. Flight Control

Subsystem testing begins with the prepower up checks including crew station switch settings. External power is applied to the vehicle via the Main Power Control Units (MPCU) through the umbilical. When proper voltages at the MPCU are indicated, the Power Distribution Units (PDU) are activated by closing the feeder power controllers located in the MCPU's by operation of hardwired switches. The Data Management System (DMS) is placed in operation by manual operation of switches hardwired to the Remote Power Controllers (RPC) associated with the DMS. Following this the ECLS is brought up via the data bus and the proper operation of the activated subsystem is verified. Other subsystems can now be brought up to satisfy the required test configuration.

The data management subsystem must be verified first and remain up and operating along with the ECLS coolant flow to support all subsystem testing until vehicle power down. This subsystem must perform such functions as data processing for navigational sensors, vehicle checkout and fault isolation and configuration management. Onboard checkout capability is utilized for DMS verification of the system to the LRU level. Initial subsystem checkout and integration into the vehicle will be supported by GSE which can monitor test parameters at special test connectors on the LRU's. After the subsystem is verified in the vehicle, maximum utilization of the computer software and hardware built-in-test (BIT) will be made for all checkout.

The checkout/test process in the central computer can be divided into two major categories: hardware BIT and computer self-test. Failures in the memory unit can be detected by use of memory parity checks. In addition to this type of check, the memory also provides built-in test features such as: power transient, power failure, overvoltage and overcurrent. The memory protection scheme also enables detection of illegal memory access, errors due to programming mistakes or a hardware failure. The capability also exists to detect a lockout of a memory request for a period longer than the normal required memory access period. The Central Processing Unit (CPU) provides BIT for illegal function codes, illegal address fields and arithmetic errors which should not appear in verified programs. Synchronization with the System Control Unit (SCU) can be used to detect any failures such as unusually large drift in the CPU clock. Self-tests can be used very effectively during idle periods when the computer is not performing any operational tasks. Continuous test of the SCU is performed by real time comparison of the outputs of the quad redundant SCU's in adaptive voters to isolate non-conforming units. DIU's are tested once per second by a data bus loop test.

The Guidance and Navigation (G&N) subsystem includes the inertial measuring unit (IMU), star tracker, and horizon sensor with other equipment in the Comm-

Navaids subsystem used to perform the overall G&N functions. The DMS and computer checkout system are used to check the IMU calibration, scale factor, null shift and drift compensation and the operation of BIT functions in the subsystem. Calibration and alignment of the IMU is accomplished by gyrocompassing techniques. GSE will be used to check the installation and performance of the star tracker and horizon sensor. This provides an end-to-end check of the optical system.

The comm-Navaid subsystem is verified during subsystem tests by using the DMS for limit check, BIT and onboard checkout software and ground stations for open loop tests. The fault monitoring feature of the DMS will be checked after the test to compare results with previous tests and determine any trend toward degraded performance. VOR receivers, DME sets, ATC transponders, radar altimeters, ILS receivers, UHF transceivers, S-band equipment and intercoms are the major items in this subsystem.

The flight control subsystem includes the stability augmentation system (SAS) electronics, TVC electronics, ACPS/OMS electronics, static pressure sensors, two axis accelerometer package, three-axis rate gyro package, and air data sensors. The subsystem is verified in the prelaunch phase of operations using the onboard checkout software and DMS for automatic checkout. Checks of the air data system will be made to see that it reads ambient pressures. GSE will be required to check for leaks. The data bus will provide signals to torque the rate gyros. Subsystem response time will be checked using internally generated test stimuli. No electrical calibration of the pressure sensors will be required. An automated velocity test using low hydraulic power and transient input may be used to verify control surface deflection. Redundancies and interfaces between the main engine computers and the central computers and air data sensors will be verified.

Hydraulics Subsystem - The hydraulic subsystem is verified during this phase utilizing the onboard DMS and crew station controls and displays. However, the

Orbiter APU gear box will have to be spun-up, by a mechanical means, to obtain partial subsystem power output from the hydraulic pumps to support ground checkout. Hot firings are not planned during prelaunch operations. The hydraulic subsystem is used to verify (if applicable) the landing gears, brakes, flight control surfaces, and the main engine actuators. Pumps, accumulators, fluid reservoirs, actuators, and crew station controls are the major items that make up the hydraulic subsystem.

Propulsion Subsystems - All propulsion subsystems are verified during this phase utilizing the onboard DMS and computer test subroutines. Ground support equipment (GSE) is required to supply inert gases. Supplemental instrumentation required in support of these operational prelaunch tests will be incorporated in the GSE. Plumbing disassembly for external pressure stimuli is not planned for the operational phase.

The operational prelaunch propulsion tests are to verify the capability of the vehicles to perform the next assigned mission. Flight crew observations and/or the recorded data of the previous flight performance provides a positive, conclusive indication of stage condition and capability for continued operation. This represents testing under the most realistic environments possible. Post flight data analysis of the propulsion subsystems will be utilized to determine that the propulsion tankage, lines, engines and components show no deterioration in integrity due to operations since the previous launch. Those subsystems components for which the analysis is not conclusive will require reverification if dictated by a stringent mission or safety requirement. This consideration establishes the prelaunch testing as a verification that the condition of the functional elements of the vehicles have not changed since the landing, a verification that all maintenance, repair or replacement has been satisfactorily accomplished, and a verification that the redundant elements not operated during the last mission are still in operational readiness.

A. ACPS/OMS/APU Propulsion Subsystems - The ACPS/OMS/APU propulsion systems are verified during the same time frame due to having common tankage, propellant conditioners and accumulators. However, the OMS is peculiar to the Orbiter vehicle. Automatic functional checks will be performed on these subsystems.

B. Air Breathing Engines Subsystem (ABES) - Automatic functional checks will be performed on the ABES.

C. Main Propulsion Subsystem - Pressure check of main engine bells are not planned. Utilizing only the capability of the DMS required for flight and with minimum simulation, the main propulsion systems are run through an automatic simulated flight sequence using the pneumatic power control system to operate pneumatic valves. Most backup elements and functional relief devices (not burst discs) will be verified but not necessarily on a routine basis. Tanks will be protected against contamination by maintaining a positive pressure which is provided by the ground pressurant supply.

Environmental Control Life Support (ECLS) Subsystem - The ECLS subsystem is made up of the cabin atmosphere/pressurization loop, and cabin and equipment coolant loops. Checkout is primarily performed from onboard using crew procedures and computer monitoring. GSE is required to supply inert gases for subsystem integrity checks and for flight servicing of onboard tankage, and to perform certain redundancy verification checks.

GSE conditioned air supply is required when personnel are inside the crew or passenger compartments. A GSE coolant unit is required to provide cooling fluid to the vehicle ground cooling heat exchanger when power is applied to the vehicles. These coolant loops are monitored using inflight capability during ground operations.

Breathing GO_2 and GN_2 (Orbiter), and air (Booster) tanks, valves, and lines are pressurized and gross integrity checks are performed. These checks are followed by servicing of the ECLS atmosphere/pressurization tankage. Servicing is to be performed on a non-interference basis with other subsystem testing.

The Orbiter water subsystems, waste management and food management subsystems are checked out. Following checkout, the water subsystems, as applicable, are serviced using GSE.

Fuel Cells Subsystem - Activation of fuel cells is not planned during prelaunch operations. The fuel cell pressurization system will be pressurized and gross integrity checks made. Functional checks will follow and are primarily performed from onboard using crew procedures and computer monitoring.

Mechanical Subsystems - Mechanical subsystems will be verified during the first day of prelaunch. However, activities will be scheduled around subsystem testing. Control surface checkout will be scheduled during this time frame (if required) because of the availability of hydraulics power.

Landing Subsystems - The landing subsystems consist of the landing gear,brakes/anti-skid,nose gear steering,and the Orbiter drag chute. Checkout of these subsystems are performed primarily from onboard using crew procedures and computer monitoring.

If no problems exist from the last flight, the landing gears subsystem will not be cycled during the prelaunch phase. Pressure switches and electrical switches are monitored via the DMS for timing and activation. During erection and mate, the landing gears are to be retracted and locked.

Brake subsystem pressure, up stream of the brake control valve, is monitored via the cabin displays when hydraulic power is available. The anti-skid subsystem has a BIT circuit which is checked and verified during this test phase.

The nose gear steering subsystem is not physically verified during prelaunch if no problems occurred during the previous flight. Switches and valves are monitored via the DMS. Steering is automatically disengaged when nose gear is retracted prior to erection and mate.

The Orbiter drag chute subsystem exclusive of the gas generator circuits, will be checked out in Prelaunch and verified on the CRT for proper response when the deploy and jettison switches are activated. Also to be checked out at the same time is the time delay function to the gas generator circuits.

3.3.1.5.1.2 Combined Subsystems Test (CST) - Upon completion of subsystems checkout, a combined subsystems test (CST) will be performed for the Booster and Orbiter individually. During CST the central computation capability, the data management subsystem, and test software are used to:

A. Acquire, checkout, evaluate, and display related parameters
B. Exercise redundant modes and demonstrate switching capability
C. Exercise caution and warning subsystem checks
D. Verify the cargo module and Orbiter Vehicle interfaces
E. Perform automatic test sequence
F. Perform automatic simulated abort checks during ascent

An electro-mechanical test will be conducted with all subsystems as nearly as possible in flight configuration, in order to establish confidence that previously performed maintenance actions did not inadvertently damage vehicle wiring. All electronic, electrical, and electrical to mechanical subsystem wiring will be checked for continuity by exercising components, monitoring talk backs, etc.

3.3.1.5.1.3 Erection and Mate - Erection and mate of the Booster and Orbiter is accomplished after the completion of CST. Activities begin by disconnecting test GSE, inspecting and closing up the vehicles and installing the appropriate erection GSE. Platforms and access stands will then be removed and the vehicles towed to the appropriate VAB high bay cell.

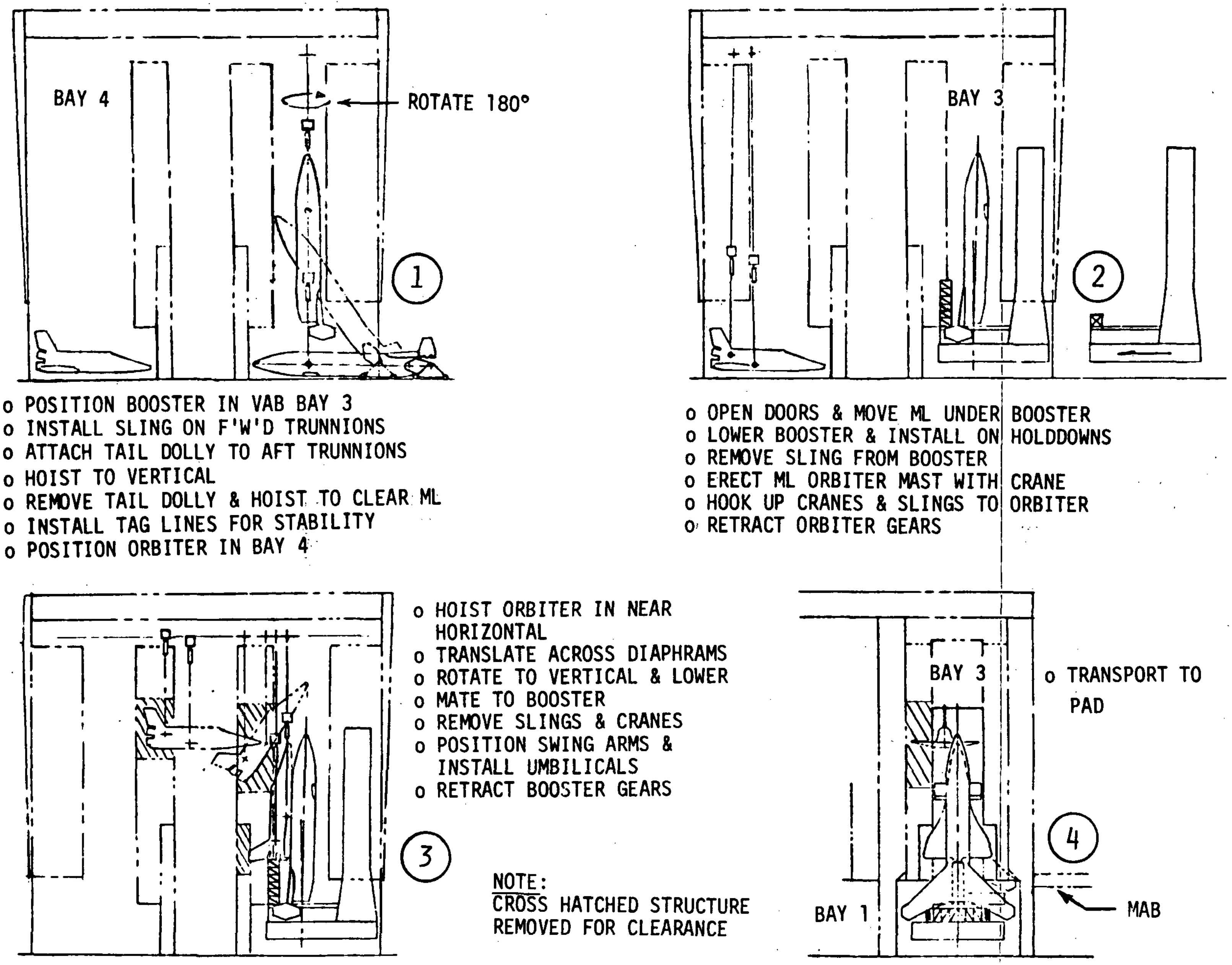
Per the baseline concept, the Booster will be moved to VAB Bay 3 for erection See Figure 3.3-13. This bay will have been widened to 180 feet for a depth of 152 feet and height of 112 feet. Also, the doors will have been appropriately reworked to accommodate the vehicles and Mobile Launcher when exiting the bay.

The Booster will be nosed into the bay and the sling, which had previously been suspended on the crane, attached to the intertank trunnion fittings. The aft trunnion fittings will be mated to a tail dolly that is tracked and restrained from tipping when subjected to the initial hoisting forces. The Booster will then be hoisted to the vertical position, with the tail dolly translating (via a powered system) along its track, moving into the building in order to keep the crane and sling cables near vertical. When erect, and after the horizontal bay doors have been closed and the aft trunnion is no longer bottomed in the tail dolly trunnion slot (i.e., indicates the vehicle is no longer loading the tail dolly pivoted trunnion arm), the tail dolly will be removed and the Booster rotated 180° (using the powered load block) so the belly is facing the doors.

The ML, on its C/T, will be outside the bay with the Orbiter tail mast folded at the raised platform, in an outboard direction, so as not to interfere with emplacement of the Booster. The Booster will be power taglined for stability (to prevent swinging) and the bay doors, horizontal and vertical, opened to permit entry of the ML, which will be moved under the Booster. After closing the doors, the Booster will be lowered and installed on its hard points and the Orbiter tail mast raised to the vertical by the crane.

The Orbiter will be moved into Bay 4 and, using two cranes and two slings, raised horizontally and translated over the transfer aisle diaphrams to Bay 3. The structure (i.e., elevator shafts, extensible platform structure, etc.) on one side of the bay (preferably south) will be removed as required to permit translation and rotation to the vertical. Also, the 192 foot high diaphrams in Bay 3 will be

VAB ERECTION PROCEDURE



①
- o POSITION BOOSTER IN VAB BAY 3
- o INSTALL SLING ON F'W'D TRUNNIONS
- o ATTACH TAIL DOLLY TO AFT TRUNNIONS
- o HOIST TO VERTICAL
- o REMOVE TAIL DOLLY & HOIST TO CLEAR ML
- o INSTALL TAG LINES FOR STABILITY
- o POSITION ORBITER IN BAY 4

②
- o OPEN DOORS & MOVE ML UNDER BOOSTER
- o LOWER BOOSTER & INSTALL ON HOLDDOWNS
- o REMOVE SLING FROM BOOSTER
- o ERECT ML ORBITER MAST WITH CRANE
- o HOOK UP CRANES & SLINGS TO ORBITER
- o RETRACT ORBITER GEARS

③
- o HOIST ORBITER IN NEAR HORIZONTAL
- o TRANSLATE ACROSS DIAPHRAMS
- o ROTATE TO VERTICAL & LOWER
- o MATE TO BOOSTER
- o REMOVE SLINGS & CRANES
- o POSITION SWING ARMS & INSTALL UMBILICALS
- o RETRACT BOOSTER GEARS

NOTE:
CROSS HATCHED STRUCTURE REMOVED FOR CLEARANCE

④
- o TRANSPORT TO PAD

FIGURE 3.3-13

lowered approximately 75 feet for Orbiter tail clearance (Ref. Figure 3.3-13). After rotating to the vertical in Bay 3, the vehicle will be lowered and mated to the Booster. The swing arms and Booster damper will be positioned and mated to the erected vehicles during and/or after the erection and mating sequence and the umbilicals installed and verified.

Alternate erection methods, areas, ML configurations and vehicle positioning concepts that are viable and cost competitive with the above baseline are presented in Design Note I-EAST-GLO-8 Rev. A. Of particular interest in the Design Note is the concept that uses a new high bay area, built against the north wall of the VAB and as part of the Maintenance and Assembly Building (MAB), to erect the vehicles in an area that would afford more clearance for handling. Also, it would negate the need to fold the Orbiter tail mast, and allow the ML to be positioned indoors on its hard points. VAB Bays 3 and 4 would then be used for Orbiter maintenance.

Another concept of interest is the use of a twin towered ML with the top of the vehicles facing the towers. More detail of this configuration is given in paragraph 3.3.1.6.1.4 and Design Note I-EAST-GLO-8 Rev. A.

3.3.1.5.1.4 Integrated Systems Test (IST) - Interface verification tests between the Booster and Orbiter, and from each to ground systems are required after installation of the Shuttle System on the mobile launcher. These interfaces are to be verified during the IST. This will be the only complete system test of the Shuttle System prior to starting launch operations at the pad.

During IST, the central computation capability and the data management subsystems of both the Booster and Orbiter are used to:

A. Verify hardwire voice communication links

B. Verify capability to transmit safety, separation, and abort signals between the Booster and Orbiter

C. Verify the caution and warning parameters

D. Perform automatic simulated launch and mission test sequence

E. Perform automatic simulated ascent abort checks

F. Verify data bus interface between DMS (OBC) and GATS

3.3.1.5.1.5 Prepare for Move to Pad - After completion of IST, preparations will be made for the move to the launch pad. These activities will include removal of GSE, inspection and vehicle close up, positioning of the vehicle damper arm and positioning of the ML on the crawler.

3.3.1.5.2 LRU Management System - It is recognized that LRU management is a very necessary tool in the Shuttle System due to the anticipated length of the program and the limited amount of vehicles in the fleet. Another factor that must be taken into account is that although there is a concentrated effort to use airline "off-the-shelf" equipment in the Shuttle design, there will probably be a substantial amount of equipment that is being designed specially for shuttle. This would indicate that this shuttle peculiar LRU's would be one of a kind from a vendor and, therefore, would be likely candidates for inhouse repair and overhaul.

Pan Am maintenance personnel were consulted as to their LRU management system. In reviewing their statistics on cost significant LRU's, they are repaired and overhauled inhouse with exception of eight components. The rationale for sending these components back to the vendor tends to indicate that a key trade-off factor is the cost of test equipment versus failure rate. The eight LRU's that are sent to the vendor for repair and overhaul and the rationale for this action are noted below:

LRU	Rationale
Doppler Nav. System	Pall Resolver subassembly returned for repair. Cost of special shop jigs required

	for repair and readjustment prohibitive considering low failure rate.
Low Range Radio Altimeter	Transmitter Module returned for repair. Costs of special equipment and training levels required are prohibitive.
HF Comm Lightning Arrester	Special shop test equipment required does not warrant cost since failure rate is low.
Rate Gyros	Test equipment cost prohibitive. Vendor turnaround price too attractive to pass up.
Autopilot Flare Coupler	Cost of test equipment will not justify inhouse repair for so few boxes.
Radome	Major structural repairs made at vendor because of high cost of equipment required to test electromagnetic characteristics.
Auxiliary Power Unit	Vendor repair due to cost of specialized tooling and equipment.
Cabin press Electropneumatic Control	Vendor repair due to cost of equipment

The Shuttle LRU management system will be modeled after the Pan Am system. The decision as to whether the LRU is repaired in-house or sent back to the vendor will be based on an economic study taking into account the following factors:

- Cost of equipment

- o Shop flow (number of units and turnaround times)
- o Cost of spares (pipeline) and piece parts inventory
- o Warranties (vendor)
- o Vendor overhaul charges
- o Manpower availability
- o Facilities

For "off-the-shelf" LRU's, the decision should be more readily made since an economic study will have been made by the airlines. However, the airlines as a cost saving device, have "pooling" agreements. For a given LRU, one airline repairs and overhauls for several other airlines as well as themselves. This presents a further option in determining where the "off-the-shelf" LRU's will be handled. Pan Am recommends that the Shuttle should enter a pooling agreement with the airlines for those LRU's that the airlines are currently processing.

The Shuttle peculiar LRU's will require a complete economic study. During the early development phase of the program and through the vendor warranty period, a data package will be kept for each LRU considering the evaluation factors noted above. Past spacecraft experience indicates that for Shuttle peculiar LRU's, it will probably be more cost effective to repair and overhaul "inhouse" which, for the shuttle program, will be at the launch site.

A cursory study of the Shuttle subsystem indicates that the hardware will fall into one or more of three design categories: Aircraft Standard, Aerospace Standard or Shuttle Unique. Figure 3.3-14 identifies potential overhaul and repair locations for this hardware. An economic trade study using the previously mentioned decision factors will eventually determine the most cost effective location for the overhaul and repair cycle.

3.3.1.5.3 Cargo Management System - Ground operation functions involved in

SUBSYSTEM OVERHAUL AND REPAIR ALLOCATION

DESIGN CATEGORY	OVERHAUL AND REPAIR DEPOT			REPAIR SHOPS OPERATIONS SITE
	EQUIPMENT, MANUFACTURE	DOD	AIRLINES	
AIRCRAFT STANDARD	• AIRBREATHING ENGINE • APU (JP)	• HYDRAULIC • LANDING GEAR • AIRBREATHING ENGINE • APU (JP) • COMMUNICATIONS & NAVAIDS • CONTROLS & DISPLAYS • HYDRAULIC POWER	• HYDRAULIC • LANDING GEAR • AIRBREATHING • HYDRAULIC POWER	• RECOVERY AIDS • LANDING GEAR • AIRBREATHING ENGINE • APU (JP) • COMMUNICATIONS & NAVAIDS • CONTROLS & DISPLAYS • HYDRAULIC POWER
AEROSPACE STANDARD	• ORBITER ECLS • PRODUCT WATER SYSTEM • ELECTRICAL POWER • ORBIT MANEUVERING ENGINE • MAIN PROPULSION	• GUIDANCE & NAV • CONTROLS & DISPLAYS • EQUIPMENT COOLANT LOOP • CABIN COOLANT LOOP • CABIN GAS SUPPLY & CONTROL • ELECTRICAL POWER MAIN PROPULSION • ORBIT MANEUVERING ENGINE	• CABIN AIR SYSTEM • CABIN GAS SUPPLY & CONTROL • ELECTRICAL POWER	• GUIDANCE & NAV • CONTROLS & DISPLAYS • WASTE MANAGEMENT • EQUIPMENT COOLANT LOOP • CABIN COOLANT LOOP • CABIN AIR SYSTEM • PRODUCT WATER SYSTEM • CABIN GAS SUPPLY & CONTROL • ELECTRICAL POWER
SHUTTLE UNIQUE	• FLIGHT CONTROL ELECTRONICS • APU (CRYO) • DATA MANAGEMENT • THERMAL PROTECTION • ATTITUDE CONTROL ENGINE	• INTERSTAGE SEPARATION • APU (CRYO) • FLIGHT CONTROL ELECTRONICS • DATA MANAGEMENT • ATTITUDE CONTROL ENGINE		• STRUCTURE • THERMAL PROTECTION • PAYLOAD ACCOMMODATIONS • APU (CRYO) • FLIGHT CONTROL ELECTRONICS • DATA MANAGEMENT • WASTE MANAGEMENT

FIGURE 3.3-14

the Cargo Management System are identified in Figure 3.3-15. To reduce the volume of packaging activity at the launch site cargo processing facility, every effort will be made to purchase materials and supplies which are packaged by the manufacturer for space delivery. The manufacturer will be furnished specifications of the protective requirements and suggested packaging materials that meet both earth and space transportation and storage environments. Cargo handling procedures and techniques, used to restrain the cargo in the orbiter and to transfer or handle it in space, will also be furnished. Figure 3.3-16 outlines a preliminary packaging specification plan.

The package cargo will be transported from the manufacturer's facility to the launch/refurbishment site. The mode of transportation (air, rail, or truck) largely depends on the proximity of the manufacturer's plant to the launch/refurbishment site and the urgency of need and nature of the cargo.

Upon arrival at the launch/refurbishment site, the cargo will be delivered to the Cargo Processing Facility where its receipt is documented into the accounting system. The cargo packaging will then be visually inspected for damage in transit. Cargo items sensitive to g-loading will have g-indicators incorporated in the packaging which are visible without compromising packaging integrity. Appropriate handling equipment, such as a forklifter hoist, will be used for lifting and moving cargo items whose weight exceeds safe limits for manual handling. Cargo items with damaged packaging or whose load/stress monitors indicate exposure to excessive loads will be returned to the manufacturer. After passing a visual inspection, the cargo is moved to a holding area where it will be incorporated into a specific flight inventory and stored until it is integrated into a cargo module.

The means by which a cargo item is integrated depends on the type of cargo to be loaded. If the cargo is to be all propellants, the cargo module will be in-

CARGO FUNCTIONAL FLOW SOURCE–TO–USER–AND–RETURN

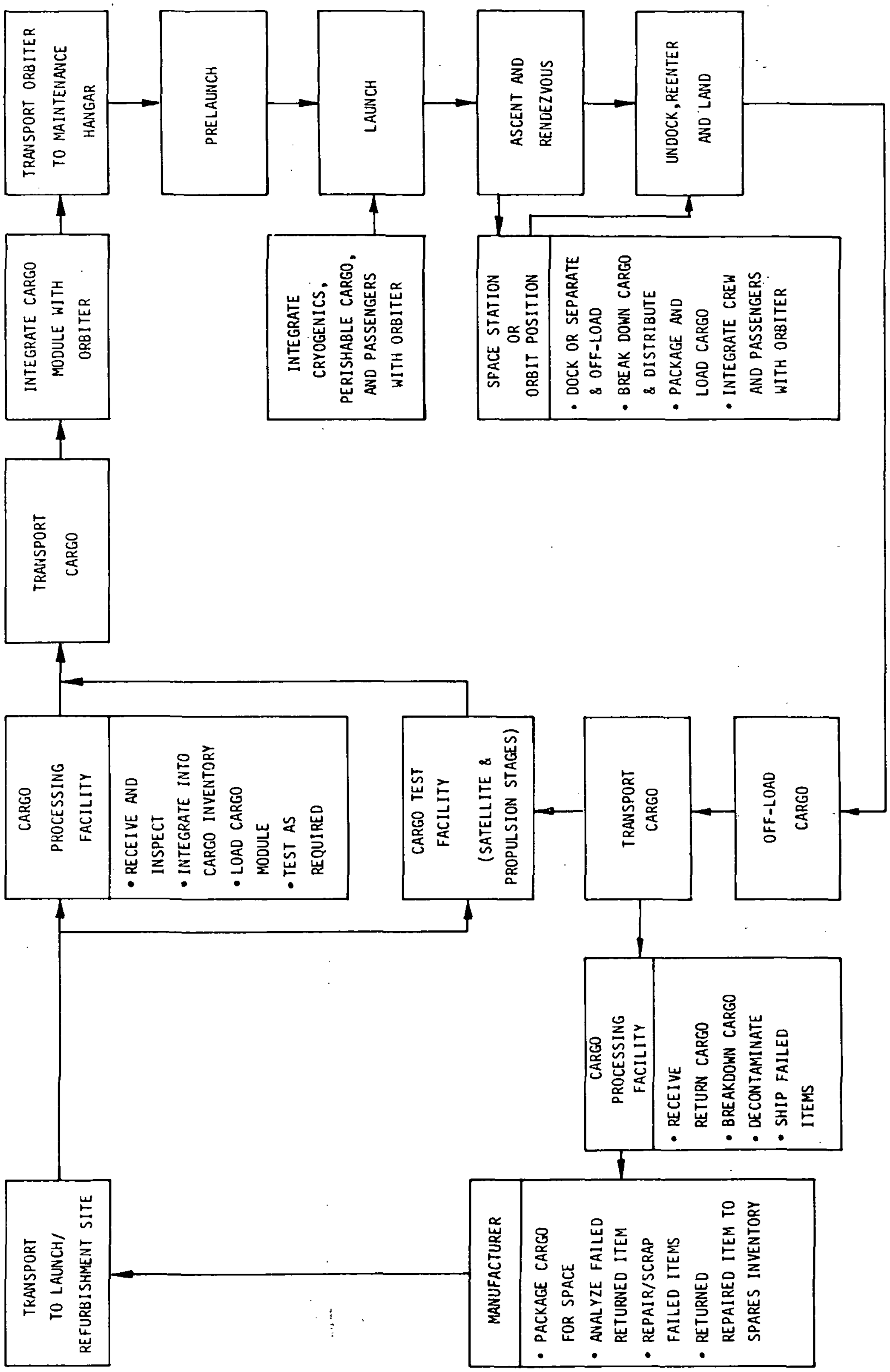


FIGURE 3.3-15

PACKAGING SPECIFICATION PLAN

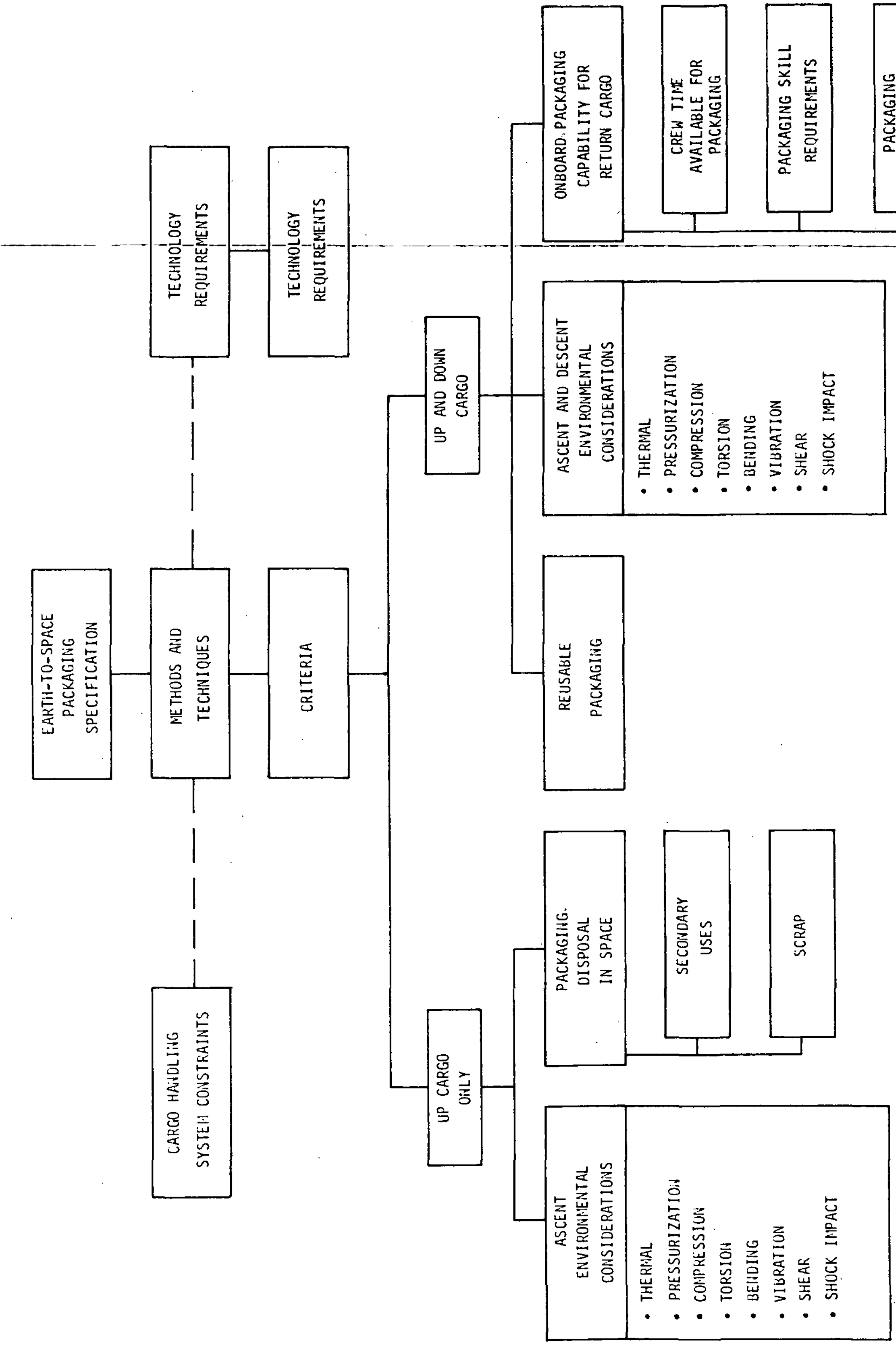


FIGURE 3.3-16

corporated into the orbiter at the maintenance location and filled with propellants at the launch pad. Outsized or special cargo such as free-flying experiments or a space tug will be loaded into the orbiter at the maintenance location. It will be restrained within the cargo bay to the orbiter structure by the hold down provisions.

The loaded cargo module is placed on a transporter vehicle by means of cranes or hoists, and moved to the maintenance area where removed from the transporter and integrated with the orbiter. After the cargo module is installed in the orbiter, it flows with the orbiter through the VAB, prelaunch, and launch operations.

Orbital operations vary significantly with each type of mission. However, the space station logistic support mission is representative. Upon arrival at the space station, the cargo module is deployed from the cargo bay, docked to the space station and the cargo will be off-loaded, broken to individual items, and distributed to point of use. Failed components, return data, and disposable materials are packaged and loaded into the cargo module for return to Earth.

The orbiter then undocks the cargo module, restows it in the cargo bay, reenters, and lands at the Operations Site where deservicing is initiated. The cargo module is then off-loaded from the orbiter and transported to the Cargo Processing Facility where the return cargo is off-loaded, received, broken down, and inspected. Recoverable data and materials are channeled to the appropriate users. Disposable materials are sorted for potential salvage or disposal. Returned failed space station components (if any) are shipped to the manufacturer for a detailed failure analysis. If the item is repaired, it is inspected, tested, packaged for space, and returned to the spares inventory.

3.3.1.6 Launch and Post Launch Operations - Launch and post launch operations consist of those activities required during pad operations before launch of a Space Shuttle and during cleanup operations in preparation of a subsequent launch. Also included in this section is the hold/recycle capabilities, crew/passenger egress (both normal and emergency), and the launch rate capabilities.

3.3.1.6.1 Launch Operations - The launch operations phase begins with movement of the mated vehicle on the mobile launcher to the pad and concludes with liftoff. The time allotted for this phase is the final twenty-four hours of the turnaround which will consist of three consecutive eight hour shifts. This phase shall be minimized in order to reduce the possibility of damage due to inclement weather which also may have deleterious effects on the schedule.

The vehicle operations at the pad should be limited to verification of the LUT/ facility connections, final integrated automatic checks, servicing the vehicle, crew ingress and final closeout. Integrated System Testing (IST) will, in general, be completed in the VAB prior to this phase. IST effort in this phase shall be limited to those tests which could not adequately be performed in the VAB. An example is the open loop communications checks. No drag-on cables or special GSE is anticipated for testing during this phase.

All vehicle servicing that is not hazardous or time critical shall be completed prior to launch operations. Servicing at the pad will be performed as soon as possible with the exception of those operations involving hazardous conditions which will be scheduled last.

The standby status point was originally planned to occur at T-2 hours. However, the existing LH_2 transfer system, located at complex 39 (KSC) has the capability of servicing the vehicle LH_2 tanks at 13,000 GPM, rather than the 20,000 GPM which was required to meet the 2 hour standby to launch requirement. The storage volume will have to be increased to meet the shuttle requirements. The existing LOX supply system and the addition of LH_2 storage volume make it possible to meet an approximate 2 1/2 hour standby to launch time; therefore, this change in times was made as a cost effective approach.

A swing arm will be provided for connecting to the cargo module for cryogenic servicing. On-pad cargo module replacement capability will be provided for contingency purposes. Normally the module will be loaded during the maintenance phase; however, due to perishable cargo, late changes and unforeseen circumstances, changeout may be required on the pad. An example would be a changeout in order to perform a rescue mission involving personnel from a space station, or an orbiter in trouble.

On-pad cargo changeout will require the use of the modified mobile service structure (MSS). The change in baseline from orbiter-to-tower to booster-to-tower caused the LUT to be inaccessible for cargo changeout; therefore, the MSS had to be baselined for this function. The MSS will require modifications so that it may allow lifting the cargo out of the orbiter and lowering it onto a handling dolly on the ground. The reverse procedure will be used to install the new cargo module. Changeout of the cargo module on the pad is much less desirable than changing it out at the maintenance area because of the additional handling equipment such as the MSS and because of the possible bad weather.

3.3.1.6.1.1 VAB Rollout to Standby - This phase begins as the crawler/transporter (C/T) starts moving the Mobile Launcher (ML) out of the VAB and continues with the five hour trip to the pad. Figure 3.3-17 identifies the flow and schedule for these activities. The existing crawler-way will be utilized. The shuttle will be maintained in a level position by the transporter throughout the trip including the 5° incline leading up to the pad.

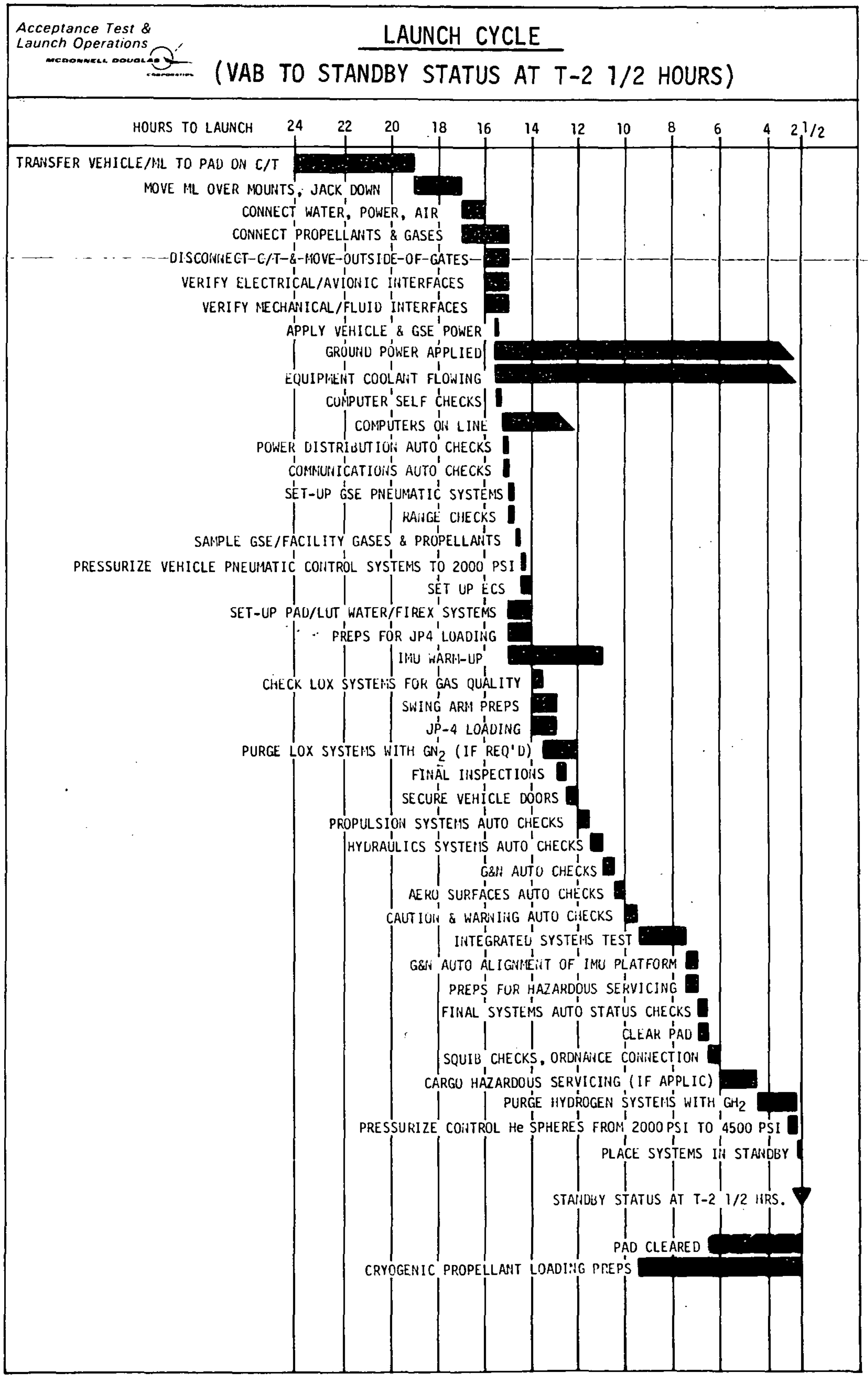

Acceptance Test & Launch Operations
McDONNELL DOUGLAS CORPORATION
LAUNCH CYCLE
(VAB TO STANDBY STATUS AT T-2 1/2 HOURS)
HOURS TO LAUNCH
24
22
20
18
16
14
12
10
8
6
4
2 1/2
TRANSFER VEHICLE/ML TO PAD ON C/T
MOVE ML OVER MOUNTS, JACK DOWN
CONNECT WATER, POWER, AIR
CONNECT PROPELLANTS & GASES
DISCONNECT C/T & MOVE OUTSIDE OF GATES
VERIFY ELECTRICAL/AVIONIC INTERFACES
VERIFY MECHANICAL/FLUID INTERFACES
APPLY VEHICLE & GSE POWER
GROUND POWER APPLIED
EQUIPMENT COOLANT FLOWING
COMPUTER SELF CHECKS
COMPUTERS ON LINE
POWER DISTRIBUTION AUTO CHECKS
COMMUNICATIONS AUTO CHECKS
SET-UP GSE PNEUMATIC SYSTEMS
RANGE CHECKS
SAMPLE GSE/FACILITY GASES & PROPELLANTS
PRESSURIZE VEHICLE PNEUMATIC CONTROL SYSTEMS TO 2000 PSI
SET UP ECS
SET-UP PAD/LUT WATER/FIREX SYSTEMS
PREPS FOR JP4 LOADING
IMU WARM-UP
CHECK LOX SYSTEMS FOR GAS QUALITY
SWING ARM PREPS
JP-4 LOADING
PURGE LOX SYSTEMS WITH GN2 (IF REQ'D)
FINAL INSPECTIONS
SECURE VEHICLE DOORS
PROPULSION SYSTEMS AUTO CHECKS
HYDRAULICS SYSTEMS AUTO CHECKS
G&N AUTO CHECKS
AERO SURFACES AUTO CHECKS
CAUTION & WARNING AUTO CHECKS
INTEGRATED SYSTEMS TEST
G&N AUTO ALIGNMENT OF IMU PLATFORM
PREPS FOR HAZARDOUS SERVICING
FINAL SYSTEMS AUTO STATUS CHECKS
CLEAR PAD
SQUIB CHECKS, ORDNANCE CONNECTION
CARGO HAZARDOUS SERVICING (IF APPLIC)
PURGE HYDROGEN SYSTEMS WITH GH2
PRESSURIZE CONTROL He SPHERES FROM 2000 PSI TO 4500 PSI
PLACE SYSTEMS IN STANDBY
STANDBY STATUS AT T-2 1/2 HRS.
PAD CLEARED
CRYOGENIC PROPELLANT LOADING PREPS

FIGURE 3.3-17

Studies at this point indicate that a dampening device may not be required for the shuttle vehicle. Additional examination will be required to establish either a firm requirement or its elimination.

If required, it will be mounted to both sides of the LUT and lowered like a drawbridge in order to attach to the underside of the booster in the nose gear area. It will stabilize the mated vehicles and dampen vibrations that might be caused by wind and transportation loads. After vehicle fueling, it will be raised and stowed against the LUT (Reference Figure 3.3-26).

Upon arrival at the pad, the C/T will lower the mobile launcher onto the pedestals and the ML will be secured. The electrical, mechanical and fluid interfaces between the ML and the facility will be connected and verified using automated methods except where external leakage checks are required. Although the preparation and line pressurization will be computer programmed, the actual leakage test will utilize a gas sensing device.

After the ground coolant system is activated for vehicle equipment cooling, ground power will be applied to the vehicle. This coolant must be circulated continuously whenever the vehicle has power applied. During the time from pad arrival to pad clearing, the vehicle cabins will be occupied by the ground crew. Automated onboard computer self checks will be performed as soon as power is applied to verify that the computer, the power distribution system, and the communication systems are performing properly. Then range checks will be performed. This effort is expected to be minimal after the shuttle becomes operational.

The flight controls systems will be activated along with other vehicle electronics. The inertial measuring units (IMU's) must warm-up for approximately four hours prior to aligning. The other systems which include the DME, ILS, VOR, ATC transponder and S-Band will be placed on standby after the quick looks are completed.

After the facility propellants and gases are sampled to verify that they meet the purity, dryness and particle count requirements, the vehicle pneumatic control systems and the orbiter cold helium system will be pressurized to 2000 psi. The oxygen systems will be automatically sampled to verify that the gases to not exceed moisture requirements and that the inerting performed during post landing operations is still acceptable. Additional purging, if required, will be performed.

The Airbreathing Engine System (ABES) servicing will begin at approximately T-14 hours. The JP-4 will be filled at a flowrate of approximately 1000 GPM which is less than the flow rates used by the airlines. The DC-10 will be filled at rates up to 1600 GPM with passengers onboard. No special personnel clearing will be required while JP-4 is being loaded. The Orbiter will only require about 5500 gallons on those missions which allow the ABES to be installed. The booster will require over 23,000 gallons of JP-4. The existing RP-1 facility is planned to be used for JP-4 at a flow rate of approximately one-half that presently required by the Apollo program. The JP-4 fill and drain line will be disconnected and secured after the tanks are filled to the prescribed level. The LUT RP-1 system, in part will be used with additional distribution established for simultaneously filling the booster and the orbiter.

After the JP-4 is loaded, final inspections will be made to verify that no fuel is leaking and that the vehicle is ready to be secured for flight. Then the few remaining access hatches will be closed and secured for flight.

During the last hours prior to hazardous operations, the various subsystems will be automatically checked to verify that all systems are ready to proceed into the hazardous operations and the standby-to-launch countdown. Included in these subsystems are propulsion, hydraulic, communications and navigation aids and caution and warning. In addition, approximately two hours are set aside to perform any integrated system testing which could not be performed in the VAB.

The Inertial Measurement Unit (IMU) which was activated for warm-up several hours earlier will at this point be ready for Guidance & Navigation (G&N) checks which will include automatic alignment of the IMU platform. All G&N checks are anticipated to be automatic in nature, requiring no special checkout GSE.

Also during these last hours, other activities will be in progress, such as final inspections, Environmental Control System (ECS) set-ups, cryogenic propellant loading preparations (facility and vehicle) and swing arm preparations. After clearing the local areas, squib checks will be performed on the limited amount of flight ordnance. At this time, the only ordnance identified for an operational vehicle is: (1) separation device, (2) orbiter drag chute deployment device, and (3) air breathing engine starter devices. After the squib checks are completed, the ordnance will be electrically connected during a controlled time span -- controlled in personnel and functions concurrent with ordnance hook-up. While local areas are still cleared, any special hazardous operations involving the cargo module will be performed.

The baseline was recently changed regarding the purge media for the hydrogen systems. Originally the plan was to purge the H_2 systems with helium during the post landing operations. There was a reluctance to change to the GN_2/GH_2 medias because of the long times that would be required for purging on launch day and the increase in risk of missing the scheduled liftoff time. The rapid purging technique was demonstrated by NASA which will allow reduction of purging time from 3 - 4 hours to less than two. Some vehicle redesign will be necessary in order to purge dead-ended lines and to purge H_2 lines downstream of the engine main LH_2 valve. Even with these penalties, over $\$14\overline{M}$ is expected to be saved and the conservation of helium will be invaluable for the nation's natural resources. Also the means of detecting the purity of gases will be automatic utilizing latest techniques such as the Polarograph which was developed by General Electric under the direction of NASA. While the purging operation is active, the vehicle ambient helium spheres will be pressurized from 2000 to 4500 psi. Just prior to T-2 1/2 hours, the purging will be completed and the systems will automatically be placed in standby condition.

3.3.1.6.1.2 Standby to Terminal Countdown - This phase will begin with initiating the standby-to-launch countdown at T-2 1/2 hours. Figure 3.3-18 identifies the flow and schedule for these activities. Upon initiating this phase, the main engines trickle GN_2 purge is started and, excepting the crew cabin, the compartments air conditioning is switched from air to GN_2 for the purpose of preventing any hydrogen leakage from igniting and preventing ice buildup inside the compartments and between the tanks and the TPS. The engine purge is required to prevent condensing and freezing of moisture from the air inside the engine.

During propellant loading the ground system - Monitor, Display and Control (MDAC) unit will have executive control. The MDAC unit will control GSE and facility components through the ground data bus and area Digital Interface Units (DIU). The Booster computer will control Booster components and the Orbiter computer will control Orbiter components. The vehicle computer will look for commands from the MDAC unit at the interface buffer on a routine basis, and in turn will monitor and control vehicle components as a subroutine.

The LH_2 facility, GSE and vehicle chilldown will be initiated at T-2 1/2 hours. See Figure 3.3-19 for propellant loading data. Chilldown return flow will proceed to the GH_2 waste dispersion system. After LH_2 chilldown has continued for approximately 5 minutes, the LOX facility and pump chilldown and cold soak will begin.

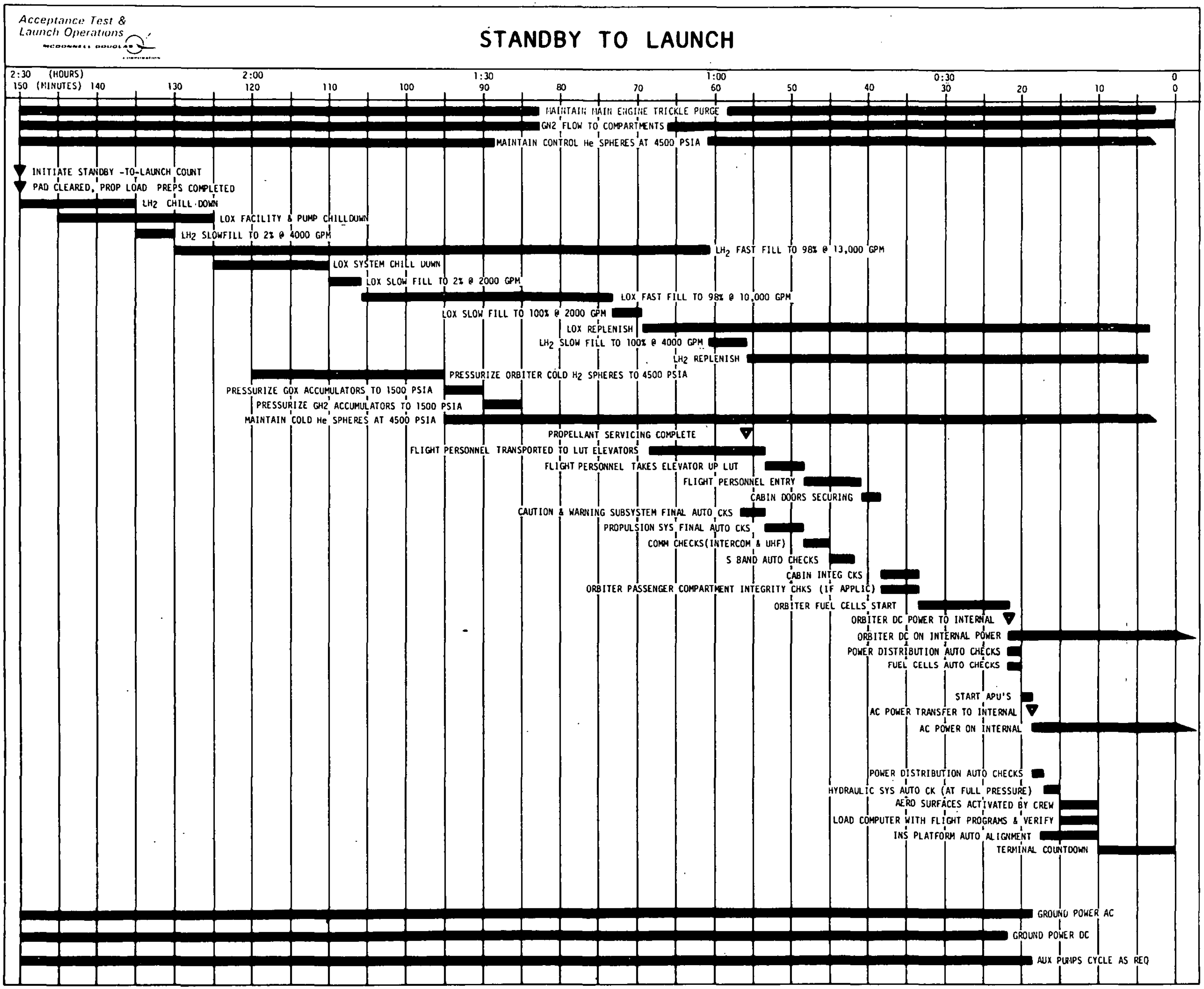

Acceptance Test & Launch Operations
McDONNELL DOUGLAS CORPORATION
STANDBY TO LAUNCH
2:30 (HOURS)
150 (MINUTES) 140 130
2:00 120 110 100
1:30 90 80 70
1:00 60 50 40
0:30 30 20 10
0 0
MAINTAIN MAIN ENGINE TRICKLE PURGE
GN2 FLOW TO COMPARTMENTS
MAINTAIN CONTROL He SPHERES AT 4500 PSIA
INITIATE STANDBY -TO-LAUNCH COUNT
PAD CLEARED, PROP LOAD PREPS COMPLETED
LH2 CHILL-DOWN
LOX FACILITY & PUMP CHILLDOWN
LH2 SLOWFILL TO 2% @ 4000 GPM
LH2 FAST FILL TO 98% @ 13,000 GPM
LOX SYSTEM CHILL DOWN
LOX SLOW FILL TO 2% @ 2000 GPM
LOX FAST FILL TO 98% @ 10,000 GPM
LOX SLOW FILL TO 100% @ 2000 GPM
LOX REPLENISH
LH2 SLOW FILL TO 100% @ 4000 GPM
LH2 REPLENISH
PRESSURIZE ORBITER COLD H2 SPHERES TO 4500 PSIA
PRESSURIZE GOX ACCUMULATORS TO 1500 PSIA
PRESSURIZE GH2 ACCUMULATORS TO 1500 PSIA
MAINTAIN COLD He SPHERES AT 4500 PSIA
PROPELLANT SERVICING COMPLETE
FLIGHT PERSONNEL TRANSPORTED TO LUT ELEVATORS
FLIGHT PERSONNEL TAKES ELEVATOR UP LUT
FLIGHT PERSONNEL ENTRY
CABIN DOORS SECURING
CAUTION & WARNING SUBSYSTEM FINAL AUTO CKS
PROPULSION SYS FINAL AUTO CKS
COMM CHECKS(INTERCOM & UHF)
S BAND AUTO CHECKS
CABIN INTEG CKS
ORBITER PASSENGER COMPARTMENT INTEGRITY CHKS (IF APPLIC)
ORBITER FUEL CELLS START
ORBITER DC POWER TO INTERNAL
ORBITER DC ON INTERNAL POWER
POWER DISTRIBUTION AUTO CHECKS
FUEL CELLS AUTO CHECKS
START APU'S
AC POWER TRANSFER TO INTERNAL
AC POWER ON INTERNAL
POWER DISTRIBUTION AUTO CHECKS
HYDRAULIC SYS AUTO CK (AT FULL PRESSURE)
AERO SURFACES ACTIVATED BY CREW
LOAD COMPUTER WITH FLIGHT PROGRAMS & VERIFY
INS PLATFORM AUTO ALIGNMENT
TERMINAL COUNTDOWN
GROUND POWER AC
GROUND POWER DC
AUX PUMPS CYCLE AS REQ

FIGURE 3.3-18

SHUTTLE PROPELLANT FILL DATA

	FLIGHT LOAD GAL	LINE SIZE INCHES	PERCENT OF FLOW	MAINFILL FLOWRATE GPM	SLOWFILL FLOWRATE GPM
LH_2					
TOTAL	939,964	10	100.0	13,000	4,000
BOOSTER MAIN	789,913	10	83.1	10,800	3,330
ORBITER MAIN	135,360	4	13.3	1,730	535
ORBITER SECONDARY	13,724	2	3.2	420	120
BOOSTER SECONDARY	967	2	0.4	50	15
SLOW FILL 0-2%	18,799	--	2.0	---	5 MIN.
FAST FILL 2-98%	902,366	--	96.0	69 MIN.	--
SLOW FILL 96-100%	18,799	--	2.0	---	5 MIN.
JP-4					
TOTAL	28,729	--	100.0	1,000 (27 MIN.)	--
BOOSTER	23,233	5	86.3	863	--
ORBITER	5,496	2	13.7	137	--
LOX					
TOTAL	339,714	14/6	100.0	10,000	2,000
BOOSTER MAIN	266,808	10	83.3	8,330	1,666
ORBITER MAIN	49,823	4	13.3	1,330	266
ORBITER SECONDARY	2,943	2	3.3	330	66
BOOSTER SECONDARY	140	2	0.1	10	2
SLOW FILL 0-2%	6,784	--	2.0	--	4 MIN
FAST FILL 2-96%	326,126	--	96.0	33 MIN.	--
SLOW FILL 96-100%	6,794	--	2.0	--	4 MIN.

FIGURE 3.3-19

This time differential between transients is typical of the cryogenic loading scheme. Although LOX and LH_2 are loaded simultaneously, the hazard level is kept to a minimum by timing and sequencing. No two transients occur at the same time. In sequencing from one condition to another (i.e., slow fill to fast fill) the new condition is completely stabilized before another transition is permitted. In addition, the LH_2 system, which has consistently encountered most of the problems in the past, is in a stabilized fast fill mode before any LOX is introduced to the GSE on the LUT or to the vehicle. Although the Apollo has not loaded simultaneously, it has drained simultaneously without any significant prolems due to simultaneous flow.

Continuing on with the fill sequence, the LH_2 chilldown is timed for 15 minutes duration. At that point the LH_2 starts slow fill to all four vehicle LH_2 tanks at a total flow rate of 4000 GPM, maximum. The Booster main LH_2 tank will receive most of the flow. The flow is divided as follows: Booster main tank - 83%, Orbiter main tank - 13%, both secondary tanks - 4%. When the tanks are at approximately 2% full, LH_2 fast fill will begin and the flow rate increases to approximately 13,000 GPM. The flow during fast fill is divided between the tanks as noted above for slow fill.

After the LH_2 fast fill is well established and stabilized with over 80,000 gallons of LH_2 loaded, the LOX systems chilldown will start. After 15 minutes of chilling the facility, the 14 inch cross country line, the LUT complex and the vehicle tanks, slow fill commences at a total flow rate of 2000 GPM, maximum. The flow is divided as follows: Booster main tank - 83%, Orbiter main tank - 13%, and the remainder in both of the secondary tanks. When the vehicle LOX tanks are filled to approximately 2%, the fill rate will increase to the LOX fast fill rate of 10,000 GPM. At 98%, the rate will decrease to 2000 GPM until 100% is reached.

Rollout will be at 100%. Replenishing will maintain the LOX tanks at the full level until the propellant system is secured during terminal count.

Approximately 8 minutes later the LH_2 tank will be filled to the 98% level, whereupon the total LH_2 flow rate will be reduced to 4000 GPM, maximum, during slow fill to 100%. The LH_2 slow fill will be terminated so that the LH_2 level rollout will be at 100%. All of the propellant tanks will be full at T-61 minutes. LH_2 replenish will be utilized to maintain the level at 100% to terminal count.

During stabilized fast fill of LH_2 and LOX, the following servicing will take place. The Orbiter cold helium system will be pressurized from 2000 to 4500 psia. Next, the LOX accumulators will be purged with GOX and pressurized to 1500 psia. Then the GH_2 accumulators will be pressurized to 1500 psia.

The flight crew and passengers will be scheduled to arrive at the pad upon start of LH_2 replenish. The flight personnel will leave their shuttle bus at the base of the LUT and take the elevators to the access levels for the Booster and Orbiter. The flight personnel will enter the vehicle and close the vehicle hatches. After closure of the vehicle doors, an integrity check of the crew cabins and passenger areas will be performed to verify that pressure will be maintained throughout flight.

In parallel with the above crew functions, certain other tests will be performed by the computer automatically. For example, upon completion of propellant loading and prior to personnel entry to the vehicle, the caution and warning subsystem will be checked. The propulsion systems final automatic checks will be performed. In addition, the communications will be checked -- including UHF, S-Band and intercom.

After the crew checks the cabin integrity, the start-up sequence of the Orbiter fuel cells is manually performed. The fuel cells start sequence will be completed and the Orbiter DC power will be switched from external to internal at approximately T-22 minutes. The computer will then perform automatic checks on the power distribution system to confirm proper fuel cell operation.

At T-20 minutes the APU's will be started using ground supplied GOX and GH_2 through the accumulators. Deleting the use of the propellant conditioners on the ground allowed the reduction of their exhaust disconnects and the associated complex vehicle valving to switch from the gound disconnect to the flight vent port. The accumulators will have sufficient capacity to operate the APU's from T-30 seconds (Booster arm swings) to T+50 seconds at which time, the first demand on the propellant conditioners will be made. After the APU's are started, the Booster and Orbiter AC power will be switched from external to internal. Power distribution automatic checks will again be performed to verify successful internal power application.

The auxiliary hydraulic pumps will cycle periodically utilizing ground power for circulation to prevent hydraulic fluid freezing during and after cryogenic loading until the APU's are started. After APU hydraulic pump pressures reach normal system pressure, many of the hydraulic components will be cycled automatically with the computer. The flight crew will operate the aerodynamic control surfaces by manually moving the "control stick".

The IMU platform alignment will be performed automatically starting at approximately T-18 minutes and ending at T-10 minutes.

Between approximately T-15 minutes and T-10 minutes, the vehicle computer will be loaded with the flight program modules and verified by memory sum checks and parity checks. This operation will be done in parallel to other operations by loading the computers individually and serially. The reason that this change does not occur prior to T-2 1/2 hours is that the vehicle computer flight program and the automatic propellant loading program, if integrated into one program, would increase the flight hardware cost and weight considerably.

3.3.1.6.1.3 Terminal Count - The last 10 minutes prior to liftoff will be the terminal count. Figure 3.3-20 identifies the flow and schedule for these activities. The crew initiates this phase. Terminal count starts with initiating the pogo suppression purge (if applicable) and pressurizing the JP-4 fuel tanks to 3 - 5 psig. Also the critical cold propulsion components will be cycled to verify that they have not frozen in their last position. In addition, the guidance computer is updated for the final time prior to liftoff. Then the computer will perform final checks on itself as well as other critical systems.

Next, the hold down release mechanisms and the swing arms release are armed. The flight crew will then arm any vehicle ordnance which requires arming prior to launch. Presently, the only items falling into this category is the separation device. Then the vehicle computer will perform the final automatic checks.

The propellant loading system will be automatically secured and ground purging begins at approximately T-3 minutes and 30 seconds. The orbiter main LH_2 tank pressurization will slightly lead the orbiter main LOX tank pressurization due to the common bulkhead. The booster cryogenic tanks and the remaining orbiter cryogenic tanks will commence pressurizing at T-2:30 minutes. Pressurization of all main propellant tanks will be by ambient helium in order to save flight weight of pressurants. The secondary tanks will be pressurized from the GOX and GH_2 accumulators. The LH_2 tank vents will be switched from the ground venting mode to airborne venting mode at T-2:20 min.

Upon completion of pressurization, the booster ignition will be armed. At T-60 seconds, the fluid umbilicals will be depressurized for ease of disconnection and the flame deflector water cooling will be initiated.

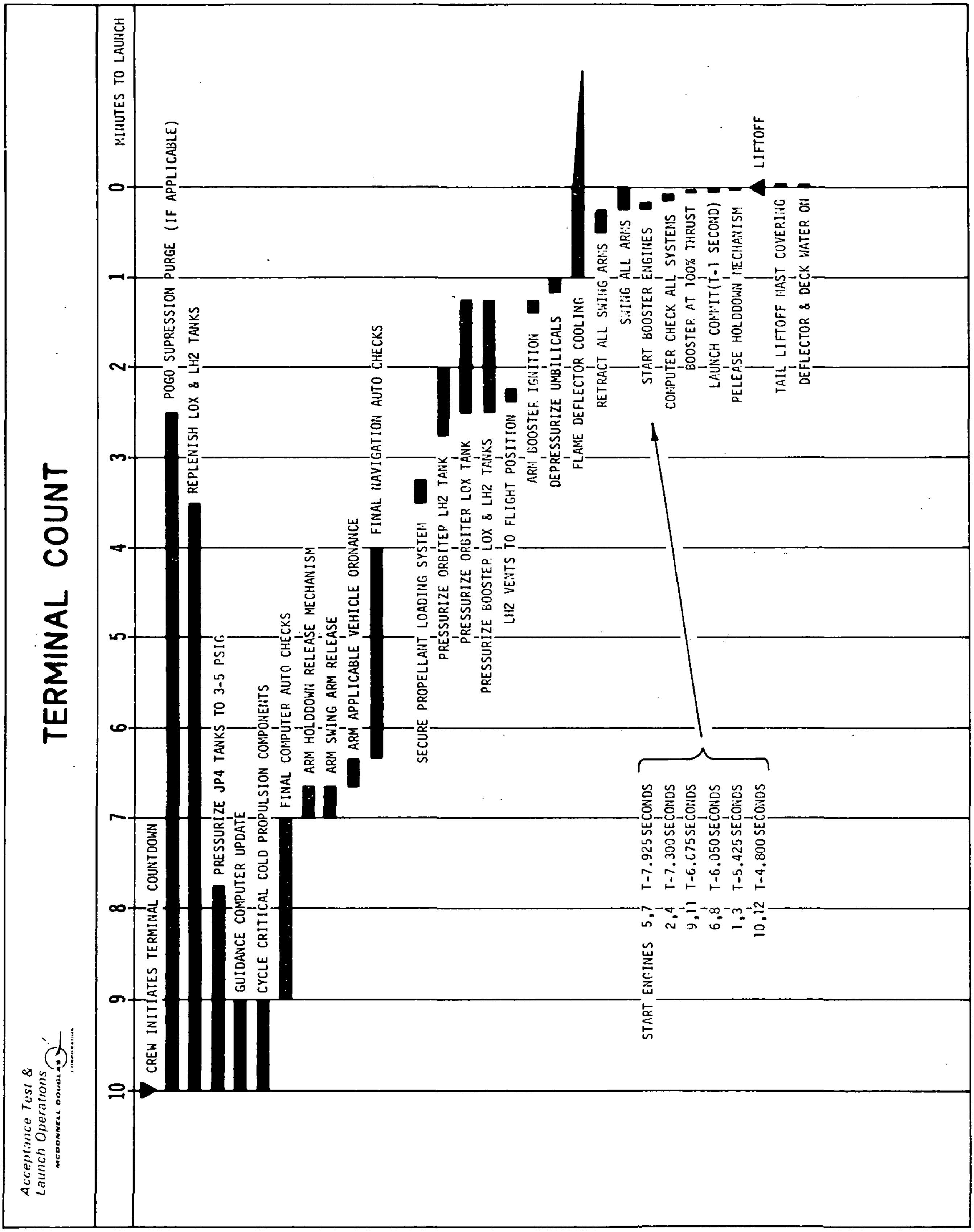

TERMINAL COUNT
MINUTES TO LAUNCH
0
1
2
3
4
5
6
7
8
9
10
CREW INITIATES TERMINAL COUNTDOWN
POGO SUPRESSION PURGE (IF APPLICABLE)
REPLENISH LOX & LH2 TANKS
PRESSURIZE JP4 TANKS TO 3-5 PSIG
GUIDANCE COMPUTER UPDATE
CYCLE CRITICAL COLD PROPULSION COMPONENTS
FINAL COMPUTER AUTO CHECKS
ARM HOLDDOWN RELEASE MECHANISM
ARM SWING ARM RELEASE
ARM APPLICABLE VEHICLE ORDNANCE
FINAL NAVIGATION AUTO CHECKS
SECURE PROPELLANT LOADING SYSTEM
PRESSURIZE ORBITER LH2 TANK
PRESSURIZE ORBITER LOX TANK
PRESSURIZE BOOSTER LOX & LH2 TANKS
LH2 VENTS TO FLIGHT POSITION
ARM BOOSTER IGNITION
DEPRESSURIZE UMBILICALS
FLAME DEFLECTOR COOLING
RETRACT ALL SWING ARMS
SWING ALL ARMS
START BOOSTER ENGINES
COMPUTER CHECK ALL SYSTEMS
BOOSTER AT 100% THRUST
LAUNCH COMMIT (T-1 SECOND)
RELEASE HOLDDOWN MECHANISM
LIFTOFF
TAIL LIFTOFF MAST COVERING
DEFLECTOR & DECK WATER ON
START ENGINES 5,7 T-7.925 SECONDS
2,4 T-7.300 SECONDS
9,11 T-6.675 SECONDS
6,8 T-6.050 SECONDS
1,3 T-5.425 SECONDS
10,12 T-4.800 SECONDS
Acceptance Test & Launch Operations
MCDONNELL DOUGLAS

FIGURE 3.3-20

At T-30 seconds all swing arms will be retracted and will start swinging in order to avoid contact with the booster canard after liftoff. The booster swing arms which are used for the LH_2 tank ground vent and crew air conditioning must be capable of reconnection remotely and automatically within 15 minutes. The booster main engine start sequence will begin at T-7.925 seconds. The engines will be started in pairs at 0.650 second intervals, to minimize the transient fluid acceleration effects on the propellant feed ducts. The pairs and sequence are as follows: 5 & 7, 2 & 4, 9 & 11, 1 & 3, and 10 & 12. After the booster main engines come up to full thrust and the onboard computers verify that all systems are normal, launch commit is automatically initiated, whereupon the hold down release mechanisms release the vehicle and liftoff occurs.

At first motion, the vehicle lifts off of the booster and orbiter tailmasts. They then rotate and are covered to prevent damage from flame impingement. The deflector and deck water comes on at high flow-rates to protect the ground equipment.

3.3.1.6.1.4 Vehicle to Mobile Launcher (ML) Interfaces - The Shuttle vehicles will be erected, mated and launch positioned (see paragraph 3.3.1.5.1.3), while in an indoor environment, on a ML that is appropriately reworked to dedicate it for the Shuttle configuration. The ML base will have a raised platform constructed around the existing flame well to support the booster hold downs and tail masts. It will be approximately 25 feet high to provide wing to ML base (ML level 0) clearance without excessively long hold downs and tail masts.

The four hold downs (see Figure 3.3-21) will be paired to the top and bottom of the booster, picking up hard points 140 inches forward of the aft skirt (F.S. 3795) and symmetrical about the vehicle centerline. They will release at thrust buildup and be similar in concept to those used on Saturn V. Two tail lift-off masts, released at first motion and rotated under a bonnet made of high

BOOSTER TO MOBILE LAUNCHER BASE INTERFACES

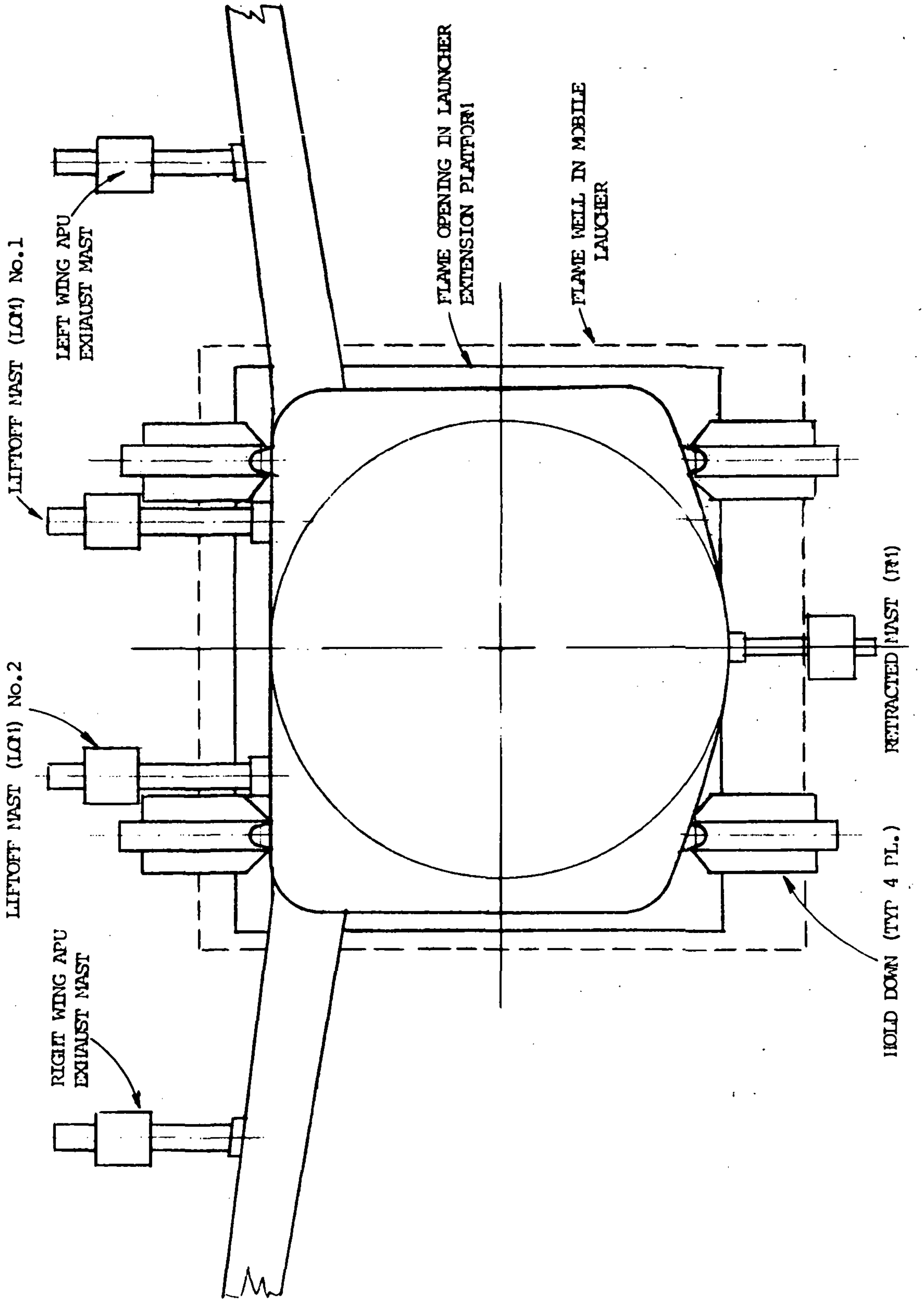


FIGURE 3.3-21

temperature materials, will be located at the upper surface, 139 inches forward of the aft skirt, symmetrically between the hold downs, and approximately 30° off the vertical. A retract mast (for JP-4 servicing) centered on the underside of the vehicle and 130 inches forward of the aft skirt, will be retracted and stowed prior to clearing the pad. Two ML base-mounted masts will mate the booster wing in flight APU exhaust ports, which are located in the trailing edge of each wing. The use of these in-flight vents instead of a single vent in a lift off tail mast avoids using six large divertor valves that would be required to meet the fail op/fail safe criteria.

A separate tower, extending approximately 90 feet above the ML base (0 level) will be constructed to house the orbiter tail unbilicals, located between and on either side of the two main engines. This tower will be hinged at the new platform to permit folding it across half the ML width, so as to provide clearance for booster emplacement on the ML in the VAB. An alternate solution would be to widen the bay for an increased height of 76 feet to permit raising the Booster over the tower.

Existing crawler/transporters (C/T's) and support pedestals will be used to transport and support the Mobile Launchers.

The GSE presently mounted on the ML and its LUT will, with few exceptions, be unsuitable for Shuttle needs. The propellants servicing, ground power, environmental and hazard purging systems will require major modifications or replacement. Similarly, the utilities, such as water, power and waste, will also need modification. The precise extent of these changes, however, cannot be determined during the Phase B study due to the lack of detail design information.

The Launch Umbilical Towers will have the structure above the 280 ft level removed to reduce the launch clearance requirements and the existing cranes and elevator machinery will be relocated to the 280 and 260 ft levels respectively. The existing swing arms and their support structure will also be removed and replaced with new swing arms and their drive units at appropriate levels. See Figures 3.3-22 and 3.3-23.

Four swing arms, two for each vehicle, are required to provide support for the umbilical connections, access to the crew compartments, and servicing of the vehicles. A fifth swing arm for cargo servicing will be kept in a stowed or retracted position except for appropriate missions. All the swing arms will retract prior to engine ignition at approximately T-30 seconds. The two Booster arms, at the intertank area and crew/forward compartment area, will require remote reconnect because they carry vehicle safing functions. All Orbiter safety functions are in the *tail plugs. Umbilical supply functions for each arm and the tail masts are* shown in Figure 3.3-24. Servicing functions are shown in Figure 3.3-25. (Reference 30 June release of ICD IF255G800).

The requirement for reconnecting the two Booster swing arms is necessitated by the magnitude of the weight penalties involved with bringing those swing arm functions associated with vehicle safing to the aft umbilical locations. The hydrogen vent in the intertank area results in a weight saving of over 3200 lbs. because of the grossly smaller diameter (4 vs 18 inches) and length. The other functions also save significant weight in addition to the secondary LH_2 and LOX fill and drain lines avoiding the vaporization problems attendant with excessive length.

Reconnect time lines are not critical and can be accomplished within 15 minutes, except for the forward (i.e. upper) arm which will be required for emergency egress. Ejection seats will be used for catastropic emergency egress (Reférence paragraph 3.3.1.6.4.2 for a more detailed discussion of emergency egress). The reconnect mechanics will be similar to the one used on the success-

MOBILE LAUNCHER CONFIGURATION

SWING ARMS TO EXISTING HATCHES AND UMBILICAL PLATE LOCATIONS

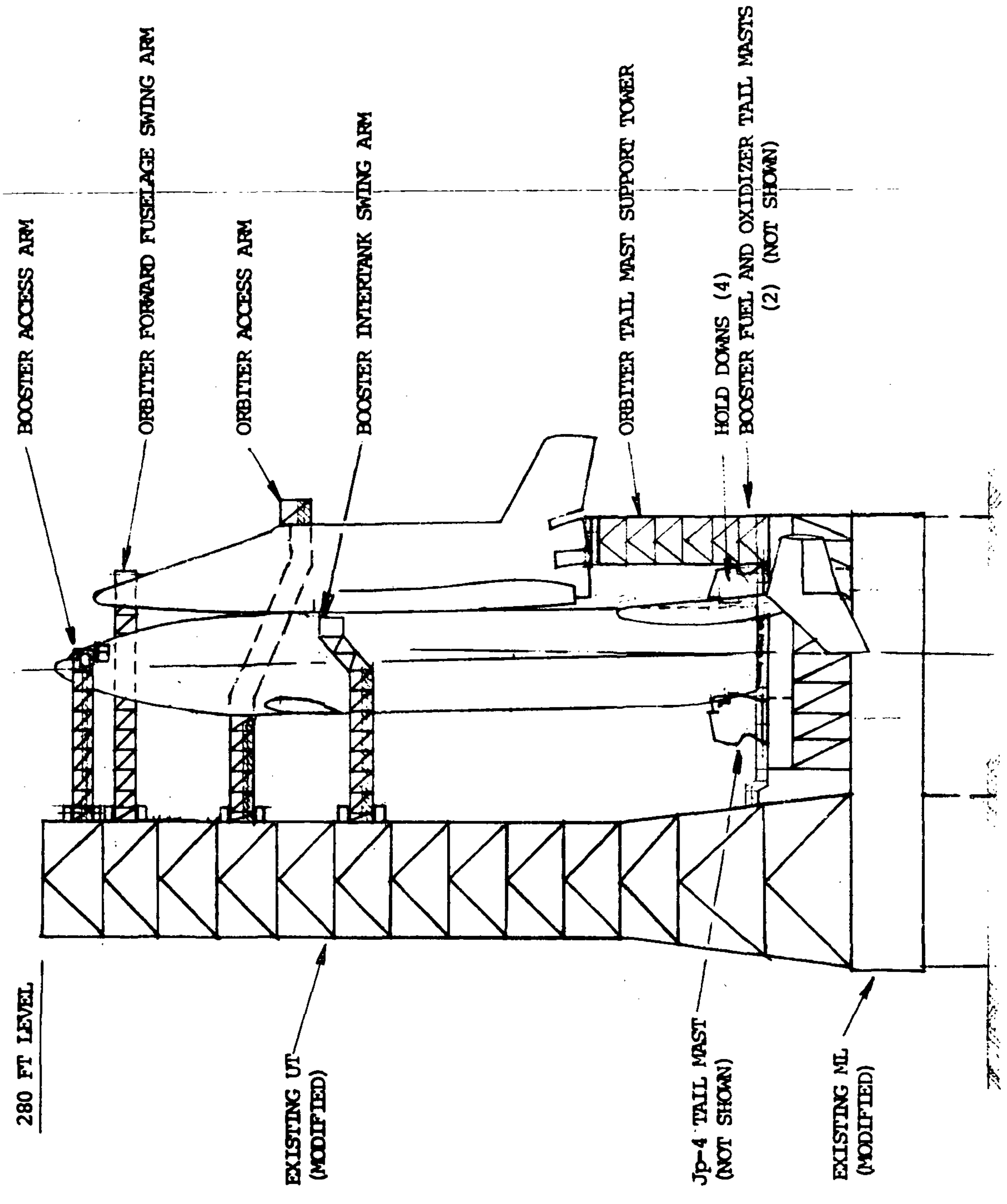
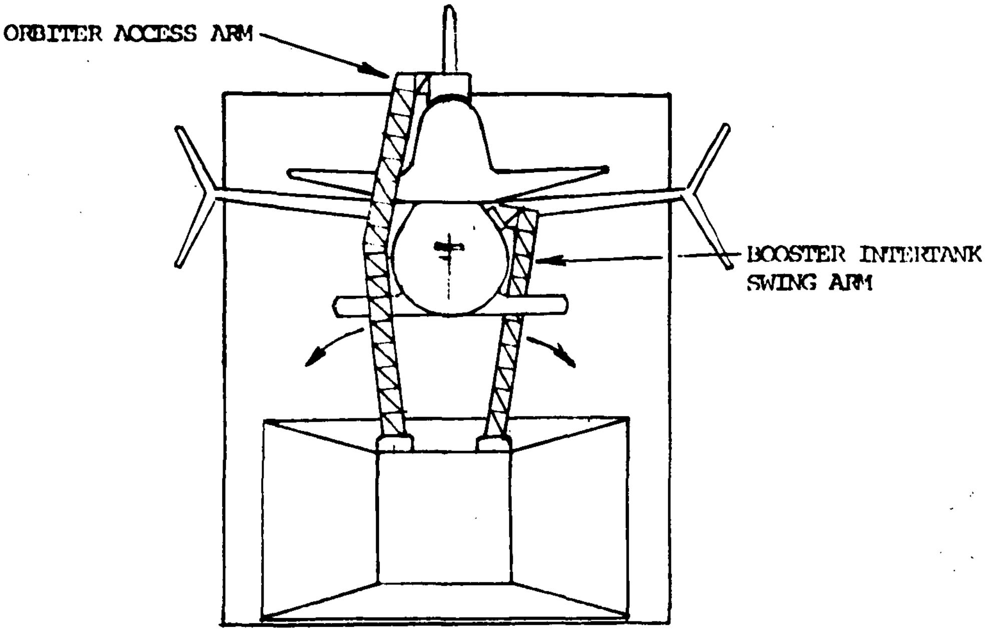


FIGURE 3.3-22

MOBILE LAUNCHER CONFIGURATION

SWING ARMS TO EXISTING HATCHES AND UMBILICAL PLATE LOCATIONS



PLAN VIEWS

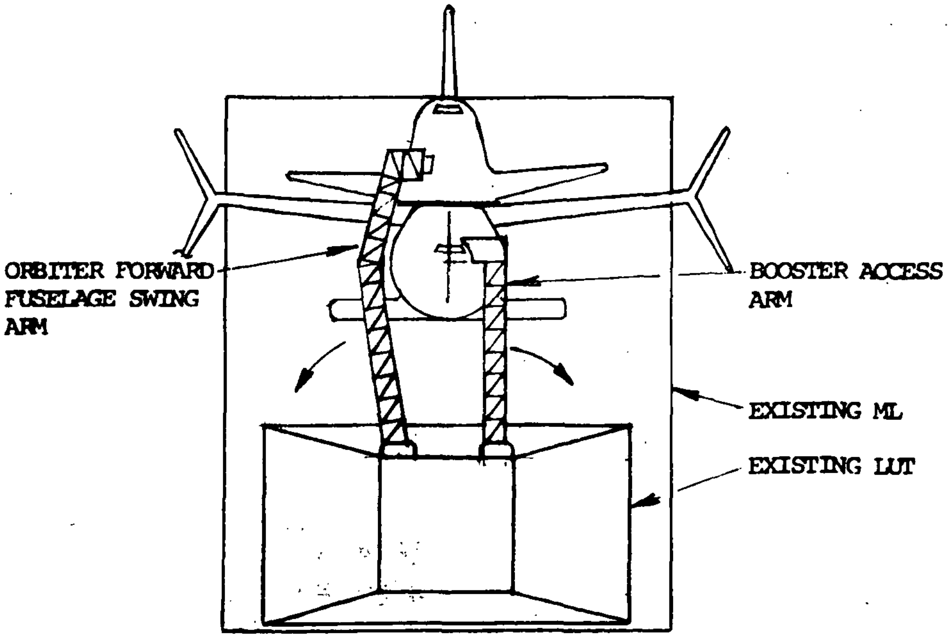
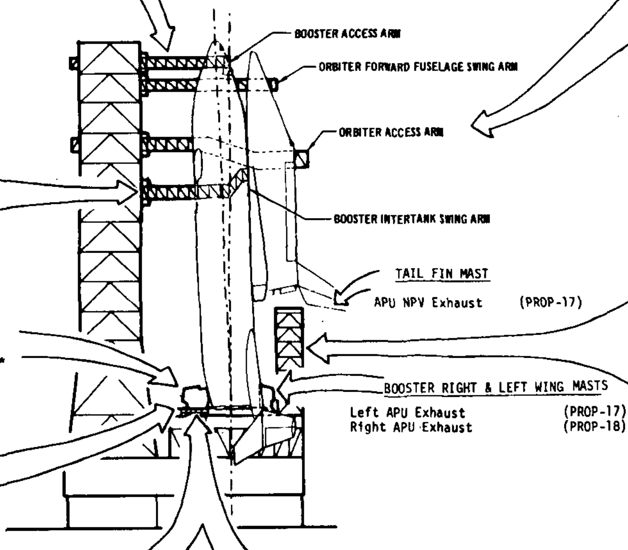


FIGURE 3.3-23

SPACE SHUTTLE BOOSTER AND ORBITER VEHICLE-TO-GROUND INTERFACES
FLY-AWAY UMBILICAL CONNECTIONS



CREW INGRESS/EGRESS ARM

Forward Comp. Air/GN_2 Purge	(ECLS-5)
Cockpit A/C	(ECLS-8)

INTERTANK SWINGARM

ACPS/APU LO_2 Fill & Drain	(PROP-1)
ACPS/APU LH_2 Fill & Drain	(PROP-2)
GOX Accumulator Precharge	(PROP-3)
GH_2 Accumulator	(PROP-4)
Main LH_2 Tank Vent	(PROP-15)
Intertank Compartment Air/GH_2	(ECLS-6)
Equipment Coolant Supply	(ECLS-12)
Equipment Coolant Return	(ECLS-13)

RETRACTED MAST

JP-4 Fill & Drain	(PROP-5) *

MECHANICAL INTERFACES

Pad Vehicle Supports (4)	(ST-1)
Vehicle Holddowns (4)	(ST-2)
Controlled Release (8)	(ST-3)

BOOSTER LIFTOFF MAST NO 1

Hyd.Reservoir Coolant Sup.	(ECLS-1)
Hyd.Reservoir Coolant Ret.	(ECLS-2)
Aft Compartment Air/GN_2	(ECLS-7)
Main LOX Fill and Drain	(ECLS-12)
Main LOX tank prepressure	(PROP-14)
Engine GN_2 Purge	(PROP-8)
Data Bus No 1	(AV-1)
Data Bus No 2	(AV-2)
Audio Bus No 1	(AV-5)
El. Power Bus No 1	(EP-1)
El. Power Bus No 2	(EP-2)
Switch, Power Bus No 1	(EP-5)
Switch, Power Bus No 2	(EP-6)

BOOSTER LIFTOFF MAST NO 2

Main LH_2 Fill and Drain	(PROP-13)
Main LH_2 tank prepressure	(PROP-16)
Stage Pneumatic Supply	(PROP-7)
Engine H_2 Drain	(PROP-9)
Data Bus No 3	(AV-3)
Data Bus No 4	(AV-4)
Audio Bus No 2	(AV-6)
El. Power Bus No 3	(EP-3)
El. Power Bus No 4	(EP-4)
Switch, Power Bus No 3	(EP-7)
Switch, Power Bus No 4	(EP-8)

TAIL FIN MAST

APU NPV Exhaust	(PROP-17)

BOOSTER RIGHT & LEFT WING MASTS

Left APU Exhaust	(PROP-17)
Right APU Exhaust	(PROP-18)

CREW INGRESS/EGRESS ARM

Cabin pressure integrity test	(ECLS-3) *
Tunnel pressure integrity test	(ECLS-4) *
Airlock pressure integrity test	(ECLS-5) *
Cabin Air Conditioning	(ECLS-20)*

ORBITER LIFTOFF MAST NO 1

Ground Cooling System Supply	(ECLS-14)
Ground Cooling System Return	(ECLS-15)
GN_2 Interstage Purge	(ECLS-23)
ACPS/APU LO_2 Fill and Drain	(PROP-1)
GO_2 Accumulator Precharge	(PROP-3)
Main LOX Tank Vent	(PROP-6)
Engine GN_2 Purge	(PROP-8)
Main LOX Tank Fill and Drain	(PROP-11)
Main LOX Tank He prepressurization	(PROP-13)
Data Bus No 1	(AV-1)
Data Bus No 2	(AV-2)
Audio Comm Bus No 1	(AV-5)
Power Bus No 1	(EP-1)

ORBITER LIFTOFF MAST NO 2

ACPS/APU LH_2 Fill and Drain	(PROP-2)
GH_2 Accumulator Precharge	(PROP-4)
JP-4 Fill and Drain	(PROP-5)
Pneumatic Supply He	(PROP-7)
Engine H_2 Drain	(PROP-9)
Cold He Fill and Drain	(PROP-10)
Main LH_2 Tank Fill and Drain	(PROP-12)
Main LH_2 Tank He Prepress	(PROP-14)
Main LH_2 Tank Vent	(PROP-15)
Data Bus No 3	(AV-3)
Data Bus No 4	(AV-4)
Audio Comm. Bus No 2	(AV-6)
Power Bus No 2	(EP-2)
Power Bus No 3	(EP-3)
Sec. Tank He Insulation Purge	(PROP-16)
Engine Shroud N_2 Purge-In	(PROP-18)
Engine Shroud N_2 Purge-Out	(PROP-19)
External DC Power	(EP-7)

* *Indicates Non-Flyaway Disconnects*

FIGURE 3.3-24

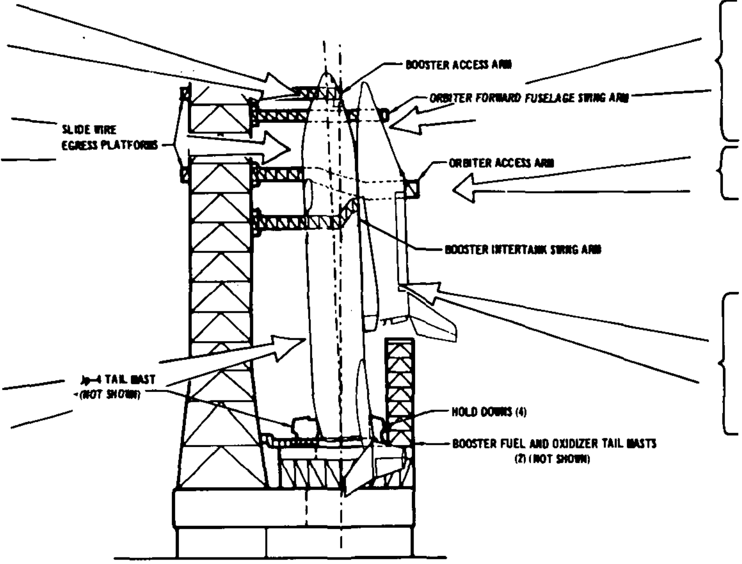
SPACE SHUTTLE BOOSTER AND ORBITER VEHICLE TO GROUND INTERFACES CONTINGENCY SERVICING CONNECTIONS

BOOSTER

COCKPIT HIGH PRESS. AIR	(ECLS -9)
BREATHING O_2 - EMERGENCY	(ECLS-10)
RAIN REMOVAL FLUID FILL/BLEED	(ECLS-11)

NOSE GEAR STRUT SERVICING	(LS -1)
NOSE GEAR TIRE SERVICING	(LS -3)

EQUIPMENT COOLING SYSTEM SERVICING	(ECLS -3)
MAIN GEAR STRUT SERVICING	(LS-2)
MAIN GEAR TIRE SERVICING	(LS-4)
HYDRAULIC SYSTEM #1 SERVICE	(HYD-1)
HYDRAULIC SYSTEM #2 SERVICE	(HYD-2)
HYDRAULIC SYSTEM #3 SERVICE	(HYD-3)
HYDRAULIC SYSTEM #4 SERVICE	(HYD-4)
HYDRAULIC SYSTEM #1 GN_2 ACC.	(HYD-5)
HYDRAULIC SYSTEM #3 GN_2 ACC.	(HYD-6)



ORBITER

NOSE GEAR STRUT SERVICING	(LS- 1)
NOSE GEAR TIRE SERVICING	(LS- 3)
BREATHING O_2 FILL/DUMP	(ECLS-1)
CABIN N_2 FILL/DUMP	(ECLS-2)
FUEL CELL COOLING H_2O FILL/DRAIN	(ECLS-16)
FUEL CELL ACCUM. "A" DRAIN	(ECLS-17)
FUEL CELL ACCUM. "B" DRAIN	(ECLS-18)
RAIN REMOVAL GAS FILL/BLEED	(ECLS-19)
CONDENSATE WATER TANK DUMP	(ECLS-27)
COND.,PROD. WATER DUMP MOD DRAIN	(ECLS-29)
CABIN COOLING FILL (PRIM.)	(ECLS-6)
CABIN COOLING VENT (PRIM.)	(ECLS-7)
CABIN COOLING FILL (SEC.)	(ECLS-8)
CABIN COOLING VENT (SEC.)	(ECLS-9)

MAIN GEAR STRUT SERVICING	(LS-2)
MAIN GEAR TIRE SERVICING	(LS-4)
EQUIPMENT COOLING FILL (PRIM.)	(ECLS-10)
EQUIPMENT COOLING VENT (PRIM.)	(ECLS-11)
EQUIPMENT COOLING FILL (SEC.)	(ECLS-12)
EQUIPMENT COOLING VENT (SEC.)	(ECLS-13)
HYDRAULIC SYSTEM #1 SERVICE	(HYD-1)
HYDRAULIC SYSTEM #2 SERVICE	(HYD-2)
HYDRAULIC SYSTEM #3 SERVICE	(HYD-3)
HYDRAULIC SYSTEM #4 SERVICE	(HYD-4)

FIGURE 3.3-25

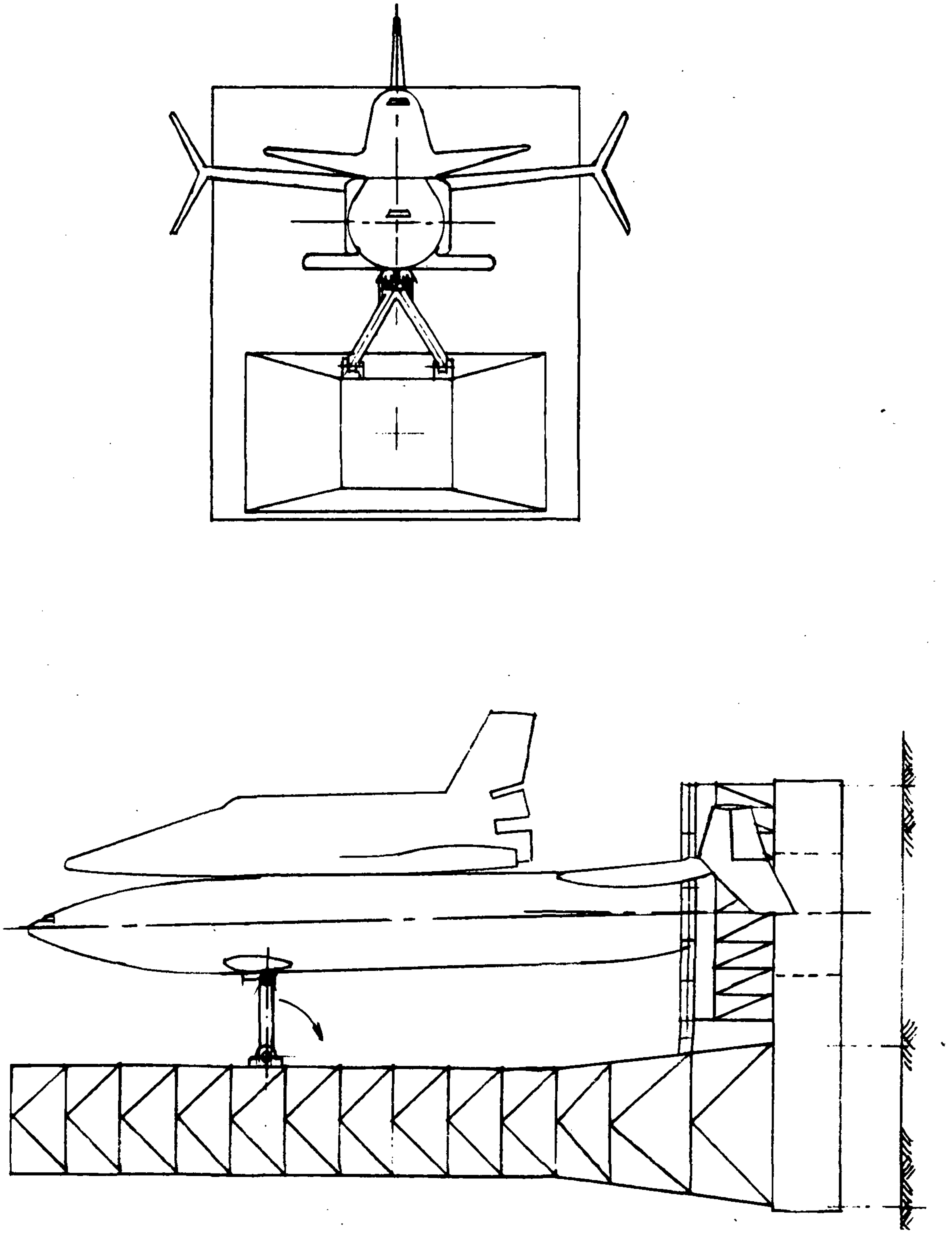
fully demonstrated Saturn S-1C intertank swing arms, which provides twin LOX fill and drain disconnects.

A vehicle damper, mounted to either side of the LUT and lowered (or raised) like a drawbridge, will attach to the underside of the Booster in the nose gear area. It will stabilize the mated vehicles and dampen vibrations that might be caused by wind and transportation loads. After vehicle fueling, it will be raised (or lowered) and stowed against the LUT. See Figure 3.3-26.

This baseline configuration will afford more than the required 24 ft of launch clearance at the top of the LUT and also provide clear ejection seat paths. Cargo changeout will readily be accomplished by transporting the existing Mobile Service Structure (MSS) to the pad with a C/T and positioning it on existing hard points. The Saturn V clam-shell work platforms will be removed and cargo handling mechanisms, including a crane will be added. To provide cargo changeout and accessibility while in the VAB, appropriate extensible platforms and their supporting structure can be reworked to afford the necessary work platforms and cargo loading mechanisms.

The disadvantage of the configuration as described above (Reference Figures 3.3-22 and 3.3-23), are the swing arm lengths required. Those to the Orbiter are greater than 110 feet and to the Booster greater than 60 feet. Figure 3.3-27 shows much more idealized umbilical and crew hatch locations, but as can be seen, the percent change in length is slight.

The upper orbiter swing arm will be used for servicing only (no fly away functions) and will therefore be slow moving and normally retracted. The crew ingress/egress and cabin air conditioning swing arm is scheduled to start retracting at T-30 seconds, but its enormous length and consequent large moment of inertia might preclude withdrawing it that late in the count. Also, quick repositioning from the stowed position for catastrophic emergency egress will be improbable and the crew will be forced to rely on the ejection seats.



DAMPER ARM CONCEPT

DAMPER ARM APPLIED AT NOSE LANDING GEAR.
ALSO PROVIDES ACCESS TO WHEEL WELL.

FIGURE 3.3-26

MOBILE LAUNCHER CONFIGURATION

SWING ARMS TO IDEALIZED HATCH AND UMBILICAL PLATE LOCATIONS

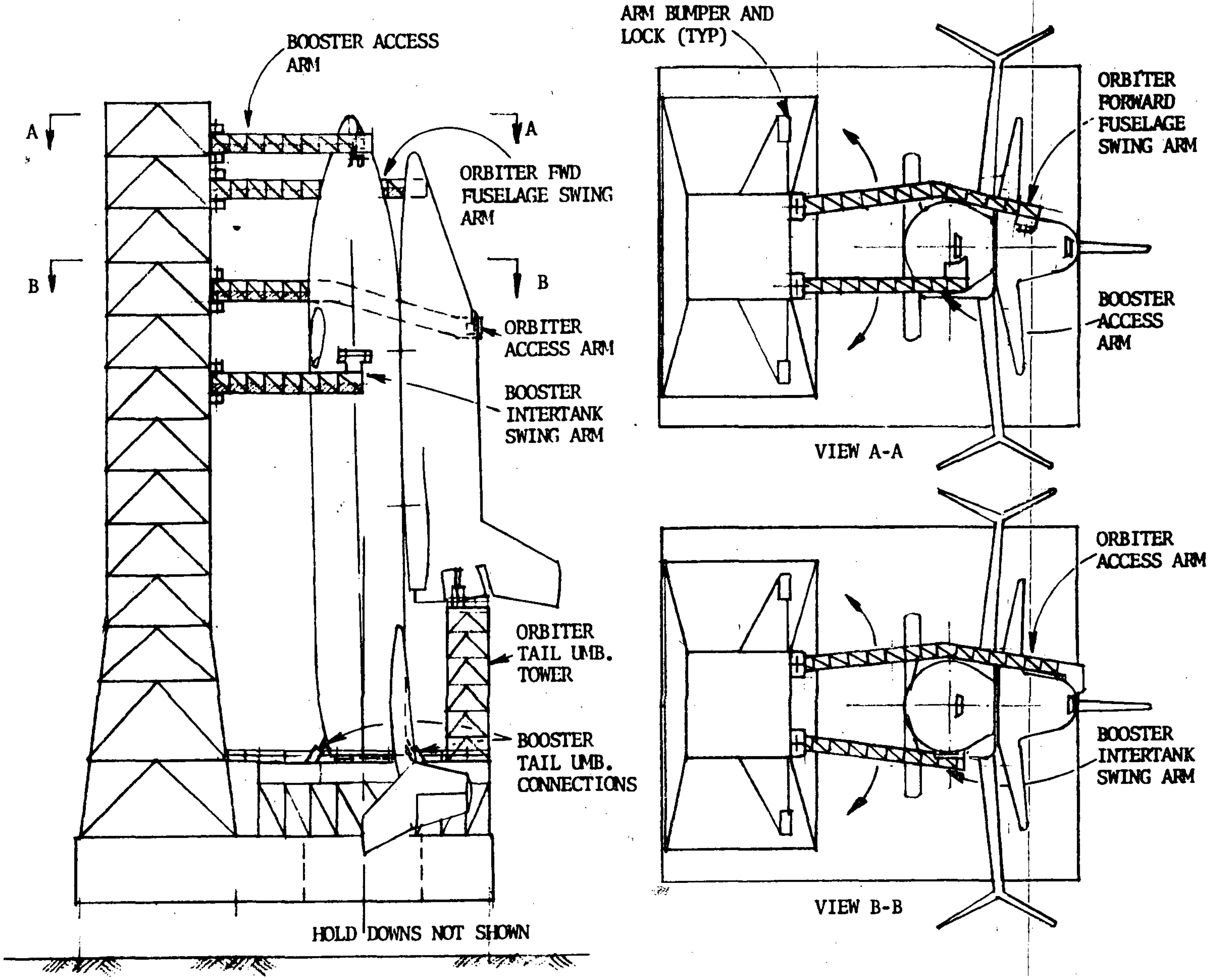


FIGURE 3.3-27

An alternate solution to the above problems is to replace the existing LUT with twin towers as shown in Figures 3.3-28 and 3.3-29. The Orbiter would then be located on the tower side of the Booster (i.e., belly away from the tower) with its vertical stabilizer projecting between the towers. Here the swing arms are relatively short, the longest being the Booster crew egress/ingress arm, which is approximately 60 feet. Cargo changeout platforms and mechanisms can easily be mounted between and to the towers, as well as quick timeline emergency egress systems for crew/passengers.

The major disadvantage of this concept is restricted ejection seat path clearances. The crew of both vehicles would be ejected between the towers. Also, the high bay (VAB Bay 3) doors would need major rework to provide tower clearance. It should be noted, however, that preliminary estimates indicate the twin tower concept is cost competitive with the baseline, principally due to the high cost of the long swing arms associated with the latter.

3.3.1.6.2 Post Launch - The activities associated with post launch are divided into two areas: (1) Revalidation of the facilities and GSE which are required to service and launch the shuttle vehicle and (2) Revalidation of the facilities and GSE which are required to support prelaunch checkout. These activities include scheduled and unscheduled maintenance and checkout.

3.3.1.6.2.1 Service and Launch Facilities and GSE Revalidation - These activities begin with liftoff of a shuttle vehicle and will be completed prior to their usage on the next shuttle launch. As soon as the pad is safe for return of personnel, a pad damage assessment will be made in order that the unscheduled maintenance may be planned. A time of three days is anticipated to be required to turn around the launch facility. After the damage assessment is made, the planned maintenance will start. Included in this effort will be tasks covering the following areas of work:

LAUNCH CONFIGURATION CONCEPT

NEW TWIN TOWER LUT (EXISTING ML)

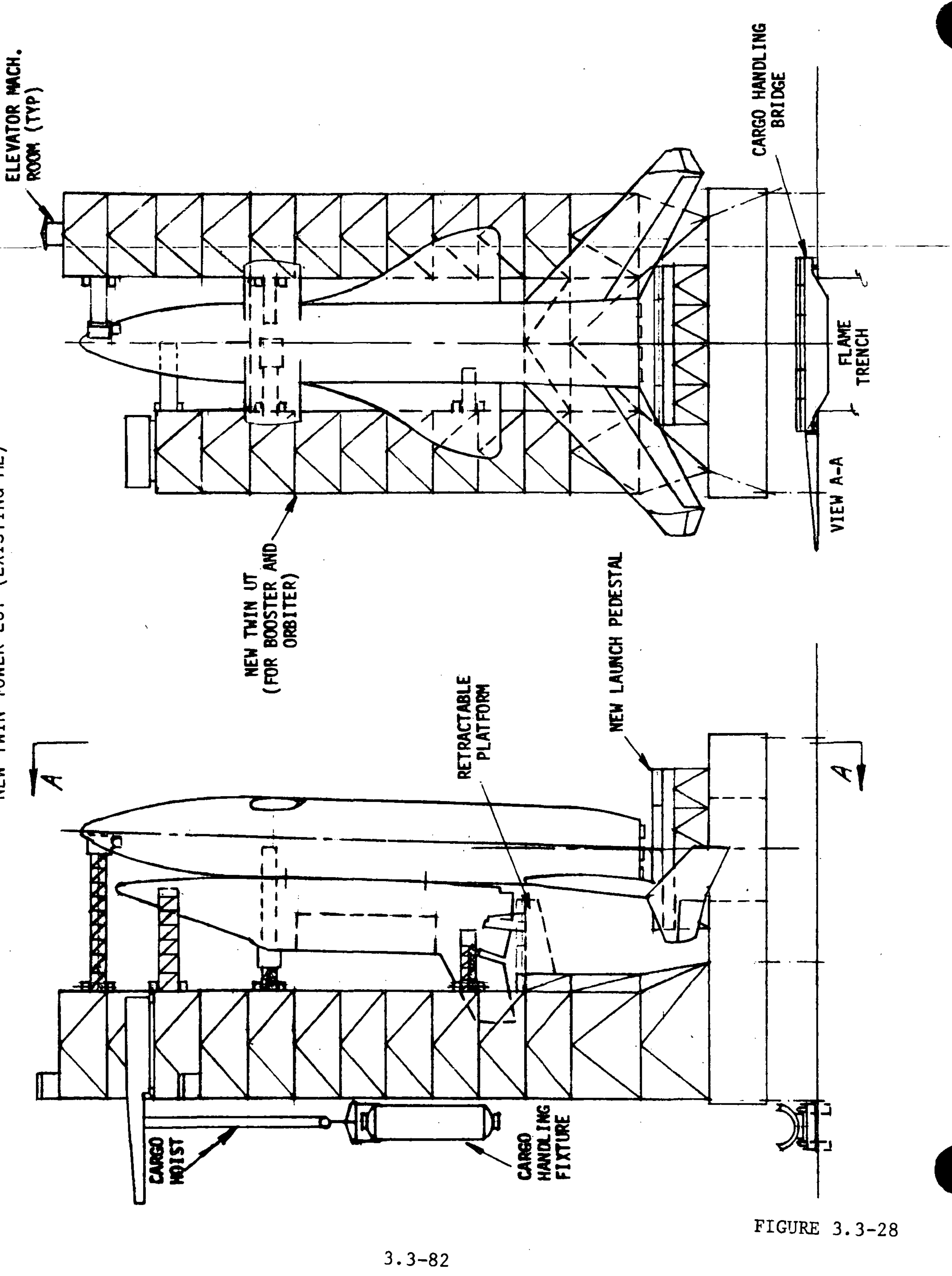


FIGURE 3.3-28

LAUNCH CONFIGURATION CONCEPT

NEW TWIN TOWER PLAN VIEW

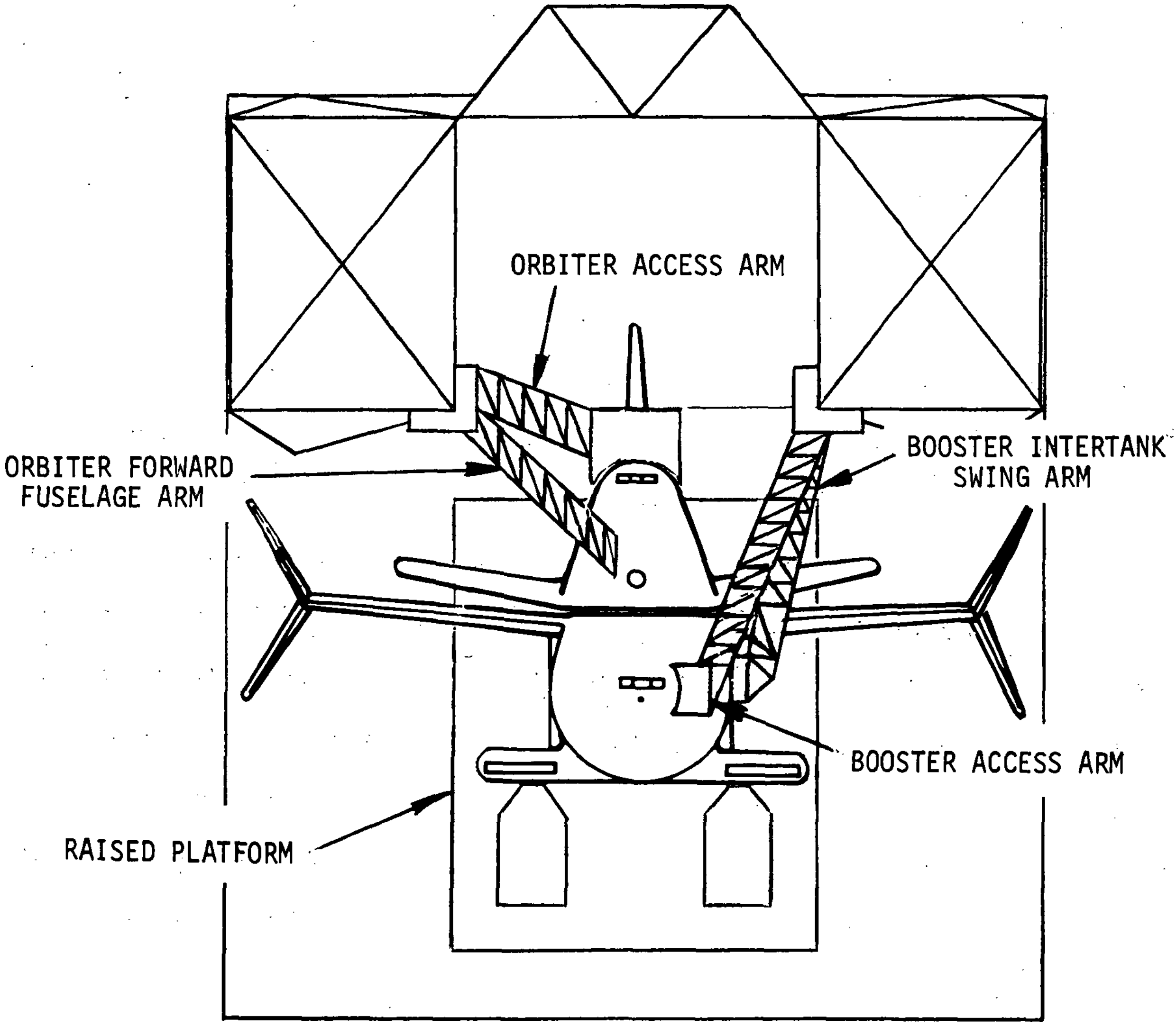


FIGURE 3.3-29

A. Purge propellant and gas lines

B. Visual inspection

C. Non-destructive testing (NDT)

D. Corrosion control activity

E. Replace expended equipment (i.e., ordnance)

F. Replenish propellants and gases

G. Functional checkout

H. Movement of the ML to the VAB area

Methodology in maintenance, repair, replacement and checkout of facility and GSE will be essentially the same as for a vehicle. The techniques developed for the vehicle will also be utilized for ground hardware.

Three areas which support the launch activities are the Launch Control Center (LCC), the Mobile Launcher (ML) and the pad/facility areas. The LCC will require the least amount of effort, and that effort is primarily related to the computer and the Monitor, Display and Control (MDAC) unit. This equipment must be serviced, repaired and reprogrammed for the next vehicle prior to usage. In addition, the peripheral equipment must also be readied for the next launch. Functional checks will, in general, be limited to computer self checks and redundancy verification.

The pad/facility area will require more effort than the LCC, but less than the ML. Damage to the pad is expected to be minimal. Routine maintenance will be required on the electrical, mechanical and fluid systems. Such systems are air conditioning, power distribution and fluid farms. Again only those tests will be performed that are required to ascertain that the equipment is ready to support the next launch. The LH_2 propellant facility is an example of the level of effort required. The cross-country and farm LH_2 vacuum jacketed lines will be checked for vacuum and pumped down if necessary. The system will be automatically leak checked utilizing the MDAC unit for control. A series of pressure decay tests will be performed to verify internal and external integrity. The computer will be programmed to set-up pneumatics, pressurize the system in sections, monitor pressure decay over a period of time, calculate the leakage rate and determine its acceptibility. In addition, the MDAC unit will verify that the redundant components and assemblies operate properly. The storage tanks will require refilling.

The ML is anticipated to receive some damage during each launch; however, design reviews will be conducted after early launches and design improvements incorporated, as necessary, to reduce recurring damage. Preliminary design will investigate avenues which will reduce the damage and expected losses that have been realized on the Apollo Program. An example is the TPS studies conducted for the vehicle which will be analyzed for application to the holddown arms and other equipment which is presently protected from high temperatures by ablatives. After the routine maintenance is performed on the ML, checkout will be performed to the degree necessary to verify that the hardware is ready to support the next launch. Checkout of the holddown system, swing arms, pneumatic and propellant distribution system, power distribution system and data management system will be to the same level as described above for the pad and will also be automatically performed by the MDAC unit.

3.3.1.6.2.2 Maintenance Area Facilities & GSE Revalidation - The GSE constraint is not just for support of the vehicle for a 10 day turnaround -- the GSE must also be capable of turnaround itself between usages in a rapid manner. Fast GSE turnaround will require more advanced methods of checkout and maintenance than were utilized on previous programs. This requirement leads the GSE to the same maintenance and checkout methods as those planned for the vehicle. Performance and trend analysis, go-no go checks, automatic fault isolation, automatic test, computerized data reduction will be implemented. The equipment located in the maintenance area is considered part of the turnaround critical equipment. Its ability to support vehicle revalidation after repair/replacement of parts and to support prelaunch checkout which includes subsystem checkout and combined systems tests must be uninterrupted in order to meet the two week turnaround requirement. All equipment in this category will be revalidated on an elapsed time basis. The equipment should not require checkout prior to usage for each vehicle since it is not subjected to the extremes that the launch equipment is exposed to, nor does it handle hazardous fluids. Redundancy within the equipment and backup end items will insure that the hardware will not cause a shuttle delay. Again GSE revalidation, when required, will be highly automatic and will be controlled by the MDAC unit.

3.3.1.6.3 Hold/Recycle Capability - The plan is for continuous capability to launch. To meet delays which were not caused by the shuttle's inability to launch due to technical problems, the shuttle should have the capability to meet delays on a continuous basis.

3.3.1.6.3.1 Hold Capability - The shuttle system will have the capability to hold indefinitely at the T-2 1/2 hour standby point. The shuttle at that point, will not have any time critical systems activated. Also, the shuttle is not expected to be in a hazardous condition other than having JP-4 fuel onboard, gaseous hydrogen in the hydrogen tankage systems, and all flight ordnance connected.

After propellants are loaded, the shuttle system will have the capability of holding for a maximum of 10 hours. During this hold, the cryogenic propellant tanks will be continuously replenished and maintained at the 100% level. The 10 hour time figure was chosen for two reasons: (1) the reference space station support mission has two launch windows per day and they are 9 hours apart, and

(2) the confidence of meeting the second window is greater if the cryogenic propellants remain aboard.

The shuttle tankage systems are in the replenish mode because past experience has indicated that most problems with cryogenic systems occur during transitional operations. Further, the transition which is most critical is chilldown where the tankage and components see temperature changes which start at ambient and fall to as low as -423°F; a change of approximately 500 degrees.

The cost of the hold will be primarily driven by the cost of the propellants which has a boiloff rate of approximately 8% per hour for LH_2 and something less for LO_2. The facility storage tanks will have to be sized accordingly.

3.3.1.6.3.2 Turnaround Capability - The shuttle system will have the capability of turning around in 9 hours, maximum. Again this requirement comes from the two daily windows of the reference space station support mission occurring 9 hours apart. The 9 hours includes time to correct minor repairs to the shuttle vehicle which may have caused the delay. Since fixed turnaround activities will not take the full 9 hours, some time can be set aside for repairs. Detanking the cryogenics will require approximately 2 1/2 hours and purging to the level required for repair will depend on the location and use of the component. The maximum time allowed for purging, repairing, and retesting will be four hours in order to meet the 9 hour turnaround requirement. The last 2 1/2 hours of a turnaround will be a normal "standby-to-launch" countdown. In addition to the above, a turnaround which includes draining the propellants, will be utilized if the hold is estimated to be over 10 hours in duration even if the delay is not attributable to the shuttle system.

3.3.1.6.4 Crew/Passenger Egress - The Shuttle concept requires personnel egress capability with the vehicles horizontal during the post landing period and vertical for on-pad launch operations. The positions of the mated vehicles and orientation on the Mobile Launchers are considerations in the design and location of the hatches. The Booster hatch is located on the left side (looking forward) in the crew station area (See Figure 3.3-30). The Orbiter hatches are located in two areas along the vehicle top centerline. The forward hatch is in the crew station over the cargo specialists seats. The aft hatch is over the airlock, just forward of the cargo module compartment. Figure 3.3-31 shows the personnel seating locations and internal passageway configuration.

PROFILE – BOOSTER
CREW COMPARTMENT

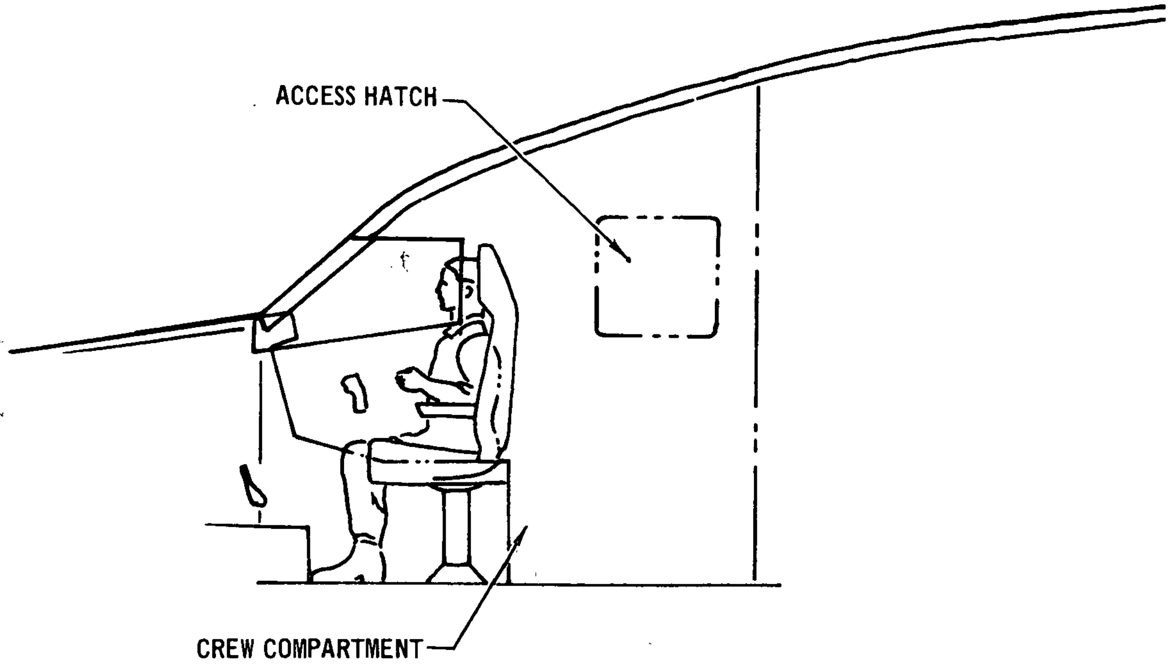


FIGURE 3.3-30

3.3.1.6.4.1 <u>Normal Egress</u> - This condition is defined as the movement of personnel during normal vehicle operations at landing sites and the launch pad. For horizontal operations of the vehicles, mobile units similar to standard airport equipment will be provided. In the vertical mode, egress will be via the launcher. These units include swing arms which interconnect the vehicle hatches with the launcher umbilical tower. The tower includes elevators which transport personnel to the launcher base level.

3.3.1.6.4.2 Emergency Egress - This condition is defined as a situation which requires rapid egress due to a hazardous condition at the landing sites or the launch pad. Figure 3.3-32 shows the use of the inertia reel escape device which is adaptable to Booster and Orbiter vehicles for horizontal operations. The reel units will be located at each hatch. A thermal blanket will be unrolled over the side prior to egress of the personnel. The blanket will be secured to the vehicle at the same location as the inertia reel units. Vehicle emergency egress on the launch pad will be via the mobile launcher swing arms similar to the Apollo method. The arms are fully extended to the vehicle hatches. Prior to lift off these arms are partially retracted and can be extended to the vehicle hatches within seconds. Under emergency conditions personnel will egress through their respective hatches and move over the swing arms to the umbilical tower. The access swing arms will be enclosed walkways with guide rails, panic hardware and protection systems (extinguishers, nonslip flooring, tool kit, water spray, etc.). From the tower levels, two (2) means of escape will be available. The elevators will descend to the launcher deck level at a speed of 600 fpm. At this level personnel will proceed via a slide tube to the below ground level blast room. The alternate method of tower egress is use of slide wires located on each tower level adjacent to the vehicle hatch. As personnel reach the slide they will proceed individually down the slide to ground level where they will go into the blast room or the waiting evacuation vehicles. The ground systems from the mobile launcher to the blast room will be modified. Slide wire elevation will decrease by approximately one hundred feet. At ground level the termination area will be relocated and underground protective structures provided which will decrease the total egress time and thereby increase survivability probability.

PROFILE – ORBITER
CREW & PASSENGER COMPARTMENT

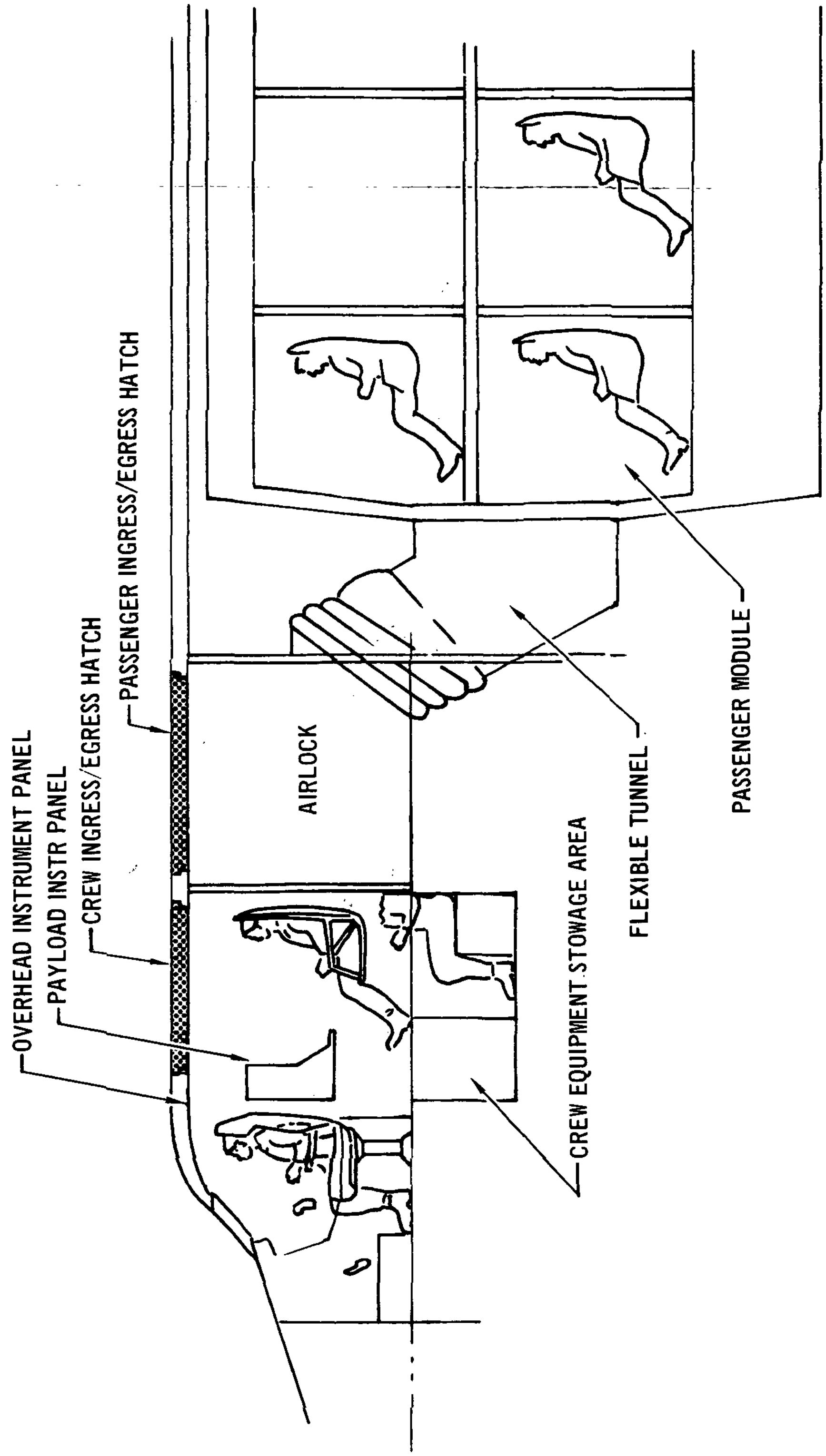


FIGURE 3.3-31

INERTIA REEL ESCAPE

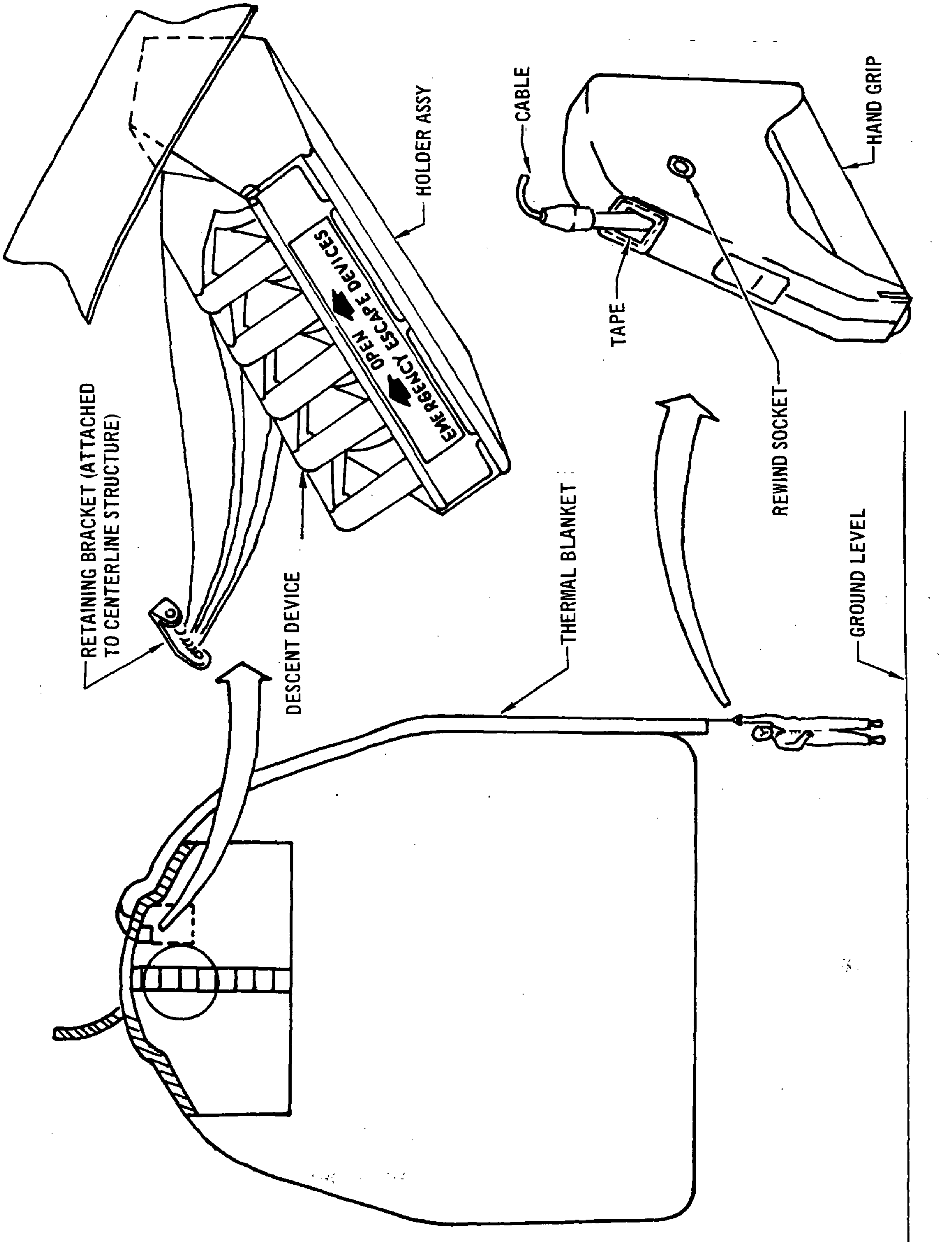


FIGURE 3.3-32

3.3.1.6.4.3 Baseline Shuttle/Mobile Launcher Configuration - Figure 3.3-33 shows the Shuttle orientation with the Orbiter positioned outboard using an existing single tower mobile launcher. The Booster crew will egress through the vehicle side hatch and proceed over the swing arm to the umbilical tower. The Orbiter crew and cargo specialists will egress through the overhead hatch (Ref.figure 3.3-31). Passengers will move forward via the tunnel from the cargo module and egress through the overhead hatch to the swing arm.

Egress from the umbilical tower will be by slide wire or the high speed elevators. Communications from the control center prior to personnel egress will inform the vehicle personnel of the conditions and provide recommendations for egress. Additionally, visual and audio aids will be provided on the tower. If the elevators are selected, the personnel will leave the elevator at the base level of the launcher and proceed independently through the slide tube into the underground protection area. Figure 3.3-34 identifies the estimates of time for personnel egress from alarm through arrival in a protected area. The total time includes one activity which may not be a required operation. In this event the time would be reduced proportionately. The donning of individual air packs depends upon the atmospheric contamination level and whether the swing arm safety systems have been activated. The use of crew ejection seats provides the shortest time lapse in the event of a catastrophic event. With the orientation shown in Ref. Figure 3.3-33, the ejection path, to the south, is unobstructed by the mobile launcher umbilical tower.

3.3.1.6.4.4 Alternate Shuttle/Mobile Launcher Configuration - Figure 3.3-35 presents an alternate concept of vehicle orientation, which although requiring the same activities the time estimates are different due to the shorter distances. The Orbiter arm is approximately ninety (90) feet shorter than in the baseline configuration. Egress activities within the vehicle, and from the tower to ground level are the same for both concepts. Figure 3.3-36 shows the time estimates for this concept.

BASELINE SHUTTLE/MOBILE LAUNCHER ORIENTATION – ORBITER OUTBOARD

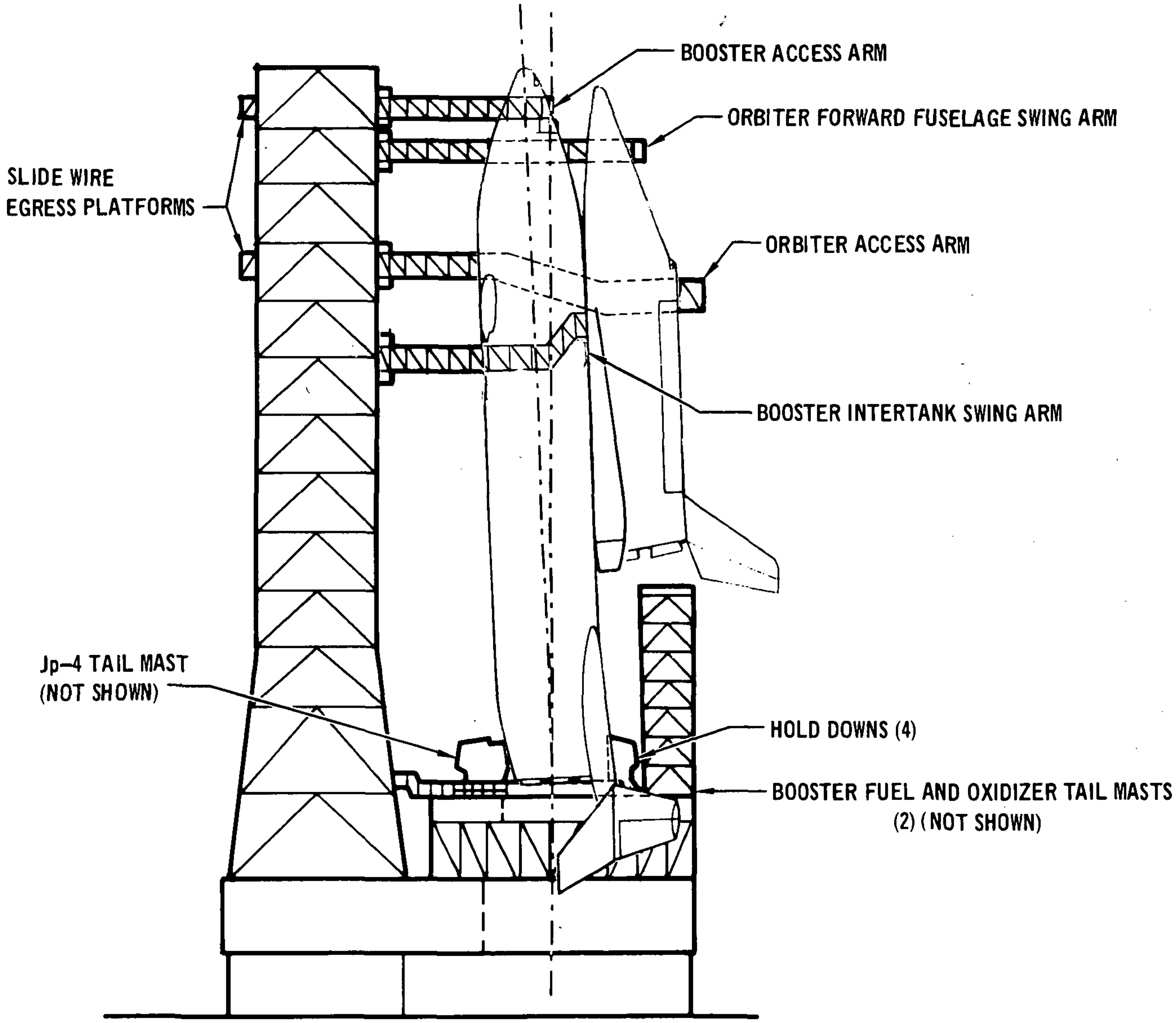


FIGURE 3.3-33

SHUTTLE/MOBILE LAUNCHER ORIENTATION - ORBITER OUTBOARD

(EXISTING SINGLE TOWER MOBILE LAUNCHER)

EVENT	CREW COMPARTMENT		CARGO COMPARTMENT
	ONE PERSON	FOUR PERSONNEL	TEN PERSONNEL
ALARM REACTION TIME	3	3	3
PERSONNEL ACTIVITY SEATED	2	2	2
INTERIOR MOVEMENT	4	10	22
VEHICLE HATCH OPENING	2	2	2
VEHICLE HATCH PASS THRU	2	8	20
DON AIR PACKS (IF REQUIRED)	20	20	20
MOVEMENT OVER SWING ARM	12	18	30
DESCENT TO GROUND INTO PROTECTION AREA	70	73	79
	115	136	178
TOTALS	(1 MIN. + 55 SEC.)	(2 MIN. + 16 SEC.)	(2 MIN. + 58 SEC.)

FIGURE 3.3-34

ALTERNATE SHUTTLE/MOBILE LAUNCHER ORIENTATION – ORBITER INBOARD

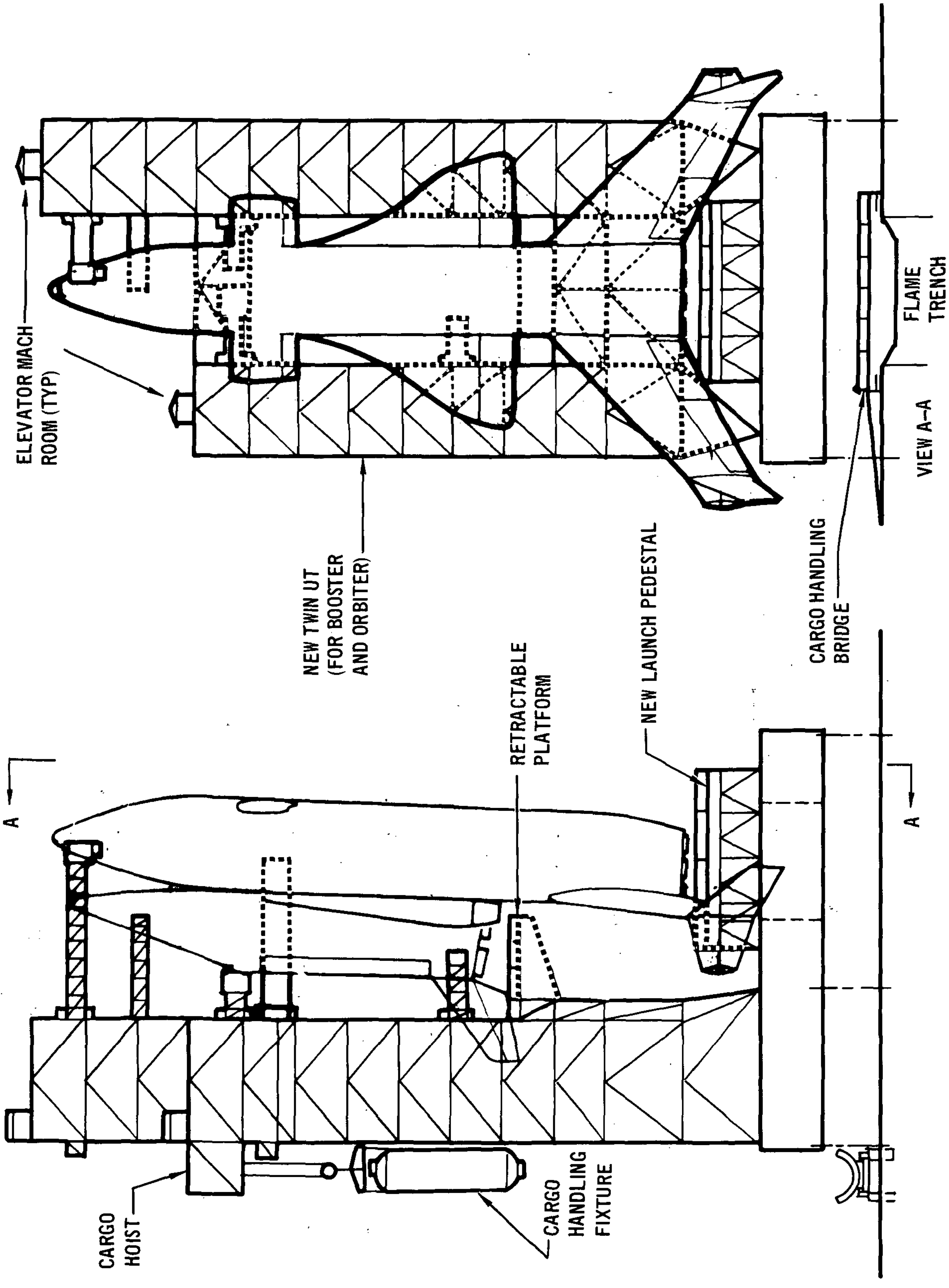


FIGURE 3.3-35

SHUTTLE/MOBILE LAUNCHER ORIENTATION - ORBITER INBOARD

	CREW COMPARTMENT		CARGO COMPARTMENT
	ONE PERSON	FOUR PERSONNEL	TEN PERSONNEL
ALARM REACTION TIME	3	3	3
PERSONNEL ACTIVITY SEATED	2	2	2
INTERIOR MOVEMENT	4	10	22
VEHICLE HATCH OPENING	2	2	2
VEHICLE HATCH PASS THRU	2	8	20
DON AIR PACKS (IF REQUIRED)	20	20	20
MOVEMENT OVER SWING ARM	4	10	22
DESCENT TO GROUND (AND INTO PROTECTION AREA)	70	73	79
	107	128	170
TOTALS	(1 MIN. + 47 SEC.)	(2 MIN. + 8 SEC.)	(2 MIN. + 50 SEC.)

FIGURE 3.3-36

3.3.1.6.5 Launch Capabilities - Launch capabilities for the Space Shuttle depends on the availability of vehicles, facilities, personnel and ground turnaround time required to support each launch. This section includes the rationale for the baseline fleet size and the launch rate capability utilizing this fleet size.

3.3.1.6.5.1 Fleet Size - The baseline fleet size is 4 Orbiters and 3 Boosters. The fleet size can accomplish the maximum launch rate of 75 with the following assumptions:

- Seven (7) day Orbiter mission
- Two pads used alternately
- Three mobile launchers used sequentially
- Launch and landing site at same location
- Interchangeability between vehicles
- Interchangeability between vehicles and mobile launchers
- Interchangeability between mobile launchers and pads
- Standard five day work week
- Dormant time and weekends available for contingency
- Launch days are equally spaced depending on vehicle availability
- No major problems

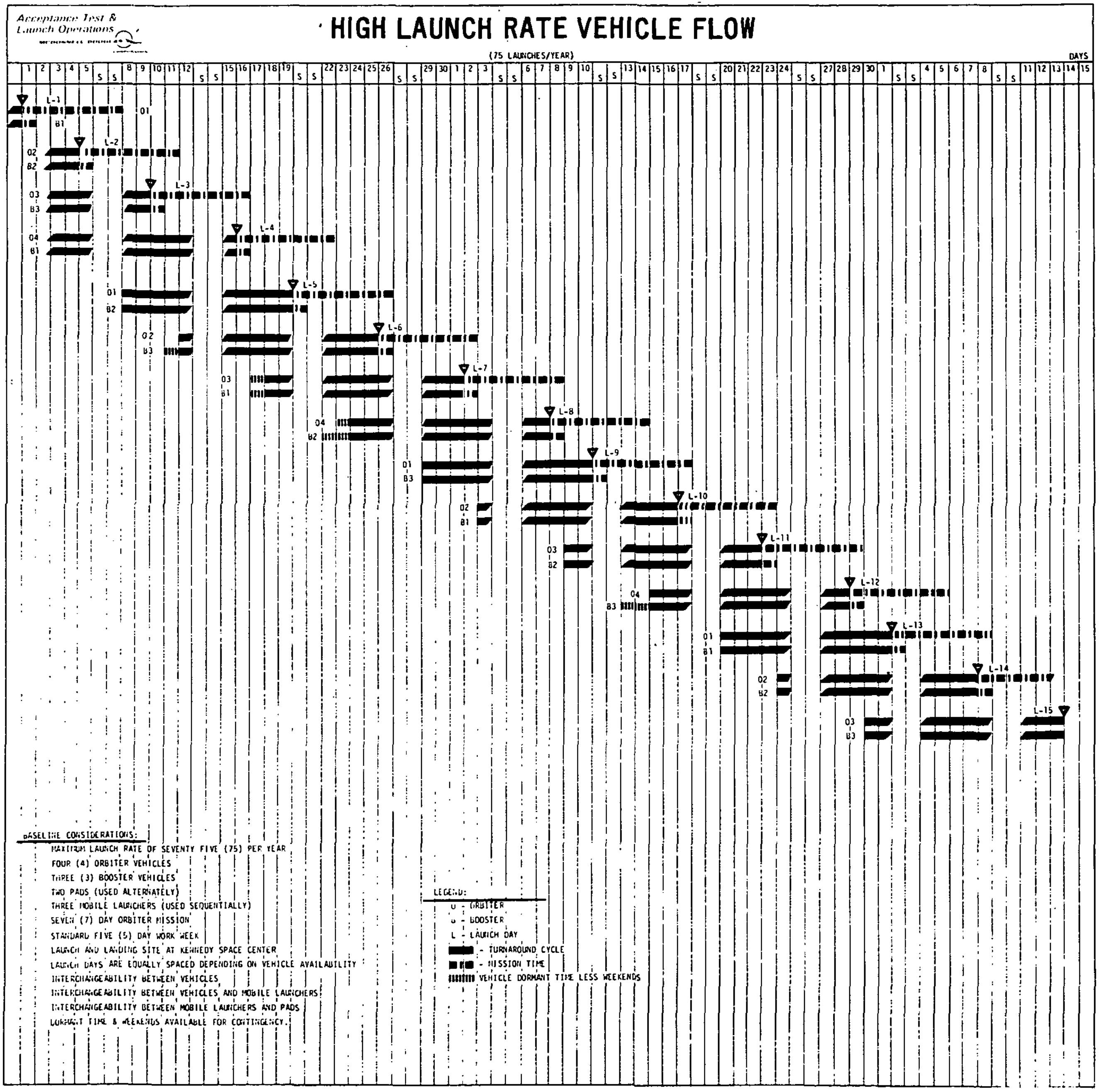
It is recognized that this is an ambitious and optimistic approach. However, it is a cost effective approach in that it eliminates the cost of an additional set of vehicles. It is anticipated that when the more realistic mission model is defined for Phase "C" and "D" that all missions will not be of seven day duration nor will the launches be equally spaced. The size of the fleet will again be reviewed to determine if it is still adequate.

It is also recognized that in order to meet the 48 hour rescue requirement that an additional set of vehicles would be required. This would be a dedicated set of vehicles, facilities and crew. This subject is discussed in more detail in paragraph 3.3.1.9.

3.3.1.6.5.2 Launch Rates - Launch rates for the Space Shuttle depend on the availability of vehicles, facilities, personnel and ground turnaround time required to support each launch. During the operational phase, three Boosters and four Orbiters will be available per our baseline. The usage projections are based on a normal orbiter mission duration of seven days and ground turnaround time, for both Booster and Orbiter, of ten working days. For planning purposes the ground activity is based on a five day 2-shift work week except launch day which is a 24 hour activity. No weekend activity is planned. Section 3.3.1.4 identifies the planned typical turnaround cycle.

High launch rates increase the number of vehicles required and correspondingly require shorter turnaround time. Lower rates require fewer vehicles and allows additional time for turnaround. For the lower launch rates, the surplus vehicles can be used for rescue or serve as backup replacements. For the forty (40) launches per year plan, three Orbiters and two Boosters are required. The ground activities will see one Booster completing its turnaround as the second Booster is in the launch mode. Two Orbiters will be in turnaround (similar to the Booster) with one on mission. Based on the time between launches, there is surplus ground time for both vehicles. There are approximately three to five dormant days for the Booster and approximately seven for the Orbiter. Available time for pad refurbishment would be about eight days if only one pad is used. If two mobile launchers were used, twelve days of refurbishment time would be available. For sixty launches per year, the full complement of vehicles is required. Minimum requirements for mobile launchers and pads are two and one respectively. However, the second launch pad is required to support rescue operations.

Figure 3.3-37 identifies the vehicle flow for a high launch rate of 75 flights per year. The baseline considerations required to achieve this launch rate are



Acceptance Test & Launch Operations

HIGH LAUNCH RATE VEHICLE FLOW

(75 LAUNCHES/YEAR)

BASELINE CONSIDERATIONS:

MAXIMUM LAUNCH RATE OF SEVENTY FIVE (75) PER YEAR
FOUR (4) ORBITER VEHICLES
THREE (3) BOOSTER VEHICLES
TWO PADS (USED ALTERNATELY)
THREE MOBILE LAUNCHERS (USED SEQUENTIALLY)
SEVEN (7) DAY ORBITER MISSION
STANDARD FIVE (5) DAY WORK WEEK
LAUNCH AND LANDING SITE AT KENNEDY SPACE CENTER
LAUNCH DAYS ARE EQUALLY SPACED DEPENDING ON VEHICLE AVAILABILITY
INTERCHANGEABILITY BETWEEN VEHICLES
INTERCHANGEABILITY BETWEEN VEHICLES AND MOBILE LAUNCHERS
INTERCHANGEABILITY BETWEEN MOBILE LAUNCHERS AND PADS
DORMANT TIME & WEEKENDS AVAILABLE FOR CONTINGENCY.

LEGEND:

O - ORBITER
B - BOOSTER
L - LAUNCH DAY
▬ - TURNAROUND CYCLE
■ ■ - MISSION TIME
|||||| VEHICLE DORMANT TIME LESS WEEKENDS

FIGURE 3.3-37

noted on the Figure. It should be noted that time critical activities will obviously be continued into a third shift or weekend to ensure launch on time requirements and to support rescue operations.

A typical cross section of activities provides one Orbiter on mission, one at the pad and two in maintenance, with two Boosters in maintenance and one on the pad. Facility support will require two launch pads, two integration cells and three mobile launchers.

3.3.1.7 Post Landing Operations - The post landing phase will normally take place at the launch site. This phase will take approximately 3 1/2 hours for the Booster and 5 hours for the Orbiter to complete after touchdown and rollout. Figures 3.3-38 & 3.3-39 identify the flow and schedule for these activities. This phase is concluded upon towing the safed vehicle from the deservicing area to the hangar for maintenance. Alternate landing site operations are covered in Section 3.3.1.10.

Capability of deservicing both a Booster and an Orbiter simultaneously must be provided since it is possible for one of each to return to the launch site in the same time frame. An Orbiter and a Booster may land in the same time period either due to an aborted launch or due to returning from two different missions at the same time.

The deservicing area will be located near the end of the runway and at a safe distance from the normal work areas such as the LCC, VAB and Maintenance Hangar. GSE and facility items used to deservice the vehicles will be permanently located in the area.

In addition to deservicing, this area will also be utilized to service a vehicle for horizontal flights originating at the launch site for ferrying, horizontal flight test, acceptance testing after major modification and for crew training flights.

The vehicle shall be autonomous during this phase with only servicing lines

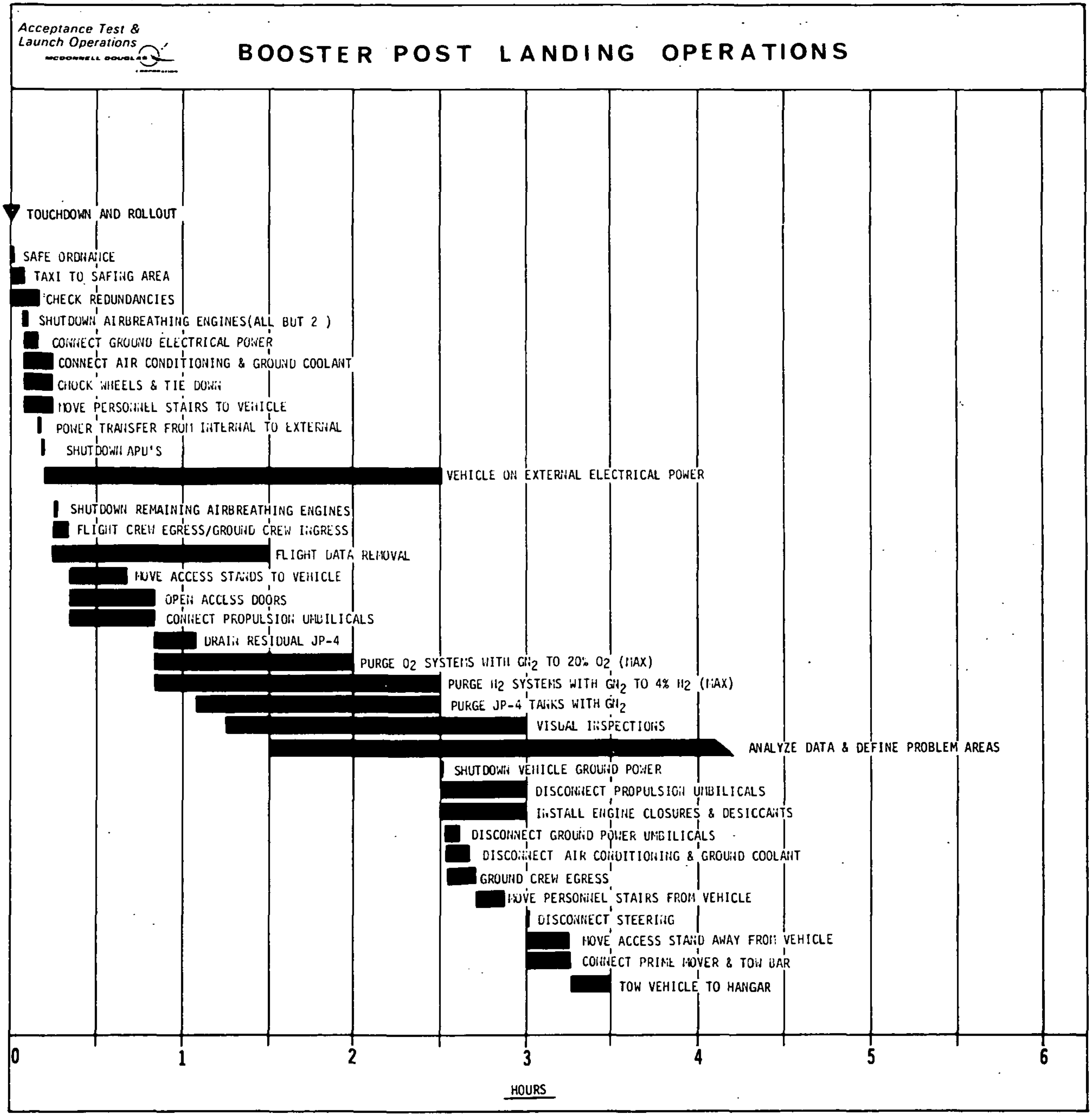

Acceptance Test & Launch Operations
McDONNELL DOUGLAS
BOOSTER POST LANDING OPERATIONS
TOUCHDOWN AND ROLLOUT
SAFE ORDNANCE
TAXI TO SAFING AREA
CHECK REDUNDANCIES
SHUTDOWN AIRBREATHING ENGINES(ALL BUT 2)
CONNECT GROUND ELECTRICAL POWER
CONNECT AIR CONDITIONING & GROUND COOLANT
CHOCK WHEELS & TIE DOWN
MOVE PERSONNEL STAIRS TO VEHICLE
POWER TRANSFER FROM INTERNAL TO EXTERNAL
SHUTDOWN APU'S
VEHICLE ON EXTERNAL ELECTRICAL POWER
SHUTDOWN REMAINING AIRBREATHING ENGINES
FLIGHT CREW EGRESS/GROUND CREW INGRESS
FLIGHT DATA REMOVAL
MOVE ACCESS STANDS TO VEHICLE
OPEN ACCESS DOORS
CONNECT PROPULSION UMBILICALS
DRAIN RESIDUAL JP-4
PURGE O_2 SYSTEMS WITH GN_2 TO 20% O_2 (MAX)
PURGE H_2 SYSTEMS WITH GN_2 TO 4% H_2 (MAX)
PURGE JP-4 TANKS WITH GN_2
VISUAL INSPECTIONS
ANALYZE DATA & DEFINE PROBLEM AREAS
SHUTDOWN VEHICLE GROUND POWER
DISCONNECT PROPULSION UMBILICALS
INSTALL ENGINE CLOSURES & DESICCANTS
DISCONNECT GROUND POWER UMBILICALS
DISCONNECT AIR CONDITIONING & GROUND COOLANT
GROUND CREW EGRESS
MOVE PERSONNEL STAIRS FROM VEHICLE
DISCONNECT STEERING
MOVE ACCESS STAND AWAY FROM VEHICLE
CONNECT PRIME MOVER & TOW BAR
TOW VEHICLE TO HANGAR
0
1
2
3
4
5
6
HOURS

FIGURE 3.3-38

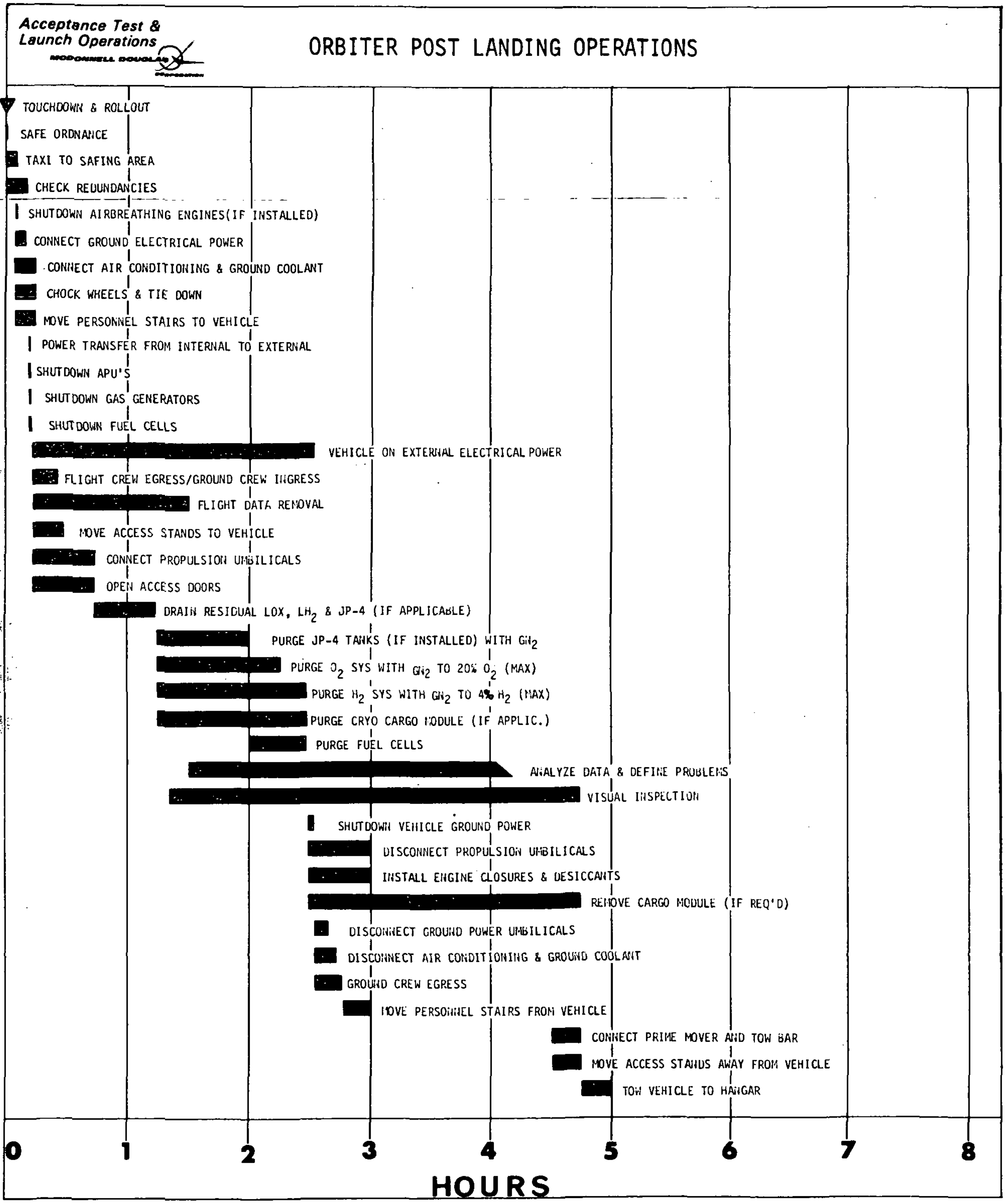

Acceptance Test & Launch Operations
McDONNELL DOUGLAS
ORBITER POST LANDING OPERATIONS
TOUCHDOWN & ROLLOUT
SAFE ORDNANCE
TAXI TO SAFING AREA
CHECK REDUNDANCIES
SHUTDOWN AIRBREATHING ENGINES (IF INSTALLED)
CONNECT GROUND ELECTRICAL POWER
CONNECT AIR CONDITIONING & GROUND COOLANT
CHOCK WHEELS & TIE DOWN
MOVE PERSONNEL STAIRS TO VEHICLE
POWER TRANSFER FROM INTERNAL TO EXTERNAL
SHUTDOWN APU'S
SHUTDOWN GAS GENERATORS
SHUTDOWN FUEL CELLS
VEHICLE ON EXTERNAL ELECTRICAL POWER
FLIGHT CREW EGRESS/GROUND CREW INGRESS
FLIGHT DATA REMOVAL
MOVE ACCESS STANDS TO VEHICLE
CONNECT PROPULSION UMBILICALS
OPEN ACCESS DOORS
DRAIN RESIDUAL LOX, LH2 & JP-4 (IF APPLICABLE)
PURGE JP-4 TANKS (IF INSTALLED) WITH GN2
PURGE O2 SYS WITH GN2 TO 20% O2 (MAX)
PURGE H2 SYS WITH GN2 TO 4% H2 (MAX)
PURGE CRYO CARGO MODULE (IF APPLIC.)
PURGE FUEL CELLS
ANALYZE DATA & DEFINE PROBLEMS
VISUAL INSPECTION
SHUTDOWN VEHICLE GROUND POWER
DISCONNECT PROPULSION UMBILICALS
INSTALL ENGINE CLOSURES & DESICCANTS
REMOVE CARGO MODULE (IF REQ'D)
DISCONNECT GROUND POWER UMBILICALS
DISCONNECT AIR CONDITIONING & GROUND COOLANT
GROUND CREW EGRESS
MOVE PERSONNEL STAIRS FROM VEHICLE
CONNECT PRIME MOVER AND TOW BAR
MOVE ACCESS STANDS AWAY FROM VEHICLE
TOW VEHICLE TO HANGAR
0
1
2
3
4
5
6
7
8
HOURS

FIGURE 3.3-39

and servicing GSE required. The onboard computers will control the operations with ground crew personnel in the cabin of the vehicle. Generally, no work will be performed during this phase except that which is required to safe the vehicle. Another exception is that some redundancy testing will be performed. The goal will be to move the vehicle into the maintenance area as soon as possible so that more people may have access to it for maintenance and checkout.

Systems that are up for the post landing operations will be tested if the hazard level is not affected. After the vehicle has arrived at the safing area, certain tests will be run which will take advantage of the fact that the APU's are running and the hydraulic systems are at full pressure. This testing will include checking redundant hydraulic pumps. In order to prove that each pump is operating properly, the other pumps must be taken off-line by opening pump bypass valves. These tests will allow autonomous checkout without any supporting GSE.

Also, while the APU's are running and their hydraulic systems have full operating capability, any tests which need this capability will be performed. An example is an end-to-end guidance and control test which moves all the main engines. A guidance error signal would be entered through the vehicle keyboard and the main engine movement would be verified for correct response. This test, if performed in the maintenance hangar, would require breaking into the hydraulic system and operating a hydraulic pumping unit to move the main engines.

During the propulsion system safing, the propulsion redundancies which were not operated and verified in flight will be checked. Other systems will be analyzed for feasibility of testing during this phase.

Visual inspections will be conducted at the safing area with emphasis placed on the airbreathing engines. If it becomes necessary to run up the airbreathing engines, it will take place at the safing area.

The hazardous condition of the vehicle upon landing varies between the Booster and Orbiter. Prior to re-entry, the main propellant tanks will be passivated -- all the liquids will be dumped and the tank pressure will be reduced to approximately 17 PSIA. Venting of the hydrogen tanks prior to connecting the vent to the ground disposal system is not anticipated. The Booster, due to incorporation of the dual mode APU, will also have its secondary cryogen tanks and accumulators passivated prior to landing.

The Orbiter which uses hydrogen and oxygen for the APU's and fuel cells will still have cryogens aboard after landing. These tanks and accumulators should not normally vent prior to connecting the ground disposal system.

This phase begins with touchdown of the vehicle on the runway and rollout. After rollout, the vehicle will be taxied to the safing area. Obviously, for those missions which the Orbiter performs without airbreathing engines, it will not have the capability to taxi from the runway to the safing area. For those missions, a prime mover will pull the Orbiter to the safing area.

Upon arrival at the safing area, the air conditioning and equipment coolant will be connected as soon as possible. Ground communications will be connected to the vehicle. After the ground power is connected to the vehicle, the flight crew will switch the power from internal to external; after which, the Auxiliary Power Units (APU's) and the Orbiter fuel cells will be shut down and secured by the flight crew. After the APU's are shut down, the Orbiter LOX and LH_2 propellant conditioners will be deactivated and secured. While the flight crew is performing the above operations, the ground crew will move the personnel boarding stairs over to the vehicle for the flight crew to disembark and for the ground crew to have access to the cabin for deservicing. Also during this time period, the vents for hazardous gases are connected to the facility so that these gases will not have to be vented in the vicinity of the vehicle. The flight data will be removed and analyzed as soon as possible so that the unscheduled maintenance may be planned in advance of the vehicle movement into the maintenance area. Generally, neither the Booster nor Orbiter will require cooling although some hot spots may require cooling prior to normal work.

Access stands will be moved to the vehicle so that the remaining propulsion umbilicals may be connected in order that the vehicle may be safed. In addition to the LH_2 tank vents which were connected earlier, the following disconnects will require connection:

A. Vehicle control H_e pneumatic supply
B. GOX accumulator precharge (GN_2)
C. GH_2 accumulator precharge (GN_2)
D. Engine GN_2 purge
E. Secondary LOX tank fill and drain
F. Secondary LH_2 tank fill and drain
G. Main LOX tank fill and drain
H. Main LH_2 tank fill and drain
I. Main LOX tank prepressure (GN_2)
J. Main LH_2 tank prepressure (GN_2)
K. JP-4 fill and drain

After draining the residual LOX and LH_2 from the Orbiter and JP-4 from either vehicle, the propellant tanks and the GOX and GH_2 accumulators will be purged with gaseous nitrogen.

After the propellant tanks are safed, the tanks will be pressurized to 3-5 psig and this pressure will be checked during the maintenance cycle to verify integrity.

At this point, the propulsion, electrical and coolant umbilicals will be removed from the vehicle and the ground crew will exit the vehicle. The cargo module will be removed from the Orbiter at this time only if required due to the module either containing hazardous materials or if it is needed in a special area very quickly. Otherwise the module will be removed in the maintenance area where handling conditions are much more favorable. As soon as the access stands are moved away from the vehicle, the prime mover will tow it to the maintenance area which will conclude the Post Landing Operations Phase.

It should be noted that returning cargo containers which were used for hazardous propellants and gases will be purged and safed in parallel with the Orbiter propulsion system purging.

3.3.1.8 Maintenance - Maintenance activities begin with arrival of the vehicles at the maintenance hangar. These activities consists of preventive and corrective maintenance, critical redundancy verifications, replacement of spent pyrotechnics, verification of cargo module area and doors, and installation of the cargo module. Figure 3.3-40 identifies the flow and schedule for these activities. Post landing analysis of onboard recorded data and inputs from flight crew debriefings are required to support the corrective maintenance activities. Work during this phase will be conducted with the vehicles horizontal.

Preventive maintenance starts with positioning of the vehicles and work stands, and removal of access doors. If the cargo module was not removed from the orbiter during post launch operations (Reference paragraph 3.3.1.7), it will be removed at the beginning of the maintenance cycle. Visual inspection of the TPS is performed, then TPS panels are removed to allow inspection of insulation and substructure in predetermined areas. In parallel with these activities, scheduled subsystems inspection, servicing, calibration, and limited life item replacement tasks will be performed.

Main engine contractors have identified tasks to be performed during this phase of operations. A representative list of these tasks is as follows:

A. Perform a visual inspection of the primary nozzle (tube dents, discoloration, etc.), main combustion chamber, and main injector assembly.

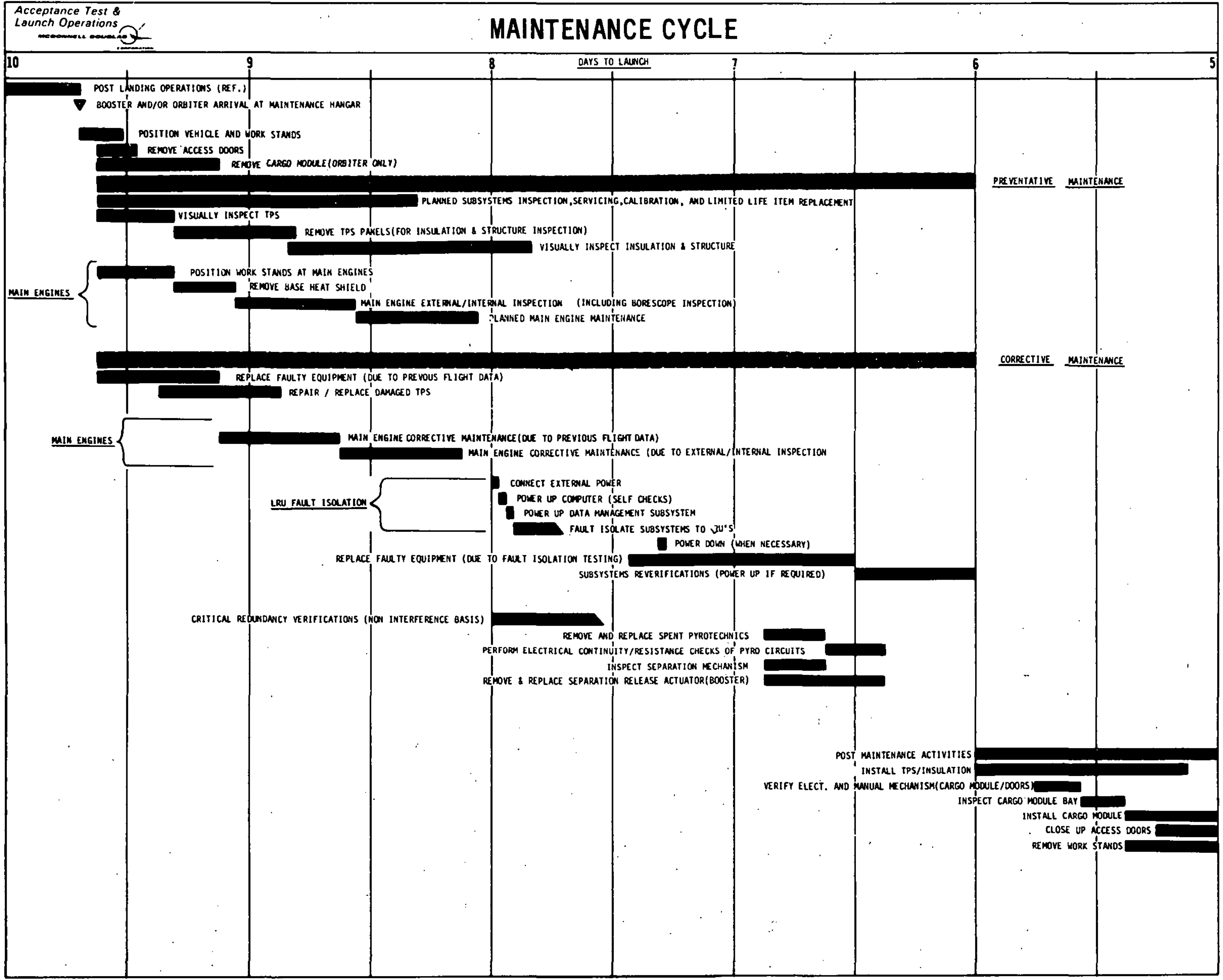

Acceptance Test &
Launch Operations
MAINTENANCE CYCLE
DAYS TO LAUNCH
10
9
8
7
6
5
POST LANDING OPERATIONS (REF.)
BOOSTER AND/OR ORBITER ARRIVAL AT MAINTENANCE HANGAR
POSITION VEHICLE AND WORK STANDS
REMOVE ACCESS DOORS
REMOVE CARGO MODULE(ORBITER ONLY)
PREVENTATIVE MAINTENANCE
PLANNED SUBSYSTEMS INSPECTION,SERVICING,CALIBRATION, AND LIMITED LIFE ITEM REPLACEMENT
VISUALLY INSPECT TPS
REMOVE TPS PANELS(FOR INSULATION & STRUCTURE INSPECTION)
VISUALLY INSPECT INSULATION & STRUCTURE
MAIN ENGINES
POSITION WORK STANDS AT MAIN ENGINES
REMOVE BASE HEAT SHIELD
MAIN ENGINE EXTERNAL/INTERNAL INSPECTION (INCLUDING BORESCOPE INSPECTION)
PLANNED MAIN ENGINE MAINTENANCE
CORRECTIVE MAINTENANCE
REPLACE FAULTY EQUIPMENT (DUE TO PREVOUS FLIGHT DATA)
REPAIR / REPLACE DAMAGED TPS
MAIN ENGINES
MAIN ENGINE CORRECTIVE MAINTENANCE(DUE TO PREVIOUS FLIGHT DATA)
MAIN ENGINE CORRECTIVE MAINTENANCE (DUE TO EXTERNAL/INTERNAL INSPECTION
LRU FAULT ISOLATION
CONNECT EXTERNAL POWER
POWER UP COMPUTER (SELF CHECKS)
POWER UP DATA MANAGEMENT SUBSYSTEM
FAULT ISOLATE SUBSYSTEMS TO LRU'S
POWER DOWN (WHEN NECESSARY)
REPLACE FAULTY EQUIPMENT (DUE TO FAULT ISOLATION TESTING)
SUBSYSTEMS REVERIFICATIONS (POWER UP IF REQUIRED)
CRITICAL REDUNDANCY VERIFICATIONS (NON INTERFERENCE BASIS)
REMOVE AND REPLACE SPENT PYROTECHNICS
PERFORM ELECTRICAL CONTINUITY/RESISTANCE CHECKS OF PYRO CIRCUITS
INSPECT SEPARATION MECHANISM
REMOVE & REPLACE SEPARATION RELEASE ACTUATOR(BOOSTER)
POST MAINTENANCE ACTIVITIES
INSTALL TPS/INSULATION
VERIFY ELECT. AND MANUAL MECHANISM(CARGO MODULE/DOORS)
INSPECT CARGO MODULE BAY
INSTALL CARGO MODULE
CLOSE UP ACCESS DOORS
REMOVE WORK STANDS

FIGURE 3.3-40

B. Perform borescope inspection of the main case internal areas.

C. Perform fuel and oxidizer system internal flow path integrity inspection (borescope).

D. Perform turbopump torque checks (spin-up method).

Corrective maintenance activities start with replacement of faulty equipment detected from the previous flight data or due to degradation of subsystem performance. Repair and/or replacement of damaged TPS, structure, and subsystem components will occur as a result of preventive maintenance inspection effort.

Fault isolation to the LRU level will be performed on malfunctioning subsystems. Voting, comparisons, and Built-In Test (BIT) discretes will be employed to detect failures. This effort is started by applying external power to the vehicles and performing computer self checks. After computers are verified, power is applied to the other subsystems. Various methods are used to self test and fault isolate. Several are identified below:

A. Computer and data management subsystems self check by parallel computation, comparison, and voting of outputs.

B. Most DIU's and major LRU's self test by self calibration and BIT circuits.

C. Operator manually calls up subsystem diagnostics to check faulted onboard subsystems.

D. Computer will compare subsystem responses and compare results from either internal or external stimuli.

Checkout of onboard subsystems will be augmented with GSE on a selective basis. Vehicles will be powered down after subsystem fault isolation activities and faulty equipment will be repaired in-place or replaced. Reverification of subsystems will follow. Vehicles will be powered up again if required.

In parallel with powered up fault isolation activities, critical redundancy verifications will be performed on a non-interference basis.

Spent pyrotechnics are to be removed and replaced. Continuity and resistance checks of pyrotechnic electrical circuits are also performed. The separation mechanism is to be inspected and the separation release actuator and the gas actuators on the aft swing links of the booster are to be removed and replaced with rebuilt units.

Post maintenance activities begins by installing TPS and insulation, inspection and close up of access doors, and removal of work stands. Only access doors and work stands not required for prelaunch activities are to be closed up or removed. In parallel with these activities, the orbiter's electrical/manual mechanisms for the radiator rotation, cargo doors, cargo module support and latches, and cargo module deployment are to be verified. The cargo module will then be installed in the orbiter vehicle.

3.3.1.9 Rescue Operations - Rescue operations is a Space Shuttle Program requirement. The requirement specifies "for the design reference mission, rescue operations (including personnel transfer) must be completed within 48 hours after notification". The need for a rapid response rescue operation can be caused by any number of reasons some of which are: (1) personnel injury or illness; (2) vehicle damage; and (3) hazardous radiation exposure. Three concepts for assisting or protecting personnel after rescue have been baselined for study. These concepts are:

a. Return personnel to launch site (KSC)
b. Return personnel to one of six orbiter remote landing sites
c. Transfer orbiter to a safe orbit prior to landing

Operations studies considered the probability of performing rescue with Shuttle vehicles partially ready at various time periods which correspond to major milestones during ground operations. The time periods considered were T-2 hours, T-10 hours, T-16 hours, and T-24 hours (vehicle at start of launch cycle in VAB and ready for move to pad).

The first approach in support of obtaining a 48 hour rescue capability was to maintain a Shuttle Vehicle at the launch pad at a T-2 hour standby condition. Figure 3.3-41 defines the total ground elapsed time for our three selected concepts considering a worst case condition for each. As shown in the figure, this approach allows us to transfer personnel to the orbiter in less than 48 hours. However; this T-2 hour continuous standby does not seem practical due to such things as:

a. Required dedicated vehicles, facilities and personnel
b. Continuous outdoor environment
c. Accessibility for maintenance at the pad
d. Hazardous consumables retained on-board

The second approach considered was with the vehicles being maintained at the pad at T-10 hours standby. The results were similar to the T-2 hour standby study.

Results from the next two approaches were more favorable. At T-16 and T-24 hour standby, the Shuttle Vehicles subsystems are not activated and full launch crews are not required. However, launch crews would have to be on standby status. The advantage of T-24 hours vs T-16 hours is that the vehicles are still located in the VAB environment. Figure 3.3-42 defines the total ground elapsed time for a T-24 hour standby considering a worst case condition for our three selected concepts. As shown in the figure, this approach allows us to transfer personnel to the orbiter in 58 hours. While this total time exceeds the 48 hour limit by 10 hours, it must be recognized that these times are based upon worst case conditions and it is recommended this approach be used.

Our T-24 hour standby is considered a practical approach. This is based on

RESCUE MISSION

(FROM T-2 HOUR STANDBY)

(WORST CASE CONDITION FOR 55° ORBIT)

	RETURN TO KSC	RETURN TO AN ALTERNATE SITE	TRANSFER TO SAFE ORBIT
o LAUNCH PREPARATION	2	2	2
o GROUND HOLD TO LAUNCH WINDOW	15	15	15
o RENDEZVOUS	16	16	16
o RESCUE OPERATION	3	3	3
o DEORBIT PHASING AND ENTRY	5	1.5	-
o TRANSFER TO SAFE ORBIT	-	-	2
TOTAL GROUND ELAPSED TIME	41 HRS	37.5 HRS	38 HRS

- SOS RECEIVED AT ≈ 2 HRS BEFORE SOUTHERLY LAUNCH OPPORTUNITY
- WORST CASE PHASING = 224°
- 10K LBS OF PAYLOAD CONVERTED TO PROPELLANT + 1500 FPS
- LOWEST SAFE ORBIT = 100/100 NM

FIGURE 3.3-4

RESCUE MISSION

(FROM T-24-HOUR STANDBY)

(WORST CASE CONDITION FOR 55° ORBIT)

	RETURN TO KSC	RETURN TO AN ALTERNATE SITE	TRANSFER TO SAFE ORBIT
o LAUNCH PREPARATION	24	24	24
o GROUND HOLD TO LAUNCH WINDOW	15	15	24
o RENDEZVOUS	16	16	2.5
o RESCUE OPERATIONS	3	3	3
o DEORBIT PHASING AND ENTRY	5	1.5	-
o TRANSFER TO SAFE ORBIT	-	-	2
TOTAL GROUND ELAPSED TIME	63 HRS	59.5 HRS	55.5 HRS

- o SOS RECEIVED AT PASSING SOUTHERLY LAUNCH OPPORTUNITY
- o WORST CASE PHASE = 224°
- o 10K LBS OF PAYLOAD CONVERTED TO PROPELLANT + 1500 FPS
- o LOWEST SAFE ORBIT IS 100/100 NM

FIGURE 3.3-42

having two (2) launch pads, pre-pad erection and vehicle quantities of four orbiters and three boosters. This provides one shuttle vehicle maintained at T-24 hours in the VAB. When the second shuttle vehicle reaches the T-24 hour status, one of these will move to the pad for the next scheduled launch. In this manner, one Shuttle Vehicle is always at T-24 and no dedicated vehicles, pads or launch crews are required. It must be recognized that utilizing this T-24 hour standby approach, the 58 hour rescue time can only be accomplished 100% of the time with a launch rate of up to 52 per year. With the maximum launch rate of 75 per year, the 58 hour rescue capability will only exist approximately 55% of the time.

3.3.1.10 Alternate Landing Sites - Shuttle vehicles use of alternate landing sites during the operational phase for providing a means of increasing payload capability or contingency operations in the event of abnormal launch or mission events. These sites will, in general, have the same landing/takeoff and servicing characteristics as the prime site. In the event a vehicle lands at an alternate site, the unique GSE equipment will be flown to the site for turnaround operations. These operations will be limited to performing the necessary activities for a safe ferry return flight.

3.3.1.10.1 Booster Downrange Landing Sites - Three sites have been identified to support booster downrange landing operations. The Seymour Johnson AFB, North Carolina field will be used to support northerly oriented launches. For easterly launches, the Nassau International field is recommended, with Kingston, Jamaica designated for southerly operations.

Figure 3.3-43 defines the typical booster turnaround activities at an alternate site. Prior to landing, the ground equipment, tug vehicles, the stands, personnel, etc., will be positioned to start turnaround immediately upon landing. The initial landing activities are the same as at the prime site up to the com-

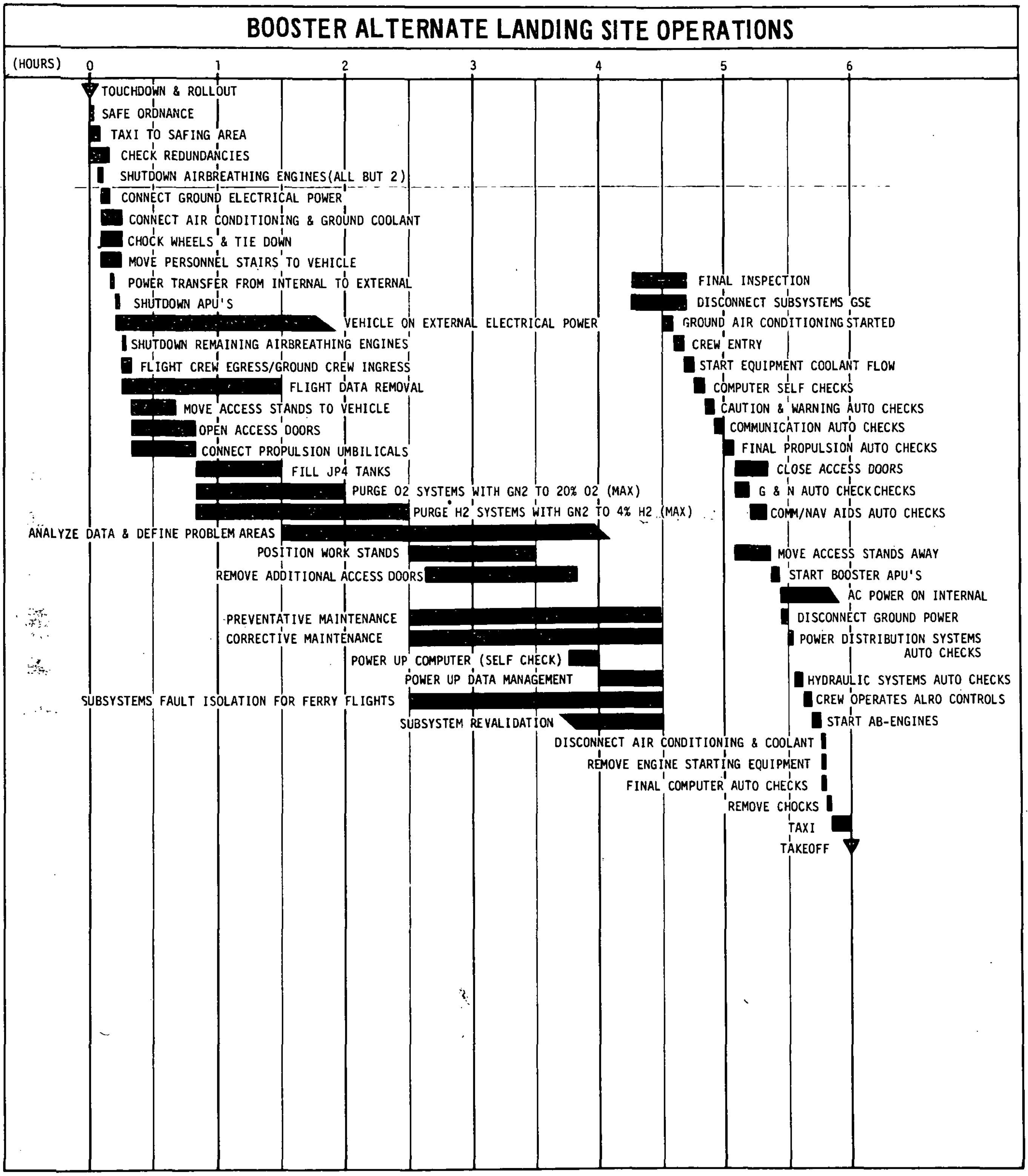

BOOSTER ALTERNATE LANDING SITE OPERATIONS
(HOURS)
0
1
2
3
4
5
6
TOUCHDOWN & ROLLOUT
SAFE ORDNANCE
TAXI TO SAFING AREA
CHECK REDUNDANCIES
SHUTDOWN AIRBREATHING ENGINES(ALL BUT 2)
CONNECT GROUND ELECTRICAL POWER
CONNECT AIR CONDITIONING & GROUND COOLANT
CHOCK WHEELS & TIE DOWN
MOVE PERSONNEL STAIRS TO VEHICLE
POWER TRANSFER FROM INTERNAL TO EXTERNAL
SHUTDOWN APU'S
VEHICLE ON EXTERNAL ELECTRICAL POWER
SHUTDOWN REMAINING AIRBREATHING ENGINES
FLIGHT CREW EGRESS/GROUND CREW INGRESS
FLIGHT DATA REMOVAL
MOVE ACCESS STANDS TO VEHICLE
OPEN ACCESS DOORS
CONNECT PROPULSION UMBILICALS
FILL JP4 TANKS
PURGE O2 SYSTEMS WITH GN2 TO 20% O2 (MAX)
PURGE H2 SYSTEMS WITH GN2 TO 4% H2 (MAX)
ANALYZE DATA & DEFINE PROBLEM AREAS
POSITION WORK STANDS
REMOVE ADDITIONAL ACCESS DOORS
PREVENTATIVE MAINTENANCE
CORRECTIVE MAINTENANCE
POWER UP COMPUTER (SELF CHECK)
POWER UP DATA MANAGEMENT
SUBSYSTEMS FAULT ISOLATION FOR FERRY FLIGHTS
SUBSYSTEM REVALIDATION
DISCONNECT AIR CONDITIONING & COOLANT
REMOVE ENGINE STARTING EQUIPMENT
FINAL COMPUTER AUTO CHECKS
REMOVE CHOCKS
TAXI
TAKEOFF
FINAL INSPECTION
DISCONNECT SUBSYSTEMS GSE
GROUND AIR CONDITIONING STARTED
CREW ENTRY
START EQUIPMENT COOLANT FLOW
COMPUTER SELF CHECKS
CAUTION & WARNING AUTO CHECKS
COMMUNICATION AUTO CHECKS
FINAL PROPULSION AUTO CHECKS
CLOSE ACCESS DOORS
G & N AUTO CHECK CHECKS
COMM/NAV AIDS AUTO CHECKS
MOVE ACCESS STANDS AWAY
START BOOSTER APU'S
AC POWER ON INTERNAL
DISCONNECT GROUND POWER
POWER DISTRIBUTION SYSTEMS AUTO CHECKS
HYDRAULIC SYSTEMS AUTO CHECKS
CREW OPERATES ALRO CONTROLS
START AB-ENGINES

FIGURE 3.3-43

pletion of tank purging operations. At this point the planned activities are oriented to accomplishing the necessary requirements for a safe ferry return flight.

Personnel will remove access doors, as necessary, and proceed with maintenance inspections. The computer and data management subsystem will support fault isolation checks. In parallel, the maintenance personnel will correct known vehicle discrepancies and any problems found during fault isolation checks. The estimated time for this is two (2) hours. Subsystems revalidation will be performed as the subsystem maintenance is completed. Upon completion, GSE will be removed, access doors closed and the flight crew will ingress. Final operations then include starting the JP4/AIR APU, transfer to internal power, final verifications of subsystems, taxi and takeoff.

3.3.1.10.2 Orbiter Landing Sites - These sites were selected for orbiter landings in the event of a mission termination requiring a reentry and landing beyond the KSC range. In the event an alternate site is used, the cargo module will be removed and transported by air to the operations site. The following items will be installed to enable a return ferry flight of the orbiter: a propellant (JP-4) module to provide ABES fuel, a refrigeration unit to provide equipment cooling, a fifth airbreathing engine to provide the required margin of flight safety, hydraulic pump kits on the airbreathing engines to provide hydraulic power. These and other required ground turnaround activities are delineated in Figure 3.3-44.

In the event of a high payload (65K) and a due east mission, the airbreathing engine system (ABES) will have been removed prior to a launch. Therefore installation of the 5 engine ABES will occur at the alternate site. The initial activities are the same as at the operations site. If the cargo module contains cryogens, purging will be done in parallel with the purging of orbiter tanks and accumulators. Inspections, fault isolation, maintenance, and the removal of the cargo module

ORBITER ALTERNATE LANDING SITE OPERATIONS

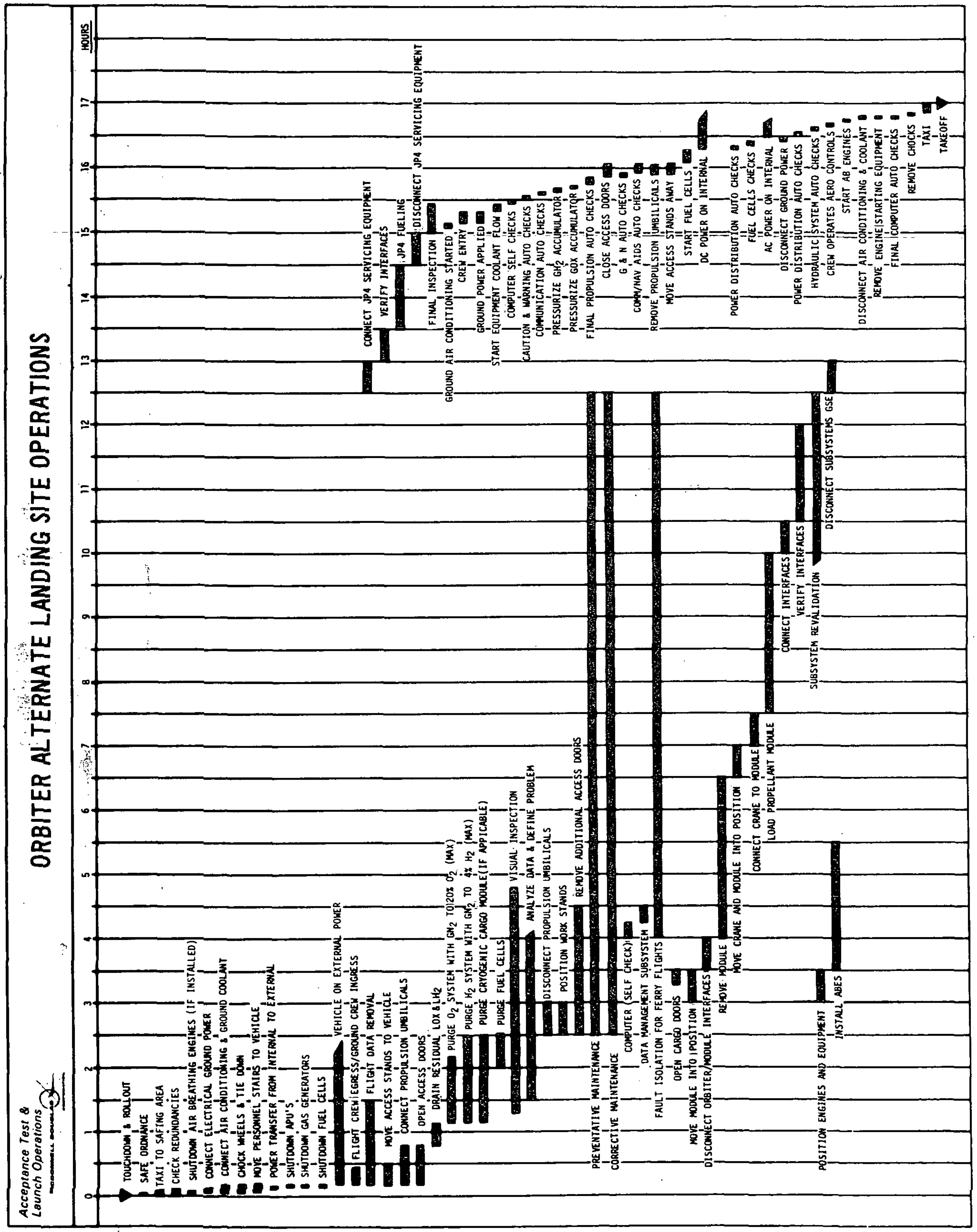


FIGURE 3.3-44

are then accomplished in parallel. The computer and data management subsystems will support fault isolation checks. Vehicle workstands, ground power units and a mobile crane will be moved into position. The cargo module will be removed and emplaced on a mobile dolly for air freight to the operations site. The JP-4 propellant module and other items will be installed prior to completion of the maintenance cycle. As required, the airbreathing engine pods (1 or 5 units) will be installed. This installation can be accomplished in parallel with other maintenance activities and does not require elevation of the vehicles. Subsystem revalidation will verify the vehicle subsystems required for the ferry flight. Upon completion, GSE and tanker vehicles will be positioned and connected for loading of JP-4 into the propellant module. Additional servicing operations are normally limited to oxygen and hydrogen for the fuel cells and freon for the environmental control systems. After servicings, the ground equipment will be removed, the flight crew will ingress and final subsystem verifications will be performed. The airbreathing engines will be run up, final pre-flight checks performed, and the vehicle will take off for return to the operational site.

3.3.1.10.3 Facility Utilization - Since the alternate sites are not a constant usage requirement, the intent is to utilize the existing capabilities with minimum modifications. Activities are planned to be continuous from landing to take-off. The vehicle may require environmental protection which can be accomplished by placement in a standard hanger with the aft tail section left protruding (NOTE: If required, protective material covering could be provided). The runway pavement requirement is 10,000' with paved overruns. A remote area is required for cooling and deservicing activities. At military fields it may be possible to accomplish this adjacent to the runway or taxiway. Commercial fields will require an area remotely located. Existing facilities will be requested on a temporary basis for storage of equipment and fixtures. JP-4 fuel storage and tankers are considered available at these sites. Base support services will be used, as required, to support vehicle personnel operations. Typical services include: utilities, weather, fire and security, communications, shops, and standard airfield equipment (tugs, crane, stands, etc.). At off-shore sites the services of Air-Sea Rescue may be requested in the event of emergency requirements. Aircraft services for personnel and equipment are also required.

3.3.1.11 Operational Site Facilities

3.3.1.11.1 KSC Baseline - Program objectives of minimizing cost and providing schedule flexibility are achievable without jeopardizing operational efficiency by using the existing facilities at Kennedy Space Center (KSC). Maximum use of existing facilities and systems capabilities adaptable to Shuttle requirements permit minimum new construction requirements at KSC. Existing facilities at KSC were designed for multiple functional use. (See Figure 3.3-45).

The MDAC baseline operations concept begins with the landing field where the vehicles land and taxi to a Deservice/Safing area. The vehicles are towed to the Maintenance and Assembly Building (MAB). Preventative and corrective maintenance activities and cargo/payload loading are accomplished in this MAB. Upon completion, the vehicles are towed to the VAB for erection, mating and prelaunch testing. The integrated vehicles (mounted on a mobile launcher) will then be moved to the Launch Pad where final servicing, crew/passenger loading and final countdown and launch occurs.

To implement this baseline concept, three new facilities must be constructed and four existing facilities require major modifications while other existing facilities may require minor modifications.

3.3.1.11.1.1 New Facilities Required at KSC

Landing Field - Landing and post landing operations that can take place at the landing field include touchdown and rollout, drag chute dropoff, ordnance safing, disconnect steering, connection of prime mover for towing, towing vehicles, air-breathing engine runup during checkout, and vehicle takeoff. (See Figure 3.3-46 and 3.3-47)

Primary Surface - The landing field will consist of a cleared primary surface measuring 13,000 feet long and 2,000 feet wide. Within this obstruction free area will be constructed a rigid pavement 10,000 feet long, 300 feet wide with 1,500-

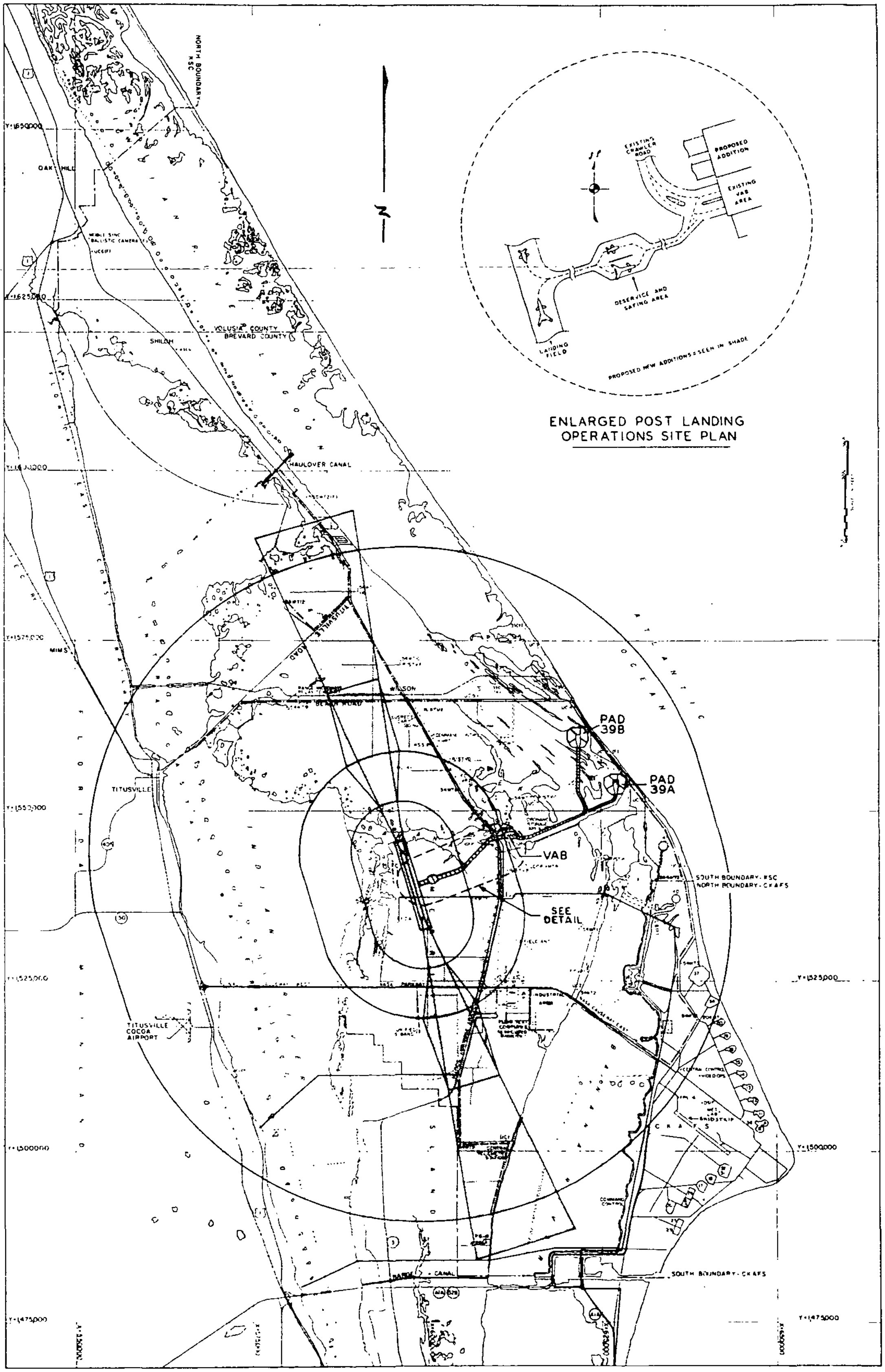
OPERATIONS SITE FACILITY UTILIZATION

REQUIREMENTS	STATUS
1. PASSENGER FACILITY	EXISTING ADEQUATE
2. LANDING FIELD	NEW - 10,000' X 300'
3. DESERVICING AREA	NEW
4. TAXIWAY	NEW - 3.1 MILES INCLUDED IN LANDING FIELD
5. MAINTENANCE FACILITY	NEW - 251,370 SF
6. INTEGRATION/FACILITY AREA	EXIST - VAB CELLS 3 - 4 - MOD
7. MOBILE TRANSPORTERS	EXIST - 3 LAUNCHERS MOD
8. COMPRESSOR CONVERTER FACILITY	EXISTING ADEQUATE
9. LAUNCH PADS (2 REQUIRED)	MODS TO 2 PADS
10. LAUNCH CONTROL CENTER	EXISTING ADEQUATE
11. INSTRUMENTATION FACILITY	EXISTING ADEQUATE
12. TRACKING FACILITIES	EXISTING ADEQUATE
13. OPTICAL SITES	EXISTING ADEQUATE
14. CARGO OPERATIONS FACILITY AND PAYLOAD STERILIZATION	MODIFICATION MSOB FACILITY
15. FLIGHT CREW FACILITY	EXISTING ADEQUATE
16. TRAINING FACILITY	EXISTING ADEQUATE
17. ORDNANCE STORAGE AND TEST FACILITIES	EXISTING ADEQUATE
18. WAREHOUSES AND STORAGE FACILITIES	EXISTING ADEQUATE
19. ELECTROMAGNETIC LABORATORY	EXISTING ADEQUATE
20. AUDITORIUM	EXISTING ADEQUATE
21. COMMUNICATIONS FACILITY	EXISTING ADEQUATE
22. PROPELLANT SYSTEMS LABORATORY	EXISTING ADEQUATE
23. AZIMUTH ALIGNMENT FACILITIES	EXISTING ADEQUATE
24. UNIFIED S-BAND FACILITY	EXISTING ADEQUATE
25. WEATHER TOWER	EXISTING ADEQUATE
26. POWER DISTRIBUTION FACILITY	EXISTING ADEQUATE
27. RAILROADS	EXISTING ADEQUATE
28. ROADWAYS AND PARKING AREA	EXISTING ADEQUATE
29. SEWAGE TREATMENT FACILITY	EXISTING ADEQUATE

FIGURE 3.3-45

OPERATIONS SITE FACILITY UTILIZATION (CONTINUED)	
REQUIREMENTS	STATUS
30. CENTRAL HEATING FACILITY	EXISTING ADEQUATE
31. FIRE STATION	EXISTING ADEQUATE
32. CAFETERIA	EXISTING ADEQUATE
33. PARACHUTE FACILITY	EXISTING ADEQUATE
34. COMMUNICATIONS MAINTENANCE AND STORAGE FACILITY	EXISTING ADEQUATE
35. HEAVY EQUIPMENT MAINTENANCE FACILITY	EXISTING ADEQUATE
36. BASE MAINTENANCE SHOPS	EXISTING ADEQUATE
37. OCCUPATIONAL HEALTH FACILITY	EXISTING ADEQUATE
38. ADMINISTRATION AND ENGINEERING OFFICES	EXISTING ADEQUATE
39. CENTRAL SUPPLY	EXISTING ADEQUATE
40. BARGE CANAL AND TERMINALS	EXISTING ADEQUATE
41. INDUSTRIAL WATER FACILITY	EXISTING ADEQUATE
42. PROPELLANT AND GAS STORAGE FACILITY	EXISTING ADEQUATE
43. SECURITY FACILITIES	EXISTING ADEQUATE
44. PHOTOGRAPHIC LABORATORY	EXISTING ADEQUATE
45. LIBRARY AND REPRODUCTION FACILITY	EXISTING ADEQUATE
46. HYDROGEN PRODUCTION FACILITY	NEW FACILITY REQUIRED

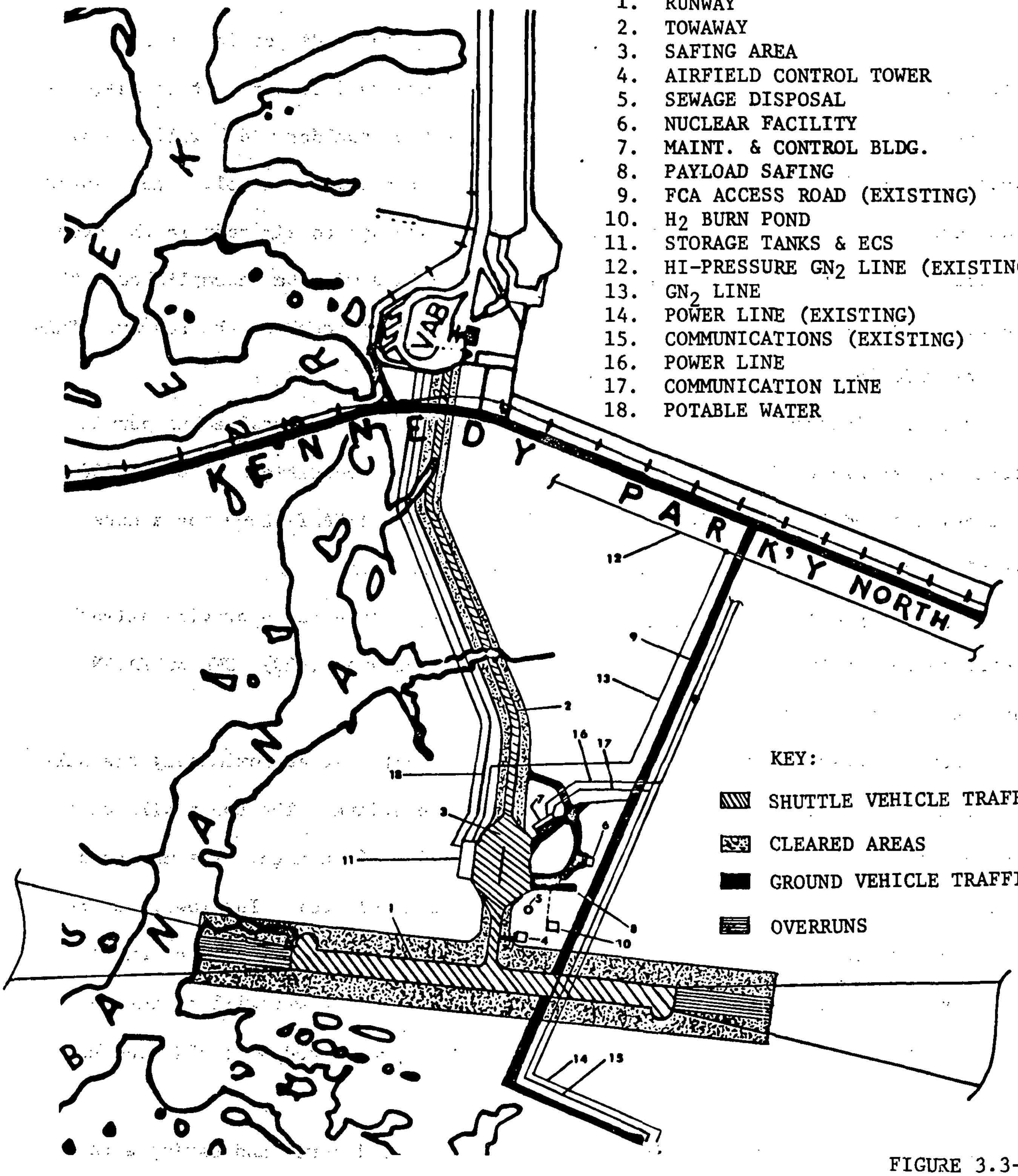
FIGURE 3.3-45 (CONT'D)



PROPOSED SPACE SHUTTLE LANDING FIELD

FIGURE 3.3-46

LANDING AND POST LANDING FACILITIES (KSC)



LEGEND

1. RUNWAY
2. TOWAWAY
3. SAFING AREA
4. AIRFIELD CONTROL TOWER
5. SEWAGE DISPOSAL
6. NUCLEAR FACILITY
7. MAINT. & CONTROL BLDG.
8. PAYLOAD SAFING
9. FCA ACCESS ROAD (EXISTING)
10. H_2 BURN POND
11. STORAGE TANKS & ECS
12. HI-PRESSURE GN_2 LINE (EXISTING)
13. GN_2 LINE
14. POWER LINE (EXISTING)
15. COMMUNICATIONS (EXISTING)
16. POWER LINE
17. COMMUNICATION LINE
18. POTABLE WATER

KEY:

▨ SHUTTLE VEHICLE TRAFFIC
░ CLEARED AREAS
■ GROUND VEHICLE TRAFFIC
▤ OVERRUNS

FIGURE 3.3-47

foot long overruns at either end. The runway/overrun surface will be elevated to 10 feet above mean sea level with sand fill, hydraulically applied and obtained from nearby submerged sources. The useable runway will be bordered by 200-foot wide shoulders sloped on a 2 to 3 percent grade. The 10-foot wide portion of the shoulders adjacent to the runway will be soil cement-stabilized to obtain adequate strength for vehicular traffic. The remainder of the shoulder width will be compacted for stability and sodded/seeded as needed for erosion control. The cleared zone beyond the shoulders will be graded to reduce damage to aircraft in the event of erratic performance. Drainage of the runway surface will be accomplished with shallow concrete gutters. The overruns are structurally equal to the runway. This will provide for economical expansion, if required.

Visual, electronic navigation and landing aids will be installed to permit operations at night time and during Category II weather conditions of below 200 feet ceiling and 1/2 mile visibility. See Design Note I-EAST-GLO-8 for a more detailed description of the Landing Field and Safing Area.

Navigation and Instrument Landing Aids - Navigation aids to provide azimuth, elevation and vertical guidance will include VHF omnirange (VOR), DME or TACAN equipment, ILS, and antennas.

Control Tower - A control tower will be constructed at approximately the halfway point of the runway and 1,350 feet from its centerline. The tower will be a non-combustible structure, 18 x 20 feet in plan and 50 feet high. The uppermost floor will have a glass-enclosed observation and control room. The lower levels will contain sanitary facilities, air-conditioning, electrical and electronics equipment. A diesel generator located at the base of the tower will be adequate in capacity to supply back-up power for control equipments and airfield landing aids.

Utilities - Utilities to the landing field, control tower and safing area will include communications cable ducts, 13.8 kv power feeders and substations for voltage transformation to 460 - 120/208 volts. Potable water for sanitation and fire fighting will be supplied from the VAB area by underground pipeline. Sewerage will connect the safing area and control tower to a new 10,000 gallon/day sewerage treatment plan.

Safing Area

General Description - The safing area will be constructed on the 80-foot wide rigid pavement tow-way at a point as close as safely possible to the runway primary surface and support structures. The tow-way pavement at this point will increase in size to accommodate, simultaneously, a Booster, an Orbiter, GSE, work platforms, and other ground vehicles required during safing operations of the Shuttle vehicles. (See Figure 3.3-48). Adjacent to the primary Shuttle vehicle parking surface, service and equipment areas will be constructed to contain:

- o Gas, Fuel and Water Tanks
- o Environmental Control Systems
- o Power Substation
- o Maintenance and Control Building
- o Payload Safing
- o H_2 Burn Pond
- o Nuclear Storage Building
- o Parking areas for Work Platforms, GSE and Ground Vehicles

Maintenance and Assembly Building (MAB) - A 513 foot wide by 490 foot long maintenance and assembly building is proposed as an addition to the North side of the existing Vertical Assembly Building at KSC. This structure will be composed of two East-West bays approximately 220 feet wide separated by a multi-story office/shop area 50 feet wide. The North section will have a clear height of approximately 100 feet with a 50 ton bridge crane hook height of 85 feet. The South section (against the VAB North wall) will have a 150 ton bridge crane hook height of 110 feet

SAFING AREA

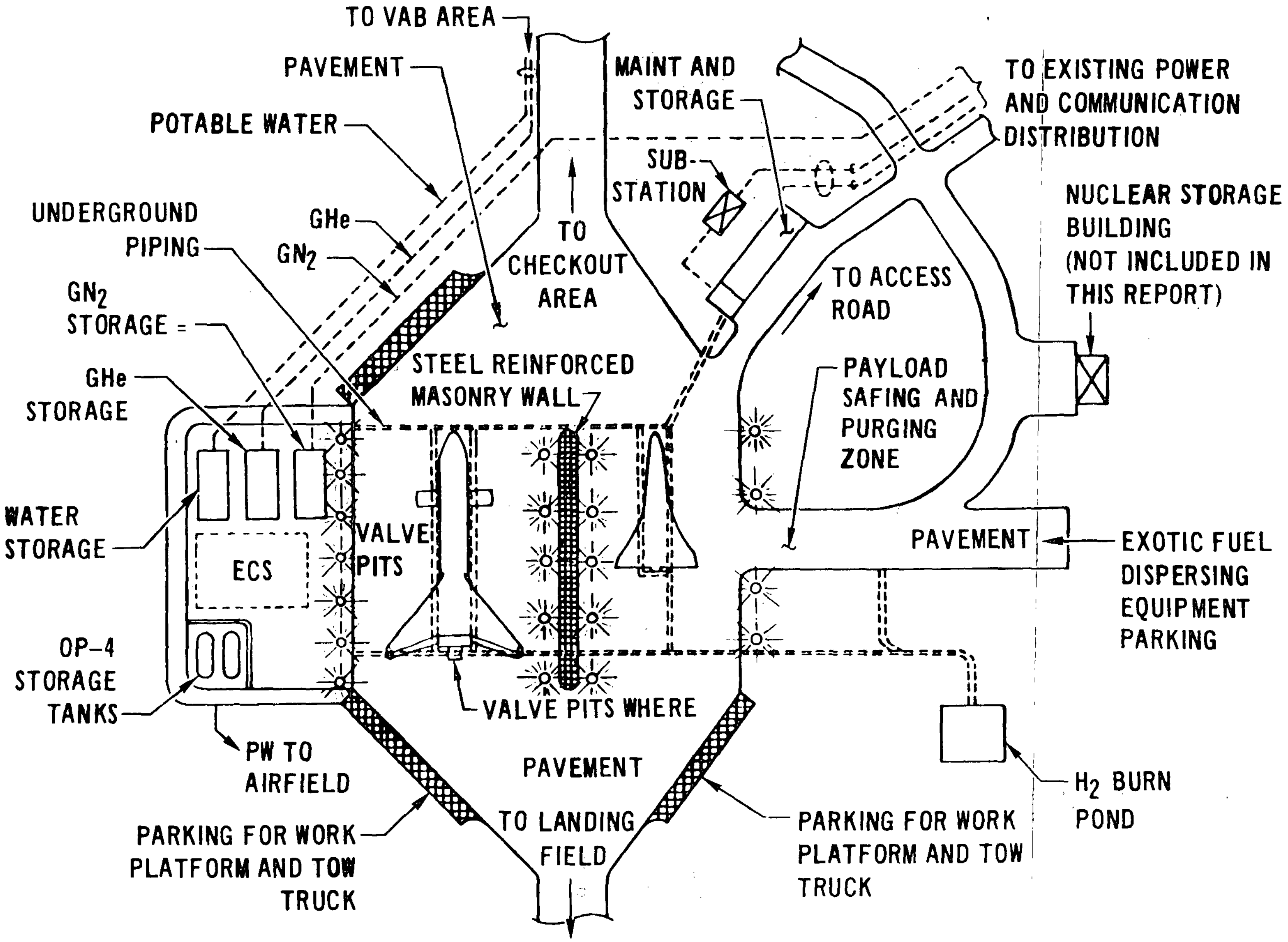


FIGURE 3.3-48

and clear height of approximately 125 feet. Vehicle proof load tests and ground vibration tests will be consummated in this area. See Figure 3.3-49.

Four horizontal overlapping/rolling doors are required, approximately 200 feet wide by 100 feet high. The structure shall be a non-air-conditioned area designed for a flexible shelter for horizontal maintenance of both vehicles. The area in combination with VAB cells 3 and 4, is large enough for housing three Boosters and four Orbiters simultaneously.

The building shall have paved access ramps to all four doors allowing access/egress of the large vehicles. This paving shall be connected to the VAB high bay cells to permit towing of vehicles to VAB high bay for erection and mating.

An opening shall be provided between the VAB transfer aisle and the new MAB to permit movement of subassemblies/materials, etc. from VAB high and low bay areas to this new area. A similar opening shall be provided in the office bay area of the new MAB to permit movement of subassemblies and materials to the North portion of the building.

This structure can be expanded to the North with similar construction should additional space be required for an accelerated program.

The proposed MAB will include areas for work platforms, handling equipment, vehicle maintenance, checkout equipment, and general work areas.

Hydrogen Production Facility - A hydrogen production facility is programmed to support the traffic model launch rates. From this facility, the hydrogen will be transferred to the LC-39 launch pad storage facility. This facility is recommended to be commercial contractor owned and operated. This will enable a savings in cost (per pound) in that during reduced launch rates the hydrogen product could be sold commercially. Preliminary sizing analyses indicate a capability of 60 tons per day is required. Supplementary quantities for high launch rates can be supplied from the existing Michoud 30 ton per day facility. The

NEW ASSEMBLY
MAINTENANCE AND REFURBISHMENT CHECKOUT
BUILDING ADDITION

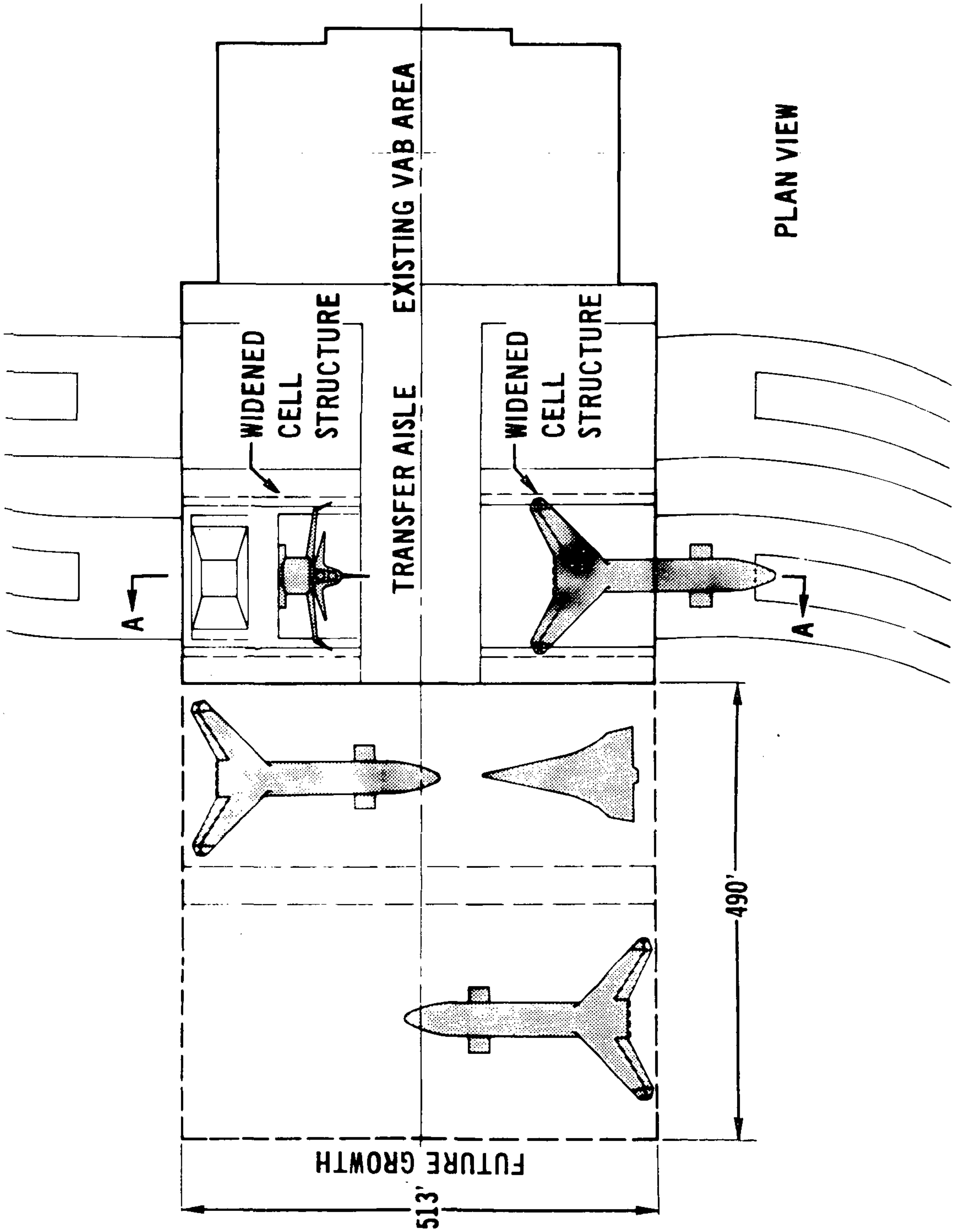


FIGURE 3.3-49

hydrocarbon supply can be natural gas (primarily methane -- CH_4) or Naptha.

3.3.1.11.1.2 Modified Facilities Required at KSC - Shuttle vehicle ground operations are centralized within the existing Launch Complex 39 area facilities.

Vertical Assembly Building Modifications - The VAB high bay cells will be used for two vehicle activities in addition to the vehicle erection, mating and prelaunch preparations. Initially, the cells (excluding the integration cell) will be used for final assembly of Orbiter vehicles. Upon completion of the assembly cycle these cells will be converted for Orbiter horizontal maintenance. The transfer aisle and low bay area are planned for subassembly activities, storage of large GSE and support services.

Modifications to the VAB include widening Cells 3 and 4 from their present width, 150 feet to 180 feet wide from the ground level to the 112-foot level, and from the doors to a depth of 152 feet into the cell. This work includes installing main structural steel columns and tying in to the existing structure. Also included is removal of existing extensible platforms (except where they can be modified and used for vehicle and cargo access), modification of existing doors,stairs, and all electrical and mechanical equipment relocation work.

Mobile Launcher Modifications - The existing Mobile Launchers are the key facility units during the prelaunch and launch cycles. One unit will be modified for Orbiter cluster firing tests.

The other two units will be reconfigured for the vertical flight vehicles. Included in these modifications are removing approximately 100 feet from the top of the Launch Umbilical Towers, relocation of the existing hammerhead cranes to the new lower level, removing existing holddowns, and installing new holddowns, installing a new launch platform, mechanical and electrical system modifications, removing existing swing arms and installing new swing arms and tail masts.

All work necessary on the Mobile Launchers can be performed within the Vertical

Assembly Building high bay areas. This will permit removal and rework in an enclosed environment and with ample overhead crane capacity for working the heavy components.

The third Mobile Launcher shall be modified similar to the above but, in addition, will be fitted with an Orbiter support fixture suitable for holding the Orbiter in a vertical position over the existing flame well for cluster firing tests. Booster cluster firing tests can be made from one of the two Mobile Launchers modified for integrated launch configuration.

Mobile Service Structure Modifications - The requirement for cargo changeout can be satisfied by providing a cargo changeout fixture on the Mobile Service Structure. (See Figure 3.3-50)

The work includes removal of the overhang structure from the 266-foot level downward, relocation and rework of work platforms, rework of structure at cargo handling fixture area, modification of the steel structure at level 88 feet for Orbiter tail clearance, installation of a new cargo handling crane, elevators, and electrical and mechanical modifications as required.

Launch Pad Modification - Launch pads 39A and B are adaptable, with modifications, for Shuttle static firing testing and the vertical flight program. Primary modifications at both pads include increasing the liquid hydrogen propellant storage from the present 850,000 gallons to 1,700,000 gallons and adding another LH_2 transfer line from this storage area to the propellant transfer line. In addition, modifications will be required to the water deluge system, and mechanical and electrical service connections required to interface with the modified Mobile Launchers. Also, personnel evacuation and protection areas will be modified to augment the new escape systems required for the Shuttle vehicles.

Existing Facilities - Numerous facilities do not require facility modifications for use by the Shuttle program. Minor alterations are planned during the activation phase. Primarily these alterations are for removal of existing nonuseable equipment

FEASIBILITY STUDY

UTILIZATION OF EXISTING MSS FOR ON-PAD CARGO HANDLING

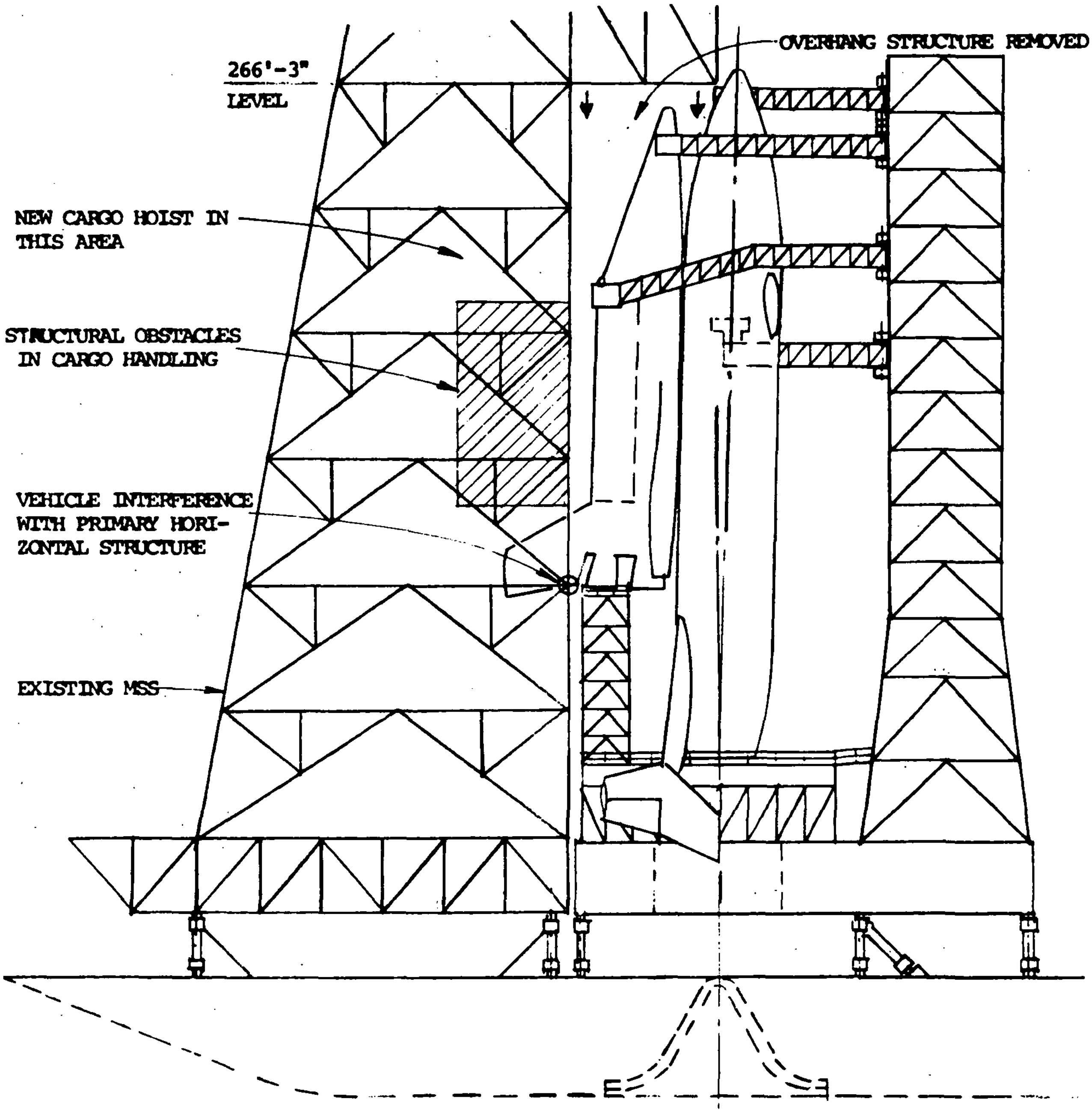


FIGURE 3.3-50

and relocation of interface systems for Shuttle ground systems equipment. Shuttle operations control will be located in the existing LC-39 Launch Control Center. Contractor supplied ground and launch control equipment (MDAC units) will support prelaunch (VAB) tests and pad launch operations. Capability will be provided for continuous backup of launch operations. The MDAC units will have switching capability between the prelaunch and launch areas.

The Manned Spacecraft Operations Building (MSOB) provides sufficient areas to support numerous Shuttle activities. The contractors administrative and engineering offices will be located in a portion of this facility. The assembly and test section is recommended for use as the centralized Cargo Operations area for test, packaging and module buildup activities. Passenger housing will be located adjacent to the cargo area. The Central Instrumentation Facility (CIF) provides large scale digital computer (GE 635 and IBM 360) equipment. These units will be used to compile variations of test and checkout programs for the onboard maintenance recorder time histories, inventory and configuration control. For the development phase, significant savings may result in the TM, recording and real time data reduction and display if used for flight test monitoring. Within the KSC industrial area numerous other facilities are planned to support the Shuttle program. Among these facilities are numerous existing Payload Preparation Facilities at KSC and CKAFS which are planned for the Shuttle operations.

3.3.1.11.2 New Site Baseline - This section generically describes the basic requirements for a new launch site. That is, it presupposes the government would have to acquire land and construct and staff the entire launch site.

3.3.1.11.2.1 Land Required - To implement the Space Shuttle Operational Site, a tract of land must be available of suitable size and with reasonably level terrain. The launch danger radius, landing field clearances, quiet zones for Unified S-Band, Telemetry and Frequency Control and Analysis requirements and other clearances, necessitate a large land area. A minimum of 158,000 acres is required to fulfill the total new site requirements. If support shops, tracking or other facilities are available, of use to the Shuttle Program, and within a few miles of the operational site, this amount could be reduced.

Any prospective site must be reasonably near existing highway transportation, railroads, electric power, potable water and populated areas for personnel support. It is desireable to be near a navigable waterway suitable for large barges to transport the big wing tank/body sections and tail assemblies of the Shuttle vehicles.

The site must have good soil bearing qualities suitable for the heavy loading required for the launch pads, maintenance building, landing field and other major facilities.

Any prospective site must be analyzed to determine performance characteristics of the Shuttle Vehicles if operated from this site. Alternate landing fields, downrange landing fields, weather conditions, latitude of site, altitude of site, overflight considerations, launch azimuths and corridors are some of the considerations which must be assessed in determining the Shuttle performance when operated from a given site.

Landing and Safing Facility - A facility similar to that described in the KSC section would be required, except the runway length would increase if the site elevation were above sea level.

3.3.1.11.2.2 Maintenance and Checkout - A Maintenance and Checkout Area, is required for weather-protected maintenance, refurbishment, servicing, cargo removal and installation, and checkout of the Space Shuttle stages. This portion of the MAB will be a non-air-conditioned hangar-type structure capable of accommodating three Orbiter and two Booster stages on their landing gears. (See Figure 3.3-51).

MAINTENANCE AND ASSEMBLY BUILDING

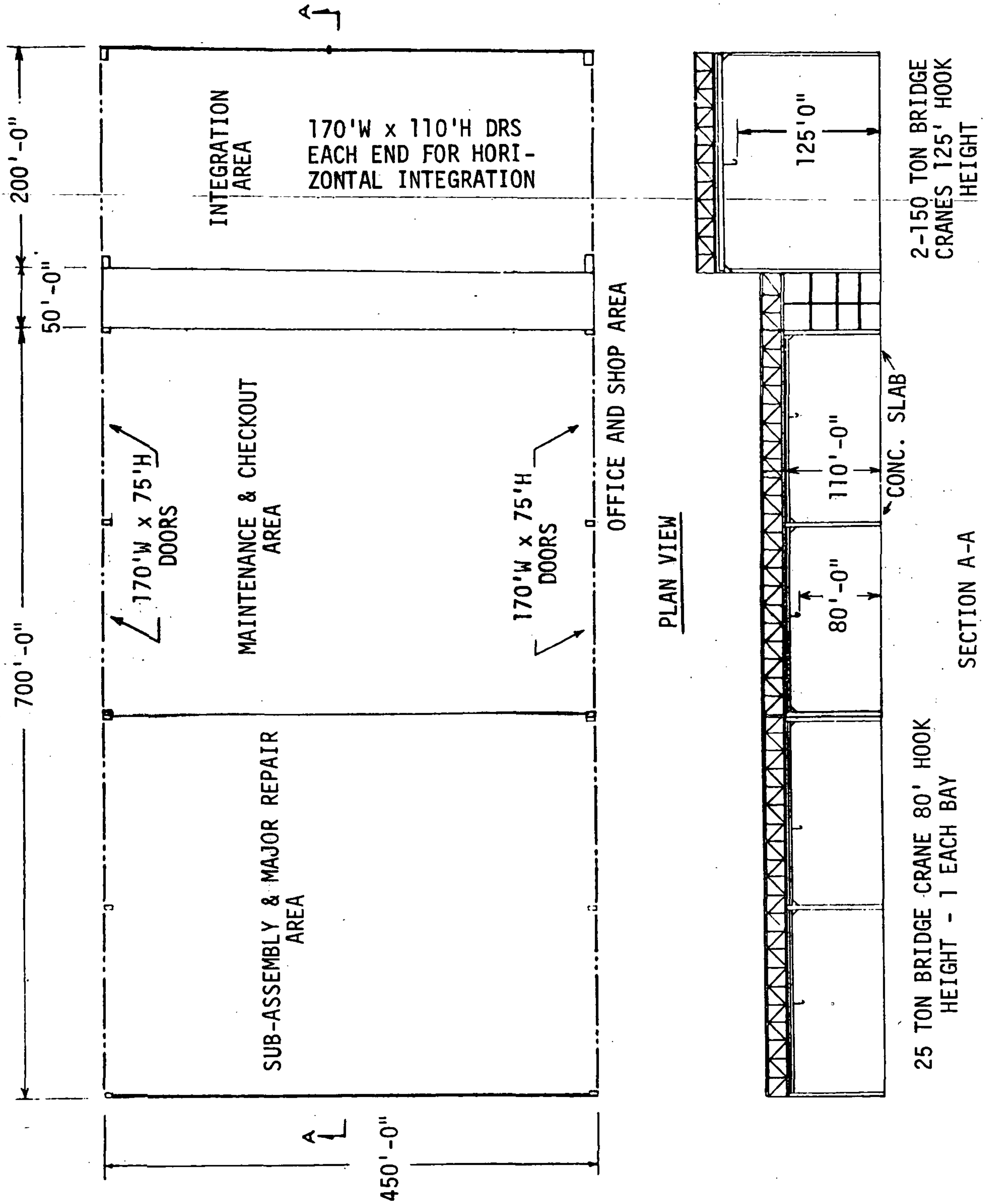


FIGURE 3.3-51

Horizontal Concept - Upon completion of individual stage checkout in the Maintenance and Checkout area, the Orbiter and Booster will be towed to the Integration/Mating portion of the MAB.

The Orbiter will be horizontally hoisted and mounted 'piggy back' on the Booster. Post-mate integrated checkout and servicing will be performed, and the mated configuration will then be towed from the Integration/Mating area to the launch pad.

3.3.1.11.2.3 Facility and Equipment Requirements

A. A Maintenance and Assembly Building will be required for weather-protected maintenance, repair, subassembly and horizontal integration mating of the vehicle. The facility will have doors at both ends to allow passage of the integrated vehicle. Overhead bridge cranes will be used to mate the vehicle stages. Work platforms will be required to provide access for integrated checkout and servicing.

B. A roadway capable of withstanding loads imposed by movement of the integrated vehicle on the Booster landing gear will be required.

C. Prime movers will be required to transport the integrated vehicle to the launch pad.

3.3.1.11.2.4 Launch Pad - The mated Space Shuttle vehicles will be towed to the pad on the Booster landing gear. The vehicle will then be backed onto the erector, which is composed of a strong back and launch base (See Figure 3.3-52 and 3.3-53). The Booster holddowns and umbilical tail masts are appropriately positioned around the flame opening and mounted to the base. The Booster gear will then be pneumatically adjusted, using a ground air supply, to align the Booster with the hold-down arms. The vehicles will then be moved backwards the proper incremental distance to permit engagement and locking of the hold-downs,

LAUNCH PAD VEHICLE ERECTOR (PRE-ERECTION)

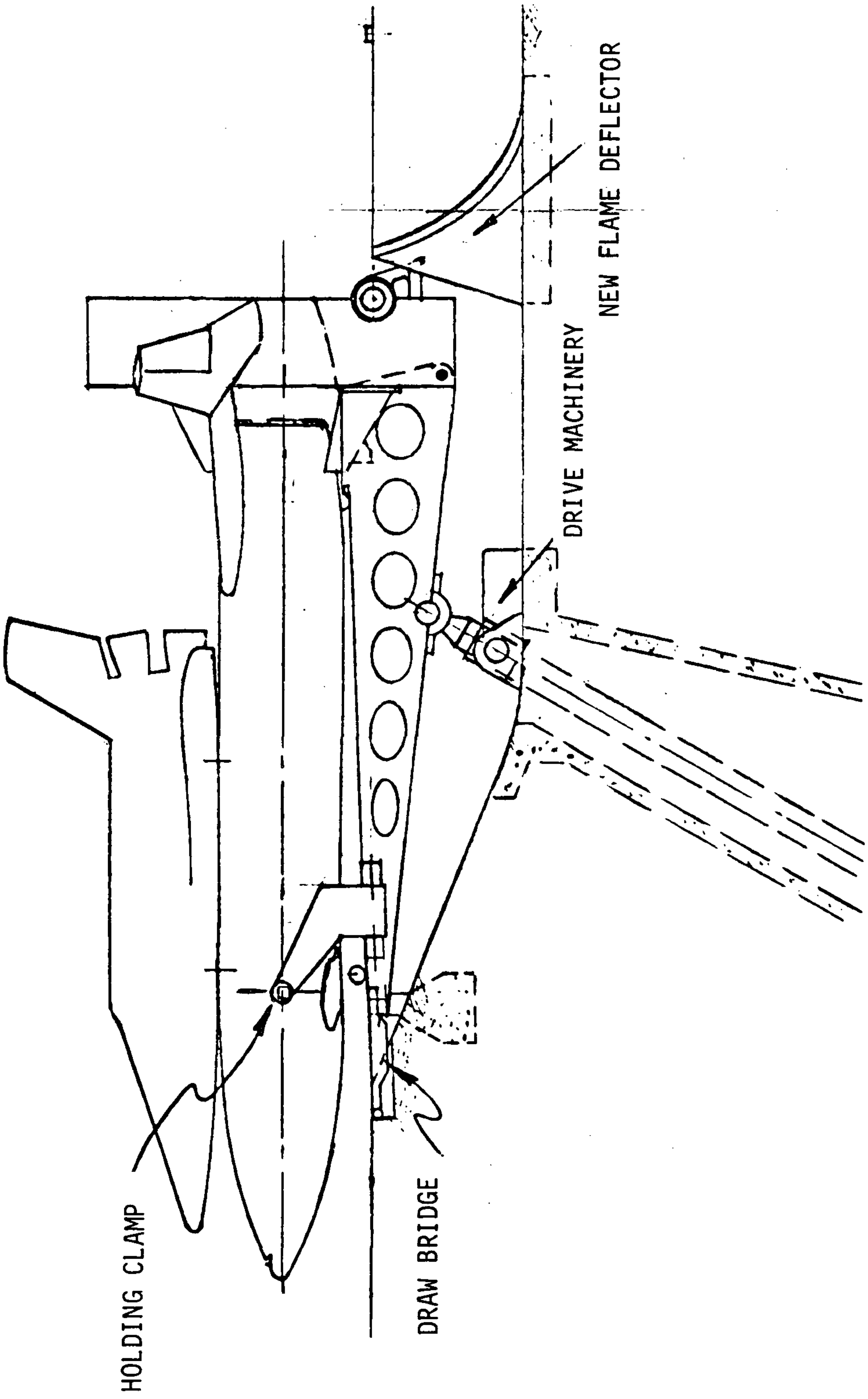
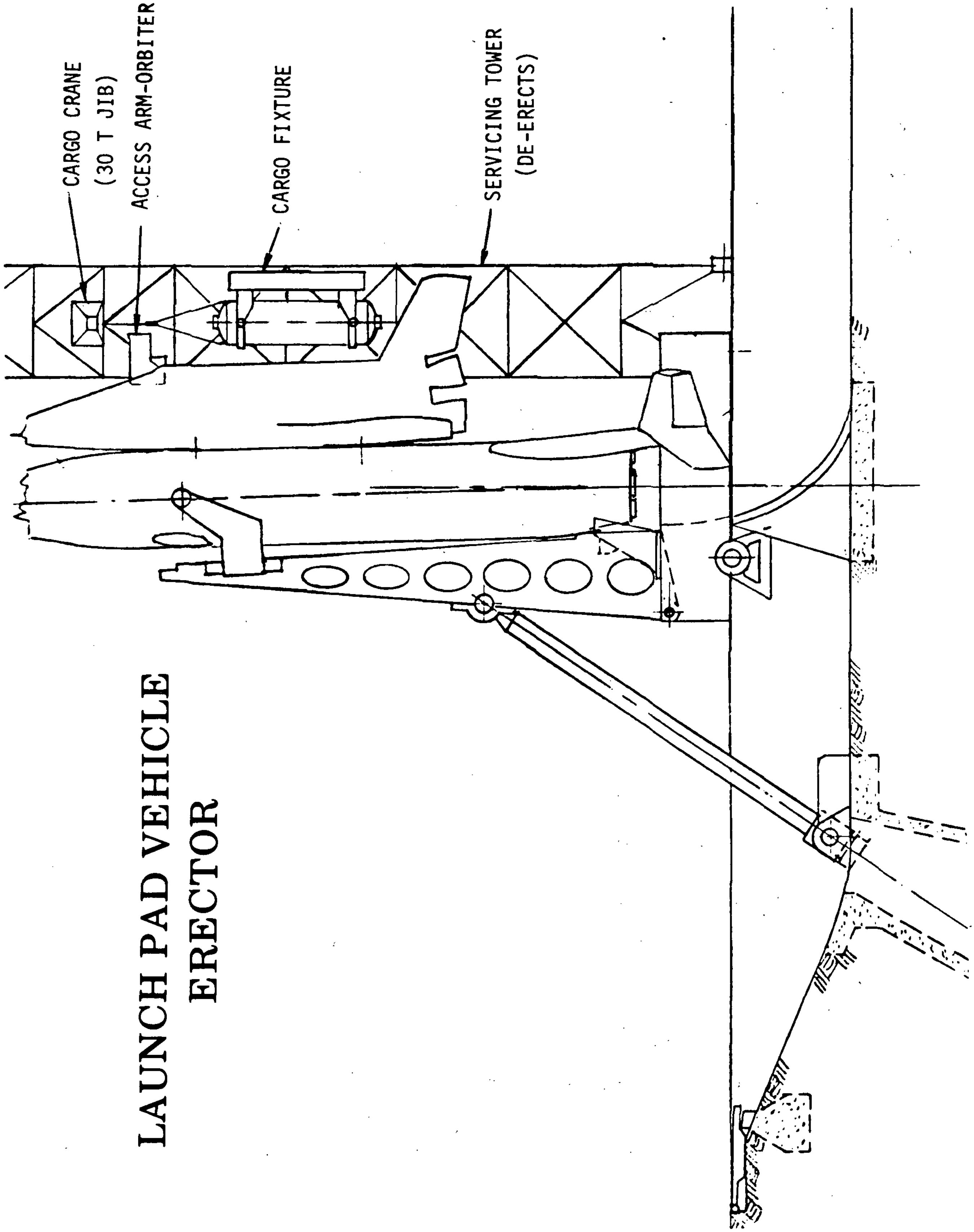


FIGURE 3.3-52



LAUNCH PAD VEHICLE ERECTOR

FIGURE 3.3-53

and connection of the strongback trunnion arms to the intertank area. The landing gear pneumatic pressure will be adjusted, the gear folded and the erector raised to place the vehicles in a vertical position. Prelaunch vehicle operations can then continue.

Facility and Equipment Requirements - The launch pad for the Horizontal Concept, (see Figure 3.3-54) to be constructed of reinforced concrete, will provide the following:

- o Flame Trench
- o Erector (capable of tilting the vehicle to a launch-ready position and retracting, prior to launch)
- o Umbilical Tower (located at a point convenient to both the Orbiter and Booster, it will provide services for the vehicle across the service and access arms)
- o Launcher (structure will provide support, hold-down, and servicing connections for the vehicle and is part of the erector)
- o Flame Deflector (V-type deflector mounts on rails in flame trench)
- o Propellant Servicing System
- o Environmental Control System
- o Gas storage and distribution with Compressor-Converter Gas Facility
- o Pad Terminal Connection Room (communication and data link interface between Launch Control and the Space Shuttle vehicle)
- o Water System
- o Emergency Egress System

3.3.1.11.2.5 Center Operational Support - The two categories of Facilities required to support the Launch Center Operations are:

A. Technical Support Facilities (to include those major facilities that directly support the Launch Operations and the Space Shuttle Processing).

LAUNCH PAD

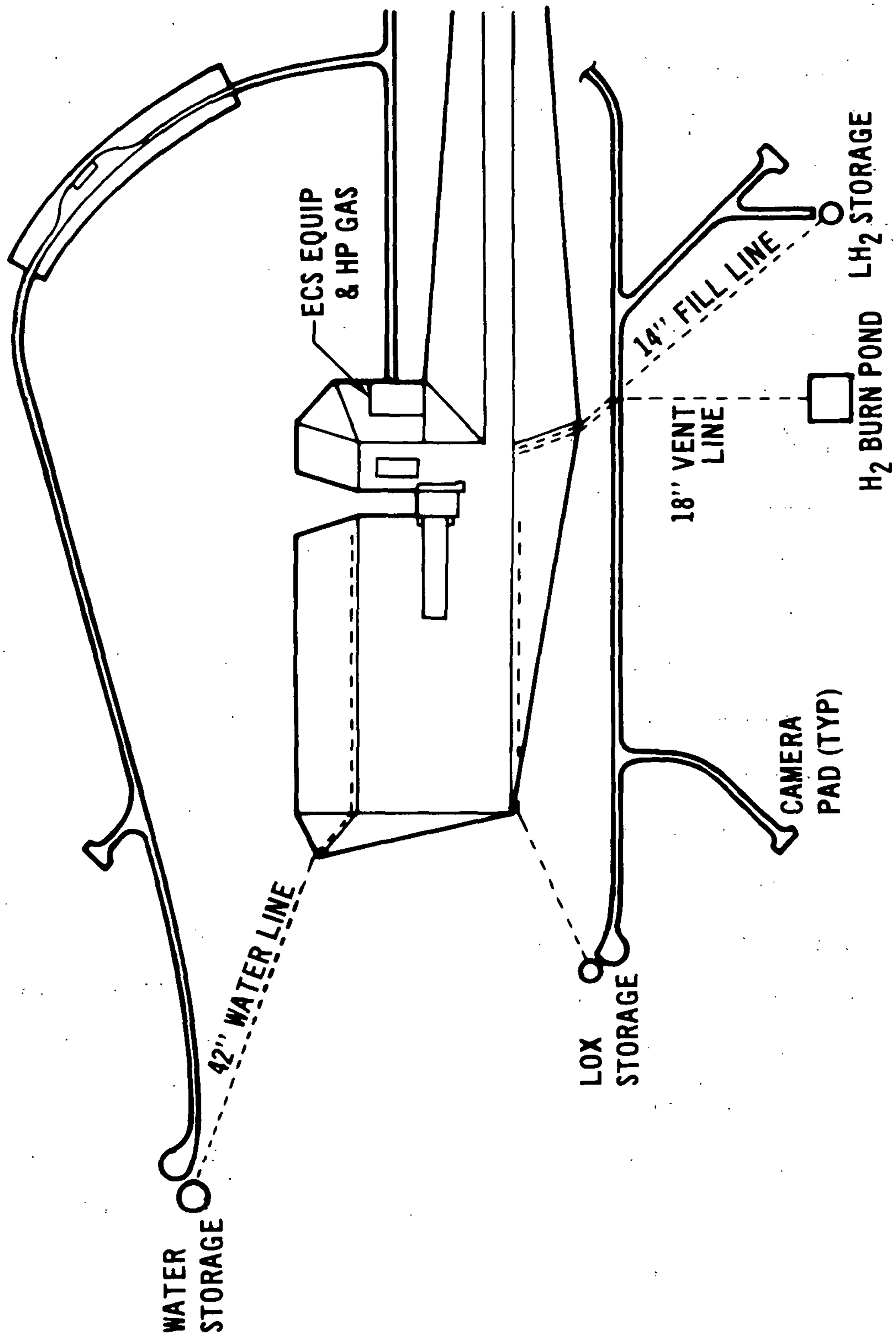


FIGURE 3.3-54

B. Base Support Facilities (to include all basic facilities required to operate and maintain the Center).

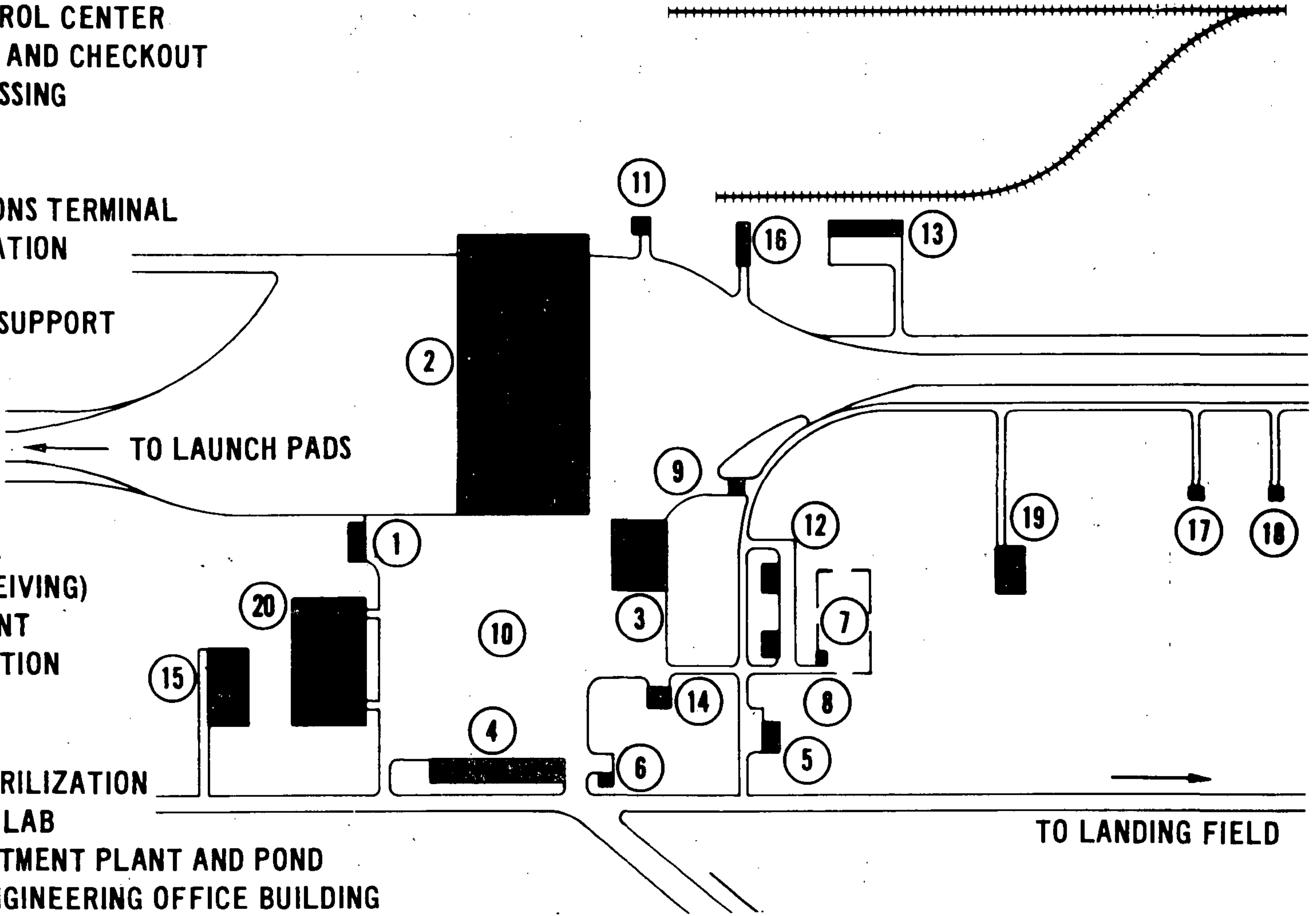
Technical Support Facilities - These will include Support Shops, Flight Crew/Passenger Processing Facility, Payload Processing Facility, and Instrumentation Facilities. (See Figure 3.3-55).

Support Shops - These shops are required to provide laboratory and fabrication services for Vehicle and GSE Test areas:

A. Laboratories and Test Areas - to provide laboratory services to support the Space Shuttle for the following:
  - Chemical and physical testing
  - Malfunction analysis
  - Prototype development and ordnance testing
  - Precision cleaning
  - Life support equipment maintenance, qualification, functional testing, and operations
  - Photographic and biological analysis
  - Electromagnetic and environmental test lab
  - Propellants laboratory

B. Shops - to provide the following support services:
  - Mechanical shops to provide support for precision milling, grinding, sheet metal work, welding, painting, engraving, pneumatic panel and hose fabrication, etc.
  - Electrical shops to provide cable and harness fabrication, electrical equipment fabrication, test and checkout, potting and molding, printed circuit fabrication, etc.

TECHNICAL SUPPORT FACILITIES



1. LAUNCH CONTROL CENTER
2. MAINTENANCE AND CHECKOUT
3. CARGO PROCESSING
4. SUPPLY
5. FIRE STATION
6. COMMUNICATIONS TERMINAL
7. POWER SUBSTATION
8. SHOPS AND CONTRACTOR SUPPORT
9. POL AREA
10. PARKING
11. GAS STORAGE
12. HEAVY EQUIPMENT MAINTENANCE
13. SUPPLY (RECEIVING)
14. HEATING PLANT
15. INSTRUMENTATION FACILITY
16. WAREHOUSE
17. PAYLOAD STERILIZATION
18. PROPELLANT LAB
19. SEWAGE TREATMENT PLANT AND POND
20. ADMIN AND ENGINEERING OFFICE BUILDING

FIGURE 3.3-55

Flight Crew/Passenger Processing Facility - This facility will provide the following:

A. Flight Crew Facility, equipped to accommodate flight crew training and prelaunch activities, will have the following:
   - o Quarters for standby or 'ready' flight crews
   - o Procedures and mockup (classroom) training and familiarization
   - o Flight simulators (mission, docking, etc.)

B. Passenger facility, equipped with living quarters and training facilities to accommodate passengers for an undetermined period of time (prior to launch), will provide the following services:
   - o Receive passengers of various ages and backgrounds
   - o Prepare passengers for space flight by training and familiarization
   - o Certify (ascertain) passenger(s) readiness for space flight
   - o Record passenger(s) condition upon return from space flight

Payload Processing Facilities - Extensive facilities will be required to process a variety of payloads. For estimating processing facility requirements, the payload handling can be classified as Routine or Special. Routine handling will involve integrating non-hazardous cargo with a cargo module and preparing it for insertion in the Orbiter. In general, cargo modules should be closed out prior to insertion in the Orbiter. Special payloads for other NASA programs are not covered under this study.

Instrumentation Facilities - Extensive facilities will be required to track, photograph, and communicate with vehicles, and to provide Range Safety Command Control, Timing and Telemetry information to and from Shuttle vehicles during launch, insertion, Booster return and Orbiter return landing operations. The facilities required for these functions are:

A. Central Instrumentation (Data Processing and Display Facility)

B. Unified S-Band Facility

C. Launch Control Center

D. Camera Sites

E. Communications Facility and Distribution System

F. Telemetry, Radar Tracking and Command Control

G. Frequency Control and Analysis

H. Meteorological System

<u>Base Support Facilities</u> - These facilities will include the following:

A. Administration and Technical Office Space to serve as the administrative and technical center for the Shuttle Launch Operations. The following support functions will occupy these facilities:

- Program Management
- Engineering
- Legal
- Procurement
- Security
- Safety
- Personnel
- Photographic
- Reproduction
- Contractor Support
- Auditorium and Training

B. Fire Stations - to serve as a central facility providing fire protection for the complete Center. Space for various specialized fire trucks will be provided, and the facility will house the Central Fire Alarm Headquarters and quarters for personnel.

C. Medical to serve as a dispensary for the entire Center and to provide support to first aid stations and other medical facilities at the Center. The following dispensary areas will be provided:

- o Offices
- o Instruction room(s)
- o Locker room
- o Bedrooms
- o Pharmacy
- o Laboratory
- o Darkroom
- o Treatment room
- o X-Ray room
- o Nurses' station

D. Food Service - cafeteria(s)

E. Motor Pool

F. Vehicle Maintenance Facility

G. Heavy Equipment Shops

H. Weather Facility to be equipped for recording and analyzing meteorological information to predict weather conditions that may affect operations.

I. Railroads - railway access to the area is necessary to support heavy construction programs dependent on rail delivery of construction materials, and to provide logistics support.

J. Roads, Grounds, and Parking Areas

K. Supply (warehousing) to provide facilities for the reception, storage, and issue of parts, spares, and supplies required to support activities at the Center.

L. Maintenance and Repair Facilities (facilities, launch equipment, grounds, roads, and utilities)

M. Electrical Utilities - underground cabling and power systems will be installed to provide industrial and precision power to the entire Center. Adequate sources of commercial power are assumed to be available

N. Heating Plant to provide central heating system for heating area facilities

O. Industrial Water System to consist of water treatment, storage, and distribution lines providing industrial water, fire control water, and potable water to facilities of the entire Center

P. Sewerage and Sewage Treatment System

Q. Parachute Shop

R. Barge Canal, Terminals and Navigational Connection if waterways are available.

S. Ordnance Storage Building

T. Security Patrol Building

U. Heliport

3.3.1.12 Ground Support Equipment (GSE)

3.3.1.12.1 General - Shuttle GSE shall be provided to transport, protect, handle, service, checkout and monitor the complete Shuttle vehicle, the separate Booster and Orbiter vehicles, or the separate assemblies and components of each vehicle during all phases of ground operations, including manufacturing assembly, factory acceptance test, prelaunch checkout, launch operations, post flight operations, and development and flight testing. Shuttle GSE design shall be compatible with ground operations at the contractor's factory, KSC facilities, development test sites, and landing sites and shall be portable or mobile to the extent required to minimize GSE quantities. The Orbiter/Booster contractors shall assure that Orbiter and Booster GSE furnished for support of mated Orbiter/Booster operations has been verified to be physically and functionally compatible with the Shuttle vehicle and using facilities.

3.3.1.12.2 GSE Performance and Design - Shuttle GSE shall be designed to meet the functional and timeline requirements specified in this plan, Maintenance and Logistics Plan, and the Booster/Orbiter GSE General Specification, Number GS255D400.

GSE design shall be compatible with the objective of maximum commonality and minimizing the amount of equipment required on the launch pad and shall employ automated techniques for test, evaluation, recording and servicing where such techniques are indicated on a cost-effective basis or by mission or operational requirements. GSE shall be designed for maximum utilization of the existing KSC facilities at Complex 39, the Manned Spacecraft Operations Building (MSOB), the Vertical Assembly Building (VAB), and the Complex 39 Mobile Launcher with minimum modification.

3.3.1.12.3 GSE Functional Description

3.3.1.12.3.1 Factory - LRU/Subsystem and System GSE shall be located at the

Booster and Orbiter factory sites to provide for manufacturing buildup, manufacturing checkout, and operational verification of the Booster/Orbiter systems.

System Test GSE shall be an integrated design, computer controlled system where applicable, capable of checking out all onboard avionic systems and supporting checkout of nonavionic vehicle systems. It shall be capable of final acceptance testing of the Booster/Orbiter installed systems.

Subsystem GSE shall be capable of functional or leak testing built-up modules prior to installation in the next assembly. Testing shall include verification of instrumentation (including BITE and onboard checkout) and flight wiring/plumbing to the module interface. Subsystem GSE shall be capable of end-to-end testing of installed subsystems in major subassemblies and shall be designed for maximum utilization of the onboard capability.

A. Electrical/Electronic GSE shall include, in addition to the main checkout system, test equipment for Shuttle Subsystems testing, supplementary support systems, and electrical interface simulators. GSE typical of that required in the above categories includes the following:

(1) Bench Test Equipment for the Shuttle Vehicle's Guidance and Navigation, Display and Control, Flight Control, Communications and Navigation Aids, Electrical Power and Data Management Systems.

(2) Ground power control and distribution systems.

(3) Checkout/Service/Support GSE including the Ground Automatic Test System (GATS), ground communications systems, and portable stimuli boxes for the installed subsystems. The GATS contains a Monitor, Display, and Control (MDAC) Unit, computer, signal conditioning and recording equipment, and a ground digital data transmission system.

(4) Electrical Interface Simulators for the Booster, Orbiter, Main Engine and Cargo Module Subsystems.

B. Mechanical GSE - Mechanical support equipment shall provide the capability to transport, handle, environmentally protect, provide access to, or support the flight vehicles during buildup and to test the mechanical subsystems and airbreathing engines. This GSE shall be capable of servicing the major segments throughout the manufacturing cycle and shipment to the launch site. Typical GSE within this category includes prime movers, cabin section transporters, wing, horizontal tail, vertical tail, and cargo module transporters, erection devices, slings, access stands and stairs, engine shipping containers, installation and overhaul units, alignment gear, ferry flight kits, mechanical simulators and miscellaneous special tools.

C. Fluids GSE - Fluids support GSE shall provide the capability to service, purge, proof, leak and functional test the Shuttle vehicles. Fluids systems GSE and component test equipment GSE shall be capable of testing the system and subsystems of the Space Shuttle vehicles. Cryogenic servicing operations shall be capable of remote operation and control. GSE representative of this category includes liquid and gaseous oxygen and hydrogen servicing equipment, JP-4 servicing equipment, gaseous helium and nitrogen, water, coolant, waste and food management servicing equipment, ground cooling units and the necessary component level and subsystems test equipment.

3.3.1.12.3.2 Ground Development Test - GSE will be provided to support the Hydraulics and Controls Test Unit, Avionics System Test Unit, Attitude Control Propulsion System Test Unit, Main Propulsion System Flight Readiness Firing, and other development tests. Typical GSE within this category includes hydraulic component test set and system checkout unit, coolant LRU and systems checkout unit, ECLS LRU and system checkout unit, engine (ABES) support GSE, cabin leak detector, Booster/Orbiter/Payload interface simulators, electrical systems checkout equipment, AC and DC power supplies, the Ground Automatic Test System/MDAC Unit, communications and navigation aids checkout equipment, breakout boxes, fluids servicing equipment and the necessary handling and transportation GSE required to support all phases of the Development Test Program.

3.3.1.12.3.3 Flight Test - GSE will be provided to support the horizontal flight test vehicles at Edwards Air Force Base and the vertical flight test vehicles at Kennedy Spacecraft Center. The operational support GSE will be the GSE that eventually will be used at the Kennedy Spacecraft Center maintenance hangar and at the launch pad. The GSE functions are described in Section 3.3.1.12.3.4 and 3.3.1.12.3.5.

3.3.1.12.3.4 Launch Site - Shuttle GSE provided by Orbiter and Booster contractors will support the following operations at KSC:

A. Erection and vertical mate, gas servicing and post mate vehicle systems test at the VAB.

B. Transportation to the launch pad on the mobile launcher.

C. Prelaunch checkout at the VAB and at the launch pad, using the GSE GATS/MDAC unit located in the Launch Control Center (LCC), to augment the Shuttle onboard checkout system and for remote control of fluids and electrical servicing systems.

D. Launch Operations on Pad 39, using the GATS/MDAC Unit to supplement the onboard checkout system, for remote control of servicing equipment, and to provide checkout redundancy and emergency override functions.

E. Cargo and payload operations at the launch pad.

F. Component/LRU test GSE shall be provided at the Maintenance and Assembly Building (MAB) area in the hangar to provide support to the maintenance turnaround cycle. This GSE shall contain self-test capability and be capable of performing preinstallation test on each procured component/LRU to the depth required to verify acceptable characteristics. Propulsion, hydraulic and electrical/electronic GSE are indicative of the types of GSE. Portable gaseous nitrogen and helium supplier for onboard vehicle component fault isolation shall be provided commodities by the facility.

G. Post maintenance checkout and servicing GSE shall be provided at the MAB area for revalidation testing after maintenance. The GSE complement includes the GATS/MDAC Unit, power supplies, and portable stimuli boxes.

3.3.1.12.3.5 Post Landing - GSE shall be provided at the primary and alternate site to support the following post landing functions:

A. Safing

B. Propellant tanks defueling, purging and fueling

C. Ground cooling and environmental control

D. Vehicle handling and transportation fixtures for movement to the horizontal checkout and maintenance area

E. Electrical power

F. Cargo handling

Landing area GSE shall provide crew and ground personnel access to the cockpit, service connections and inspection areas.

3.3.1.12.3.6 GSE Physical Description - The GSE descriptions and usage locations are identified in Appendix 1 to the GSE General Specification No. GS255D400. Figure 3.3-56 is a format description and Figure 3.3-57 is a sample page from this GSE Space Shuttle Index.

FORMAT DESCRIPTION
SAMPLE

END ITEM NAME

1. LEAK DETECTOR - He

END ITEM DESCRIPTION

2. A portable leak detector required to locate leaks in the Space Shuttle's components while undergoing LRU acceptance. Included in the unit is a "test port" station and associated auxiliary equipment.

3. Where numbers appear in usage area columns, these indicate serial numbers.

EXAMPLE: | (1-4) | | (4S) | | (5) |

(5) — 1 UNIT (SERIAL NO. 5)

(4S) — SERIAL NO. 4 SHARED BETWEEN USING AREAS

(1-4) — 4 UNITS (SERIAL NOS. 1 THROUGH 4)

TOTAL QUANTITY (5) — 5 UNITS REQUIRED

4. Where numbers appear in parenthesis:

EXAMPLE: (1,2) S   1   2

2 — PRIME USAGE

1 — PRIME USAGE

(1,2) S — SERIAL NOS. 1 AND 2 ARE SHARED WITH PRIME USING AREA

5. ACRONYMS

DIU	Digital Interface Unit	ILS	Instrument Landing System
BTE	Bench Test Equipment	DME	Distance Measuring Equipment
LRU	Line Replaceable Unit	ATC	Air Traffic Control
BIT	Built-In Test	LUT	Launcher Umbilical Tower
CRT	Cathode Ray Tube	LCC	Launch Control Center
E/M	Electromechanical	VAB	Vehicle Assembly Building
ADI	Attitude Direction Indicator	OMS	Orbit Maneuvering System
VOR	VHF Omnidirectional Range	IMU	Inertial Measurement Unit
		ACPS	Attitude Control Propulsion System

FIGURE 3.3-56

SPACE SHUTTLE GSE INDEX

End Item Description	Vendor Factory	Booster Factory		Orbiter Factory		Ground Dvt. Test	Flight Test		Turnaround					Alternate Landing Site	Total Quantity
		LRU	Vehicle	LRU	Vehicle		Horizontal	Vertical	Post Landing	Maintenance Hangar	Prelaunch (VAB)	Launch Pad	LRU		
6. HYDRAULIC SERVICE AND FLUSH UNIT This unit will provide hydraulic fluid to the Space Shuttle's hydraulic systems. The unit will also have the capability of flushing the hydraulic system after assembly for contamination removal. This unit is approximately 8'L x 6'W x 6'H.			1		2	1S	3S	4S		(1,2) S	3,4				4
7. GASEOUS HEATER A unit which will accept cool GH_2 and heat the GH_2 to 1500° for testing the vehicle hydraulic pumps. This unit will be portable and approximately 8'L x 3'W x 3'H.			1		2	1S	3S	4S		(1,2) S	3,4				4
8. SERVICE UNIT - WATER This unit consists of stainless steel tank, hoses, valves and associated hardware necessary to service the Space Shuttle's water management system. This four (4) wheel trailer with toe bar is approximately 10'L x 6'W x 6'H.							1S	2S			1,2				2
9. CARGO GROUND POWER AND COOLING UNIT This unit supplies ground power and/or cooling to the cargo module for ground operations. This hydrogen proof ground power unit will be portable and be approximately 10'L x 5'W x 6'H.					1,2	1S	1S	2S			1S	2S			2

FIGURE 3.3-57

3.3.1.13 <u>Operations Site Activation</u> - The primary objective is to provide an operational ready site compatible with the Shuttle program schedule. During the pre-site planning period it is essential to define and document facility and installation requirements, implementation methods and roles and responsibilities of all program contractors and government agenices.

3.3.1.13.1 <u>Planning and Schedules</u> - Site activation is divided into three activities identified as: Site Activation Planning, Construction/Modification and Installation and Checkout. The initial planning activity provides the critical planning necessary for successful activation of a site. Concurrent with the design of the vehicles and supporting ground systems, the activation planning coordination must be initiated. To meet the current schedule, detail design of several facilities will commence in the latter part of CY 1972. Prior to this, the criteria packages, master plans, etc. must be prepared for the design organization. A Master Facility and Activation Plan must be prepared and implemented as one of the earliest requirements. This plan serves as a management guide for the coordination of activities, documentation preparation, organizational responsibilities and schedule requirements for the construction/modification and installation and checkout activities. During the construction/modification activity, the government owned facilities will be constructed, or modified, in accordance with government/contractor facility criteria specifications. The construction will be monitored by the responsible government/contractor team. Non-compliance discrepancies will be identified and resolved by the contracting agency. The on-site Facility Working Group (FWG) will control the schedules, criteria and construction drawings, change implementation and daily site activities. The FWG will include representatives from government agencies, design and construction contractors, Shuttle contractors and other responsible organizations. During the physical construction, this group will be responsible for contractual compliance and acceptance verification. The Installation and Checkout activity will begin after the Beneficial Occupancy Date (BOD) is established. The primary task is the physical installation of government and contractor supplied equipment and interfacing secondary systems. The Activation Working Group (AWG) will be responsible for, and organized similar to the facility group. Upon completion of the installation and compliance verifications, government and contractor personnel will perform ground systems functional checkout to assure total systems operating capability prior to receiving the test vehicles and/or components. Figure 3.3-58 identifies the operations facilities and planned implementation schedule. Individual facility readiness dates are traceable to a specific program milestone (e.g. - LC 39 pad-A is keyed to the first vertical mated launch). The dates are established prior to the actual vehicle need by approximately three months for ground systems checkout and to allow contingencies for changes in ground or vehicle activities. In addition to the operations site requirements off site facilities and services, plus logistic support are identified for continuity purposes. The Ground Systems Testing is defined as the period after completion of installations and prior to receiving the first test vehicle. The intent is to demonstrate the site ground systems compatibility and the interface capability between all Shuttle sites (KSC, MSC, MSFC, FRC, GSFC, etc.). Generally this task can be subdivided into three activities, and is applicable in varying degrees, for each site. The sequence of events is typical for each site and for each facility or area. During the initial activities, contractor personnel will emplace mobile and portable equipment and proceed with verification of the interface mating checks and physical hookup of cabling, grounding, fluid/gas lines, etc. The next step is the functional validation of independent ground systems. These tests can be segregated to one location (e.g. landing field), or an integrated demonstration of several locations (e.g. LCC and Pad). The final activity will be a system demonstration of the complete Shuttle ground network including the operations site and interface links to other sites and centers.

3.3.1.13.2 Responsibilities - Activation of the operations site requires an integrated effort by all contractors and government agencies. Roles and responsibilities of each participant must be clearly identified to assure compatibility and schedule compliance. Hardware requirements of each participant must be defined and organized into one of two categories. Common requirements are those items which are needed to support more than one vehicle element. Unique requirements are those which are peculiar to one element only. Numerous other requirements must be organized in a similar manner. Documentation preparation, interface control, schedules, etc., are typical examples of other requirements essential to successfully accomplish the activation task. The integration of these requirements is the major task. Each contractor must actively participate in the timely planning and documentation of the activation package. As a vehicle contractor, the prime responsibility includes documentation preparation or support, coordination, delivery of hardware and support of working groups. One participant will be assigned the responsibility as activation integrator. Basically this task is to manage the planning and implementation of the activation phase and transition to the development/operational activities. Included in this activity is government/contractor coordination, documentation preparation control, establishment and chairing of working groups, problem identification (contractual, hardware, documentation, etc.), site surveillance and certification of operational readiness. For successful integration it is essential that the integration roles and responsibilities be assigned during the operations site activation planning period (Ref Figure 3.3-58). Two integration concepts were evaluated to define the most efficient and cost effective approach for the Shuttle activation program. In the first concept, the integration responsibility is retained by the government. A significant advantage is that it enables a direct link between the contractors and the government office and provides unbiased management overview in resolving incompatibilities in the shortest possible time. Two key criteria are necessary for this approach. The government office at the operations site must have contractual jurisdiction of all contractors' on site activities, and secondly, sufficient experienced personnel must be available. The alternate concept contractually assigns this task to one of the prime vehicle contractors. This concept can be further subdivided into associate integrators, but it is not considered cost effective. In this concept the integrator functions as a staff organization supplementing the government organization. The integrator can not give contractual direction to the participating contractors, but functions as the activation planner and "identifier" of contractual or other incompatibilities. In either case, it is mandatory that an efficient means of communicating be established to resolve problems so as not to create unnecessary schedule stoppages and subsequent rework.

Our recommendation is for the operations site government office to perform the activation integration task. Sufficient personnel exist and provide extensive knowledge in the areas of site imposed requirements, labor relations and contracting techniques, and adaptation of existing site capabilities.

3.3.1.14 Safety

Safety considerations for Space Shuttle operations can be divided into two categories:

A. Ground Operations Safety

B. Launch/Range/Flight Safety

3.3.1.14.1 Ground Operations Safety

Ground operations safety will consider safety aspects in planning, constructing and operating the ground facilities. These are:

Hazard Proofing - Hazard proofing of electrical and communications systems to be utilized while propellants are loaded or being loaded. This is normally accomplished by sealed nitrogen purged units, or a positive nitrogen purge.

Area Controls - Area controls includes the placement of fences, barricades signs and ingress, egress points to insure control of access of personnel to hazard areas. The areas include propellant storage, high pressure gases, the launch complex when propellants are loaded in the vehicle, etc.

Evacuation Routes - Evacuation routes include the marking of stairways corridors etc. on service structures underground rooms and other spaces to assist personnel in expeditious evacuation and to preclude use of dead end or overcrowded routes.

Standard Safety Practices -Standard safety practices include those items normally considered as Industrial Safety such as designation of "Hard Hat" and "No Smoking" zones, marking of propellant, gas and electrical lines, location of first aid fire equipment, etc.

Safety Training - Safety training consists of: (a) Orientation lecture and badging of all personnel who will work in the area. This training should be slanted toward the lesser skilled types such as janitors, drivers, etc. and should include:

A. Recognition of hazards and action to be taken.

B. Markings of evacuation routes and do's and don't's (use stairs not elevator, etc.).

C. First aid fire fighting

D. Specialized training for close out crews, rescue crews, propellant crews, etc. to include:

1. Emergency egress, slide wire
2. Protective equipment, gas masks, fireproof clothing, leg stats, etc.
3. Equipment operation - rescue vehicles, radios, etc.
4. Miscellaneous propellants, ordnance, etc.

Lightning Protection - Lightning protection will be designed to provide a cone of protection for the vehicle utilizing the umbilical tower. Protection for propellant storage areas should be included. Consideration will be given to lightning detection systems.

Documentation - Documentation will include provisions for inclusion of systems safety engineering input to procedures including hazardous operations. Included will be a systems safety review of these procedures prior to publication to insure compliance with safety requirements and practices.

3.3.1.14.2 Launch/Range Flight Safety - Launch safety is assumed to encompass the period of the launch preparation countdown thru lift-off including propellant loading. Flight safety includes the period from lift-off thru landing.

Launch Safety - Launch safety includes those operations during the period above that constitute a significant risk to personnel and or property.

Vehicle Ordnance - Vehicle ordnance installation of Category B ordnance can be safely accomplished with restriction to essential personnel in the immediate area of the installation only. (Category B ordnance devices are those which will not in themselves, or by initiating a chain of events, cause injury to people or damage to property). It is recommended that installation of any heavy ordnance items constituting a hazard to personnel (Category A) be deferred until just prior to propellant loading when clearing for that operation is in progress. Clearance areas for installation of Category A will be determined by the potential of the individual item.

Propellant Loading - Propellant loading constitutes the major hazardous operation prior to launch. TNT equivalency of LO_2/LH_2 propellant combinations has previously been considered to be 60% (1 pound propellant mix equals .6 pound TNT), however, tests conducted under Project Pyro have shown that under static propellant conditions it is not possible to achieve an optimum mix of propellants. Therefore NASA, the US Air Force and the Armed Services Explosive Safety Board have unofficially agreed that a TNT equivalency of 20% for LO_2/LH_2 mixtures is realistic. This would establish a blast danger area of approximately 5500 feet for the tanked Orbiter/Booster. This potential will require remote tanking of the vehicles with the 5500 foot area cleared of all personnel. Provisions can be made for reentry of a very limited number of people in the event of emergencies which may inhibit launch. Normally this reentry will be limited to an engineer and technician of the system affected accompanied by a safety engineer subject to the approval of the Launch/Test Conductor.

Crew Ingress/Egress - Crew ingress/egress will be accomplished after propellant loading. Close out crew and personnel assisting the crew/passengers in entering and securing the vehicles will be held to a minimum. An emergency method of evacuating the area is described in section 3.3.1.6.4.

Flight/Range Safety - Flight range safety in the period after lift-off presents problems that will require solution at a very high policy level. (Range Safety is concerned with safety of life and property of personnel other than the flight crew and passengers of the vehicle. Flight Safety concerns the safety of crew and passengers of the vehicle.) Responsibility for the protection of the general public from launch incidents (Range Safety) has been the assigned responsibility of the agency operating the launch facility. The usual method of insuring this protection has been to avoid population overflights and to provide a means of flight termination in the event of deviation which might lead to an overflight violation. Statements which may influence Space Shuttle range safety requirements are quoted below. These are taken from the Air Force Eastern Test Range, Range Safety Manual 127-1, 1 January 1969, Section A-2 Policy and Criteria. "For manned vehicles in which the pilot controls a portion of the flight path, the vehicle commander is responsible for taking all reasonable precautions to prevent unnecessary hazards to life and property during the time he is responsible for flight path control."

"Protection for individuals in manned vehicles must be provided by proper vehicle design. Significant risks to the general public will not be allowed solely because the vehicle is manned."

Extent of the application of this policy to the Space Shuttle will be influenced by such factors as reliability, vehicle design, and ability of the pilot to control the vehicle. The basic policy has been effective for all manned launches to date.

Safety of the vehicle when operating as an aircraft should not present any unusual problems other than those encountered in other high performance aircraft.

3.3.1.15 Ground Crew Training - The training of personnel for the ground operation activities is basically divided into two categories: on-the-job training (OJT), and classroom instruction. The training program will be structured to satisfy the selection of personnel from individuals presently employed by the contractor and new hires. The program will also be structured to satisfy all disciplines concerned with the ground operations which includes but is not limited to engineering, manufacturing technicians and quality assurance. This program will be open to the customer disciplines as well as contractor.

On-the-job training will consist of training by working with the actual hardware as it is assembled and participating in the development of test procedures, preparing for the tests and actually taking part in the testing. This would begin during the sub-assembly phase of the program and continue through final assembly. This training approach is being considered in lieu of training simulators which are considered too expensive for the number of vehicles involved and, therefore, the deletion would be a cost savings to the program.

Classroom instruction will consist of specialized training courses that will be established for each system. These courses will be designed to teach new hires the detailed theory of operation of the system, fault isolation techniques, test philosophy, and the use and preparation of test procedures. Although the classroom instruction is designed to satisfy the requirements of a new hire, the contractor personnel previously assigned to the ground operations, will participate to the level deemed necessary depending on their knowledge of the system. The instructors for these classes will be contractor specialists in their respective system.

It should be noted that the ground operations personnel would basically come from the existing launch operations department and the systems specialists that will have participated in the Shuttle systems design. This will give the program the maximum level of experience. The new hires would supplement this group.

3.3.1.16 Space Shuttle Vehicle Storage - It is anticipated that early in the Shuttle program it will be necessary to place some of the vehicles in relatively long term storage. This will be the result of the three sets of vehicles required for the development test phase of the program. Also since the launch rate early in the operational program does not require this fleet size, it is planned that some vehicles will be stored for relatively short periods of time.

Prior to storage, the vehicles will be processed through the maintenance cycle. For long term storage, the subsystems will be configured as shown in Figure 3.3- 59. A procedural plan will be instituted whereby periodic inspection of the vehicle will be accomplished to insure that the storage configuration is not altered. For example, those subsystems that require a pressure pad, will be checked to see that the pressure is as required.

Environmental control of the vehicle exterior in the stored configuration may be necessary during long term storage. Since the maintenance hangar is baselined as an open shop area, a portable enclosure would be required whereby the temperature and humidity can be controlled. Also, the storage time may dictate whether a tankage system would be placed in a storage configuration by use of a desiccant or a pressure pad. For a short storage duration, a pressure pad would suffice whereas for a long duration period, desiccants would be used.

At a pre-determined time, the vehicle will be removed from the storage area. Those life limited components will be replaced and an inspection will be made. After initialization of the vehicle as defined in Section 3.3.1.4.3, it will be ready for the pre-launch and launch phases defined in Section 3.3.1.5 and 3.3.1.6 respectively.

3.3.1.17 Management Approach - In a program of this size where there is a great deal of commonality, the role of integrator is indeed a most important task. This role in the ground operations area carries the same importance since one of the main goals is to have a low cost operation. There are many key tasks that the integrator must implement over and above the facility activation responsibilities noted in section 3.3.1.13.2. One of the most important is to eliminate redundancies in requirements and activities. This in itself would greatly reduce the formal documentation. The integrator must also establish and control the master schedule to assist him in minimizing redundancies. The key is to establish good communications between contractors and the government agency and provide an

LONG TERM VEHICLE STORAGE		
SUBSYSTEM		STORAGE CONFIGURATION
PROPULSION TANKAGE	MAIN	PURGE WITH DRY GN_2, INSTALL DESSICANTS IN VENT LINES, PERIODICALLY INSPECT
	SECONDARY	PURGE WITH DRY GN_2, INSTALL DESSICANTS IN VENT LINES, PERIODICALLY INSPECT
	JP-4	DRAIN, PURGE WITH DRY GN_2
PROPULSION ENGINES	MAIN	INSTALL COVERS, PLUGS, ETC., PURGE WITH DRY GN_2, INSTALL DESSICANTS
	ACPS	INSTALL COVERS, PLUGS, ETC., PURGE WITH DRY GN_2, INSTALL DESSICANTS
	ABES	CIRCULATE SLUSHING OIL, INSTALL COVERS INSTALL DESSICANTS
	APU	INSTALL COVERS ON VENTS, PURGE WITH DRY GN_2, INSTALL DESSICANTS
PNEUMATICS	(HELIUM)	PARTIALLY PRESSURIZE
ENVIRONMENTAL CONTROL AND LIFE SUPPORT	RECIRCULATING COOLANT SYS.	NO ACTION IDENTIFIED (SYSTEMS SERVICED AS FOR FLIGHT)
	DRINKING WATER	REMOVE TANK (NORMAL TURNAROUND FUNCTION) DRAIN, STERILIZE, PURGE WITH DRY GN_2
	PRODUCT WATER	REMOVE TANK, DRAIN, STERILIZE, PURGE WITH GN_2
	WASTE MANAGEMENT	REMOVE CERTAIN FUNCTIONAL COMPONENTS, SANITIZE AND DRY (ORBITER ONLY)
	FOOD MGMT	REMOVE (ORBITER ONLY)
	GAS SUPPLY	PARTIALLY PRESSURIZE
HYDRAULICS		NO ACTION IDENTIFIED (SYSTEMS SERVICED AS FOR FLIGHT)
FUEL CELLS		PAD WITH GN_2
AVIONICS		NO ACTION IDENTIFIED
LANDING GEAR		DEFLATE SHOCK STRUTS, PERIODICALLY CHECK TIRE PRESSURE

FIGURE 3.3-59

efficient means of resolving differences.

There are two integrator approaches that are being considered and should be evaluated to determine the most efficient and cost effective. In the first concept, the integration responsibility is retained by the government. One significant advantage is that there is a direct communications line between the contractors and the government office. This provides an unbiased management overview in resolving incompatibilities in the shortest time and most efficient manner. In order to make this approach workable, the government agency at the operations site must have contractual jurisdiction over all contractors involved in the Shuttle operational program. He also must have the experienced personnel who will be capable of handling this integration role. The second approach is to have the government agency contractually assign the integration task to one of the prime vehicle contractors. In this approach the integrator functions as a staff organization supplementing the government agency. In this approach, the integrator can not give contractual direction to the participating contractors, but functions as the ground operations program planner and identifies contractual or other incompatibilities.

Another integration approach is whereby a prime contractor is the integrator. This approach would only be workable if all other Shuttle contractors at the site would be subcontractors to the integration contractor.

3.3.1.18 Launch Site Contractor Manpower – The headcount or man years identified in this section represents the estimated contractor manpower required to support activities during ground operations. The activities covered begin after vertical development flight testing when the Space Shuttle Vehicles are considered operational. Ground operations includes all contractor activities associated with turnaround of the Space Shuttle Vehicles from post landing through launch (Ref. Paragraph 3.3.1.4). It also includes the services required for payload handling, data handling and management, technical support and sustaining engineering at the contractor's plant, and the necessary manpower to support operation of the flight crew training simulators (one Booster and one Orbiter) located at the launch site. Manpower associated with the base support and technical support (normally not a contractor responsibility) has not been included.

The data in this section is based on the following reference traffic model:

REFERENCE TRAFFIC MODEL

Year(s) Into Program	Launch Rate
1	10*
2	15
3	20
4	30
5	40
6	50
7	60
8	70
9	75
10	75

* The first year includes 5 development and 5 operational flights.

The following is a list of ground rules and/or assumptions that were utilized in estimating the contractor manpower requirements:

A. A two Shift, 5 work day week is used except for the final activities prior to launch (24 hours).

B. Orbiter/Booster dedicated ground crews are minimized. Ground crews will be utilized interchangeably on both vehicles as required.

C. Initial manpower loading for ground operations assumes one vehicle in flow. The ground operations manpower increases as the annual launch rate increases to accommodate more than one vehicle in flow.

D. Main engine recurring manpower requirements are not included.

E. Cruise engine recurring manpower requirements are included along with all other vehicle components.

F. Vehicle operational launches and landings will be conducted from one launch site (Kennedy Space Center).

G. The first 5 operational launches occur during the last 6 months of the first year.

H. NASA Management manpower is not included.

I. Program Integration manpower is not included.

J. Manpower for payload checkout and control are not included.

Initial manpower estimates for the first 2 1/2 years of the operational program utilized the fact that only one Shuttle Vehicle is "in flow" at any time. Direct contractor manpower to support one vehicle during post landing, maintenance, pre-launch, and launch was estimated at the subsystem level along with the necessary support personnel. This one vehicle "in flow" manpower estimate serves as the basis for all ground and maintenance operations manpower estimates. This manpower estimate is shown in Figure 3.3-60.

An analysis was made to determine the total ground operations manpower requirements. The one vehicle "in flow" manpower estimate, reference traffic model, turnaround cycle activities (as defined in Section 3.3.1.4), and facility/GSE baseline requirements were utilized for this analysis. The results of this analysis identified the total contractor manpower requirements for the 10 year

LAUNCH SITE GROUND OPERATIONS MANPOWER
(ONE SHUTTLE VEHICLE IN FLOW)

FUNCTION	MAN-POWER HEAD COUNT	
SYSTEM ENGINEERING	156	(INCLUDES AVE & GSE SUPPORT)
OPERATION ENGINEERING	54	(INCLUDES SAFETY, DOCUMENTATION, WEIGHTS, FACILITY AND MECH AGE SUPPORT, SCHEDULING)
MANUFACTURING AND TEST SUPPORT	186	(INCLUDES PLANNING AND LOGISTICS SUPPORT)
QUALITY ASSURANCE & RELIABILITY	38	(INCLUDES QUALITY ASSURANCE RECORDS AND RELIABILITY ENGINEERING)
TECHNICAL INTEGRATION	22	
ADMINISTRATION	50	(INCLUDES CLERICAL SUPPORT)
SUBTOTAL	506 MEN	
PAYLOAD HANDLING	72	
DATA HANDLING & MANAGEMENT	21	
GSE MAINTENANCE	19	
TECHNICAL SUPPORT AND SUSTAINING ENG	35	
TRAINING (FLIGHT CREW/SIMULATOR)	15	
TOTAL	668 MEN △1.	

△1. ONE BOOSTER AND ONE ORBITER IN FLOW AT LAUNCH SITE
2. TWO SHIFT OPERATION
3. NO PROGRAM INTEGRATION EFFORT INCLUDED
4. PERSONNEL ARE UTILIZED ON BOTH VEHICLES.

FIGURE 3.3-60

program. See Figure 3.3-61. A plot of personnel requirements per year vs. launch rate is shown in Figure 3.3-62. Also shown in this Figure is a dotted line that represents an estimated contractor headcount in support of vertical development flight testing.

CONTRACTOR MANPOWER REQUIREMENTS

YEAR	1	2	3	4	5	6	7	8	9	10
MAINTENANCE, PRELAUNCH AND LAUNCH	506	506	506	637	767	896	1048	1198	1273	1273
PAYLOAD HANDLING	72	72	72	96	120	144	173	202	216	216
DATA HANDLING AND MANAGEMENT	21	21	21	28	35	42	51	59	63	63
GSE MAINTENANCE	19	19	19	26	32	38	46	54	57	57
TECHNICAL SUPPORT AND SUSTAINING ENG	60	50	30	30	30	30	30	30	30	30
TRAINING (FLIGHT CREW/ SIMULATOR)	15	15	15	20	25	30	30	30	30	30
TOTAL	346.5	683	663	837	1009	1180	1378	1573	1669	1669

TOTAL (10 YEAR PROGRAM) – 11007.5 MAN YEARS

FIGURE 3.3-61

CONTRACTOR MANPOWER REQUIREMENTS

Personnel Per Year vs Launch Rate

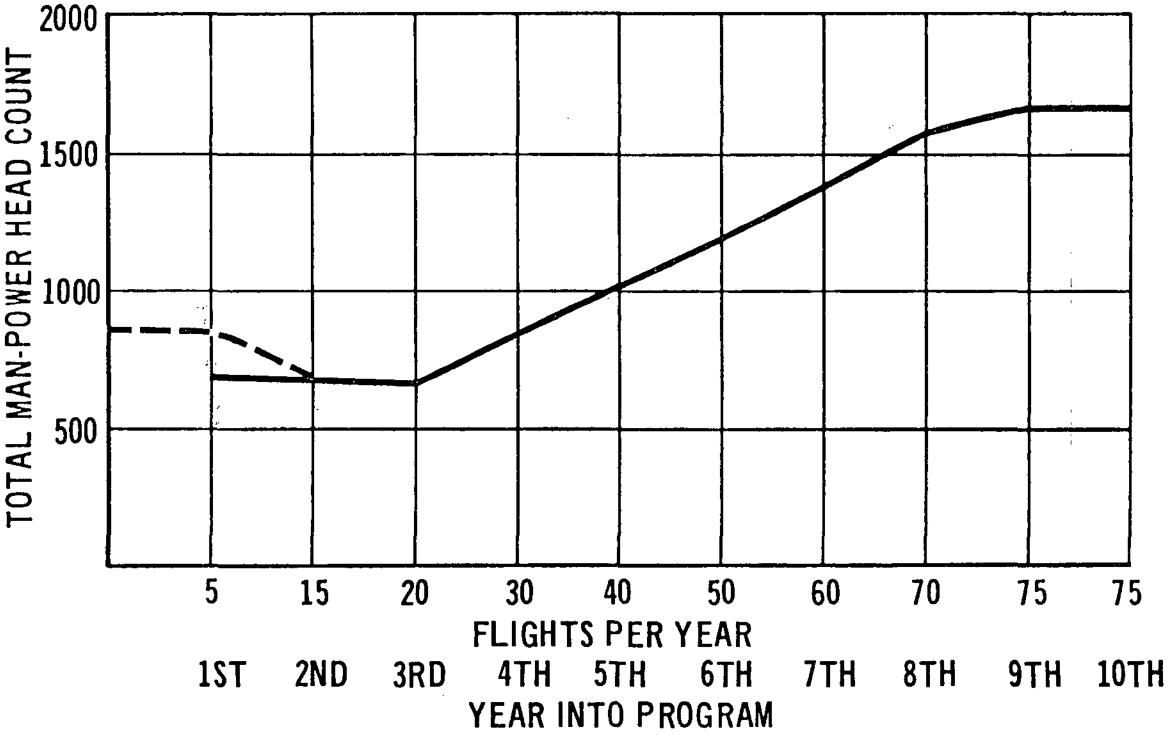


FIGURE 3.3-62

3.3.2 Flight Operations Approach - The following sections describe the current approach to Shuttle flight operations by describing the missions anticipated, the baseline mission operations system, the way in which each of the major functions will be performed, and the estimated training and mission simulator requirements. Separate sections are provided on landing and abort operations because of the unique nature of these operations and their resulting impact on vehicle design.

3.3.2.1 Mission Descriptions - The Shuttle will progress from horizontal takeoff flight test missions to vertical flight test flights and then to a wide variety of orbital missions. While no attempt will be made to describe all these types of missions, the following sections will present the current thinking on flight test missions and describe the design and reference missions.

3.3.2.1.1 Forecasted Flight Schedule - The Space Shuttle Program will consist of a Horizontal Flight Test Program followed by Vertical Development flights. The operational flights will commence with limited payload flights and then transition to full payload missions.

Figure 3.3-63 presents the preliminary schedule.

3.3.2.1.2 Horizontal Flight Test Operations - The flight test program is fully described in the Test Plan. The following is a summary of the horizontal flight program.

The horizontal flight activities will commence with taxi test and "shake-down" flights at the manufacturing facility (KSC) to verify flight performance needed for ferry flight to Edwards Air Force Base (EAFB). EAFB has been designated as the primary horizontal test site due to the excellent existing airplane flight test facilities, flying weather, and existing long runway (15,000 feet) and emergency landing facilities (Rogers Dry Lake plus other usable dry lakes in the vicinity).

SPACE SHUTTLE FLIGHT SCHEDULE

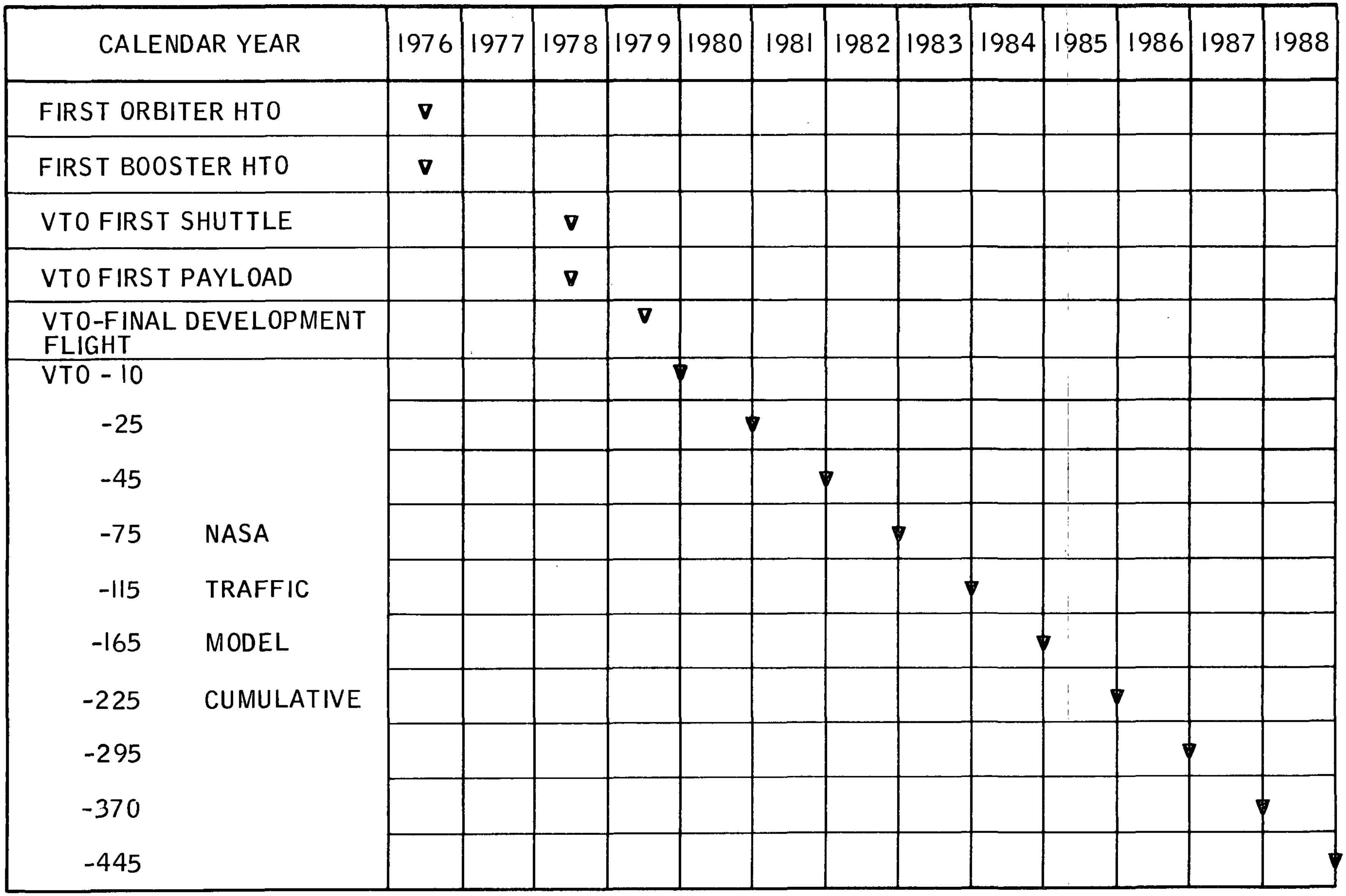


FIGURE 3.3-63

The preliminary evaluation begun at KSC will be quickly completed at EAFB, verifying that the vehicles have no major deficiencies in basic airplane mode flying characteristics, or identifying any unexpected deficiencies which may exist and require unscheduled development. The horizontal flight program will evaluate and verify specification performance for the cruiseback (Booster), landing and ferry mission phases. Vehicle characteristics to be verified will include: Longitudinal, lateral and directional stability and control; trimability; flap and landing gear transients; stall and buffet speeds and characteristics; handling qualities for unusual flight conditions or attitudes; airbreathing engine or flight control malfunction effects; cruise performance; approach and landing characteristics and performance; horizontal take-off characteristics and performance. The pressure airspeed system will be calibrated. The performance of the various vehicle subsystems - Airframe (structures, landing and recovery); Propulsion (airbreathing engines (ABES), including airstarts and APU); Avionics (flight control system, data management, communications, controls and displays, and software); ECLS; Power Supplies - will be verified for the flight regimes which are attainable in horizontal take-off flight. Figure 3.3-64 summarizes the flight hour distribution for this program.

A development flight instrumentation system consisting of sensors, signal conditioners, data buses, onboard tape recorders and telemetry transmitters will be installed. This system will utilize the operational data system's designs for sensors, signal conditioning, and data bus computers and other equipment whenever applicable. Some operational data bus signals shall be recorded on the flight test system. Real time data display and monitoring for mission control and flight safety purposes during the horizontal test flights will be similar to current airplane flight test practices. The primary function of the monitoring is the veri-

Horizontal Flight Test Program

	Horizontal Flight Hours	
	Booster	Orbiter
Vehicle Characteristics	156	130
Airframe Group	30	30
Propulsion Group	53	46
Avionics Group	169	166
ECLS Group	8	8
Power Supply Group	2	2
Miscellaneous and Ferry	20	20
TOTAL	438	402
Total Test Hours at KSC	163	134
Total Test Hours at EAFB	258	251
Total Ferry Test Hours	17	17
TOTAL	438	402

FIGURE 3.3-64

fication of the adequacy of test conditions and an overall vehicle safety monitoring. The data processing and analysis subsystems will provide for the real time display and monitoring, and the reduction and presentation of engineering first look data for immediate decision and final report data. Data will be obtained from sensors onboard via RF telemetry and from onboard tape recordings. Vehicle position data will be obtained by ground radar tracking. The level of effort will be small, compared to manned space flight procedures, and existing facilities at KSC and EAFB, suitably modified, will be utilized.

Preliminary data in engineering units from telemetry and onboard records shall be available at major engineering sites, for decision making purposes, within 24 hours of landing. Existing government data processing, reduction, and computation facilities at Edwards Air Force Base and the major NASA engineering/ management centers will be utilized.

3.3.2.1.3 First Vertical Flight - A mission profile has been defined for the first vertical flight. This mission was designed to allow fulfillment of all test objectives while operating in a mode such that less than nominal flight conditions exist where nominal conditions could degrade the probability of mission success. The mission profile is, of course, preliminary.

3.3.2.1.3.1 Desired Characteristics of the First Vertical Test Flight - The desired characteristics of the first test flight include:

A. Low vehicle ascent maximum dynamic pressure
B. Decreased vehicle ascent longitudinal acceleration
C. Low Booster entry heating and loads
D. Low vehicle separation dynamic pressure
E. Downrange Booster landing to lower entry heating and loads
F. Low Orbiter entry heating and loads.

In addition, high Manned Space Flight Network (MSFN) coverage is desired for the first revolution to provide a state vector update should a first revolution return be required. Near maximum MSFN coverage is also desired for the remainder of the mission to allow transmitting test data to the ground and to provide adequate ground monitoring of the flight. Another desired characteristic is frequent return opportunities to the continental United States, preferably to the launch site.

3.3.2.1.3.2 Required Tests - Probably the most valuable data which will be obtained on the first test flight are basic aerothermo/performance/structural/ main propulsion data for the various flight regimes. These data will be obtained as a result of performing the altered mission phases and require no special test sequences during the mission. Testing of the various systems will require special test sequences. Those tests which have been identified to date are described below:

A. Propulsion

- Fire the ACPS engines individually for five seconds each. These burns provide a check on the thrust and flow rate dispersions for these jets. (Orbiter only.).
- Fire ACPS engines for acceleration (rotational and translational) in all axes. These burns will test the ACPS engines capability to fire in groups and will test all modes of the digital autopilots. (Orbiter only.).
- Fire the OMS engines individually for a series of five second burns. These burns provide a check on the dispersions of the OMS thrust and flow rate and check the restart capability.
- Check the propellant utilization system. This test will require that sufficient OMS/APCS propellant be expended to check the operation of

the propellant utilization system.

- Test the gas generation duty cycle. Sufficiently long burns of the OMS/APCS system will be required to make the gas generator cycle on and off.

B. Navigation

- Test the star trackers with stars. These tests will be designed to check the ability of the trackers to lock on the proper star and to provide satisfactory performance.
- Test the horizon sensors. These tests will check the ability of the sensors to track the horizon and will allow a performance evaluation.
- Evaluate star tracker-horizon sensor navigation. Perform star tracker-horizon sensor navigation for the required time to compare with MSFN tracking state vector estimates.
- Determine platform drift rates. Perform IMU alignments at sufficient intervals to determine the inertial platform drift rates.
- Perform relative ranging equipment checks to determine the maximum operational range. This will be achieved with a ground based transponder.
- Test the optical tracker with ground light beacons or orbiting vehicles if available. This test will evaluate the ability of the optical tracker to track rendezvous targets.
- Perform S-Band ranging check. The object of this test is to verify S-Band ranging antenna lock-on and switching.

C. Communications

- Verify uplink and downlink capability. Ground will record signal to noise ratio and perform bit error rate evaluation.
- Verify attitudes that block out communications. While transmitting,

rotate through attitudes that block out communications to determine if the desired coverage is obtainable.

D. Environmental Control and Life Support

- Verify radiator operations limits. While the maximum demands are being made on the radiator, rotate to the most unfavorable attitude for the radiator and hold until the temperature has stabilized.
- Verify cabin thermal and humidity limits. Place vehicle in most unfavorable attitude with minimum electrical load for cabin lower temperature limit (probably pointed to deep space). Hold until temperature stabilizes (two orbits). Place vehicle in most unfavorable attitude for cabin upper temperature limit (probably pointed toward the sun). Hold until temperature stabilizes (four orbits).

E. On-Orbit Thermodynamics

- Perform a thermodynamic demonstration test. Orbiter is too large for demonstration testing in present chambers and new facilities cost would be prohibitive. Therefore, the thermal demonstration test will be performed on-orbit. This will require as long as three days hold in a specified orientation to allow valid tests to be conducted.

3.3.2.1.3.3 Trajectory Profile - The following parameters were used to achieve as many of the desired characteristics (see Section 3.3.2.1.3.1) as possible for the first mated ascent and descent test flight.

- Thrust throttling magnitude and duration
- Ascent trajectory shaping and Booster targeting
- Launch azimuth
- Entry trajectory shaping and deorbit burn targeting

Figures 3.3-65, 3.3-66, and 3.3-67 show the flight parameters of the ascent trajectory which fulfills most of the desired characteristics for the first mated

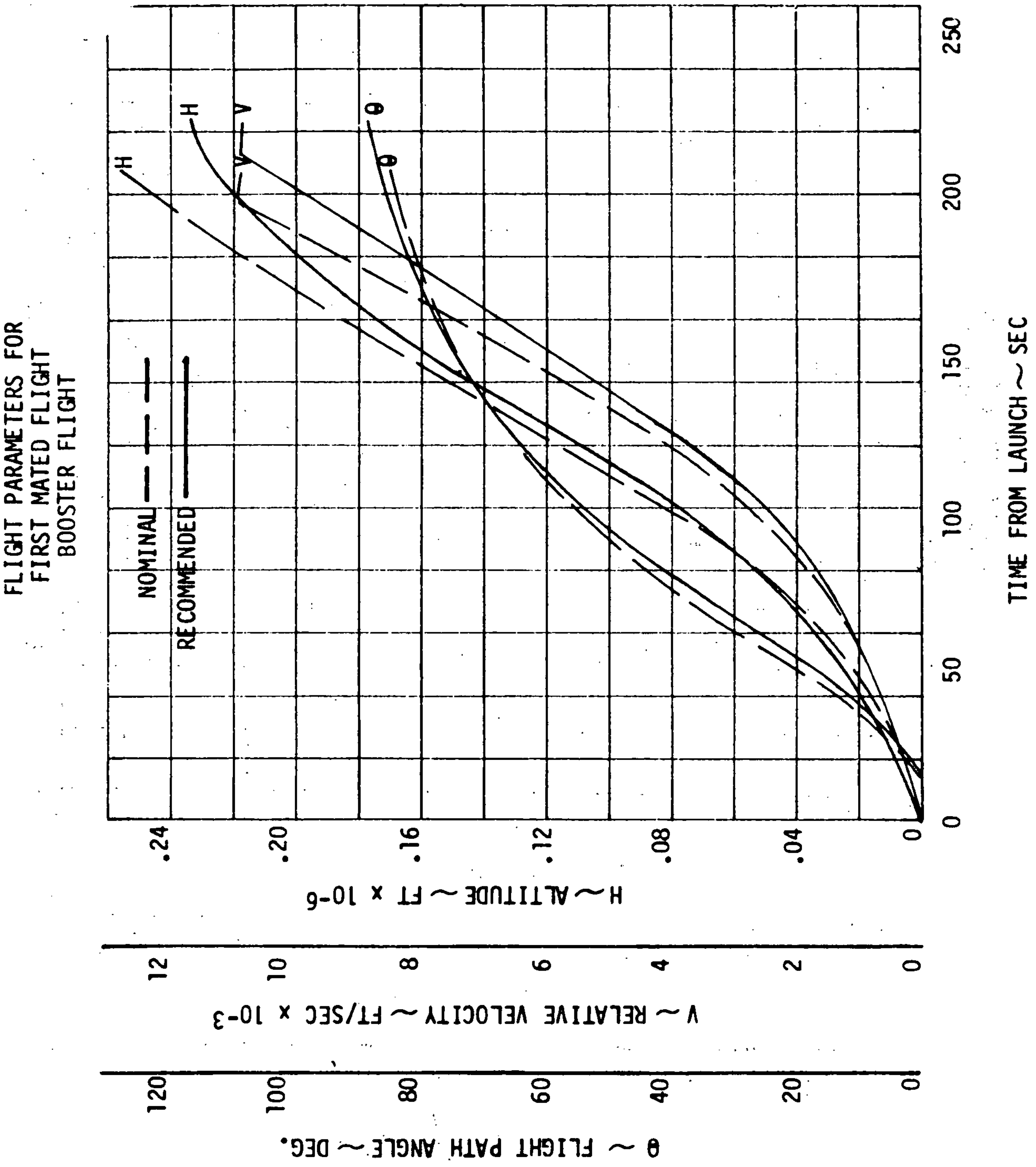

FLIGHT PARAMETERS FOR
FIRST MATED FLIGHT
BOOSTER FLIGHT
NOMINAL
RECOMMENDED
H
H
V
V
θ
θ
TIME FROM LAUNCH ~ SEC
0
50
100
150
200
250
H ~ ALTITUDE ~ FT x 10-6
0
.04
.08
.12
.16
.20
.24
V ~ RELATIVE VELOCITY ~ FT/SEC x 10-3
0
2
4
6
8
10
12
θ ~ FLIGHT PATH ANGLE ~ DEG.
0
20
40
60
80
100
120

FIGURE 3.3-65

FLIGHT PARAMETERS FOR
FIRST MATED FLIGHT
BOOSTER FLIGHT (CONT)

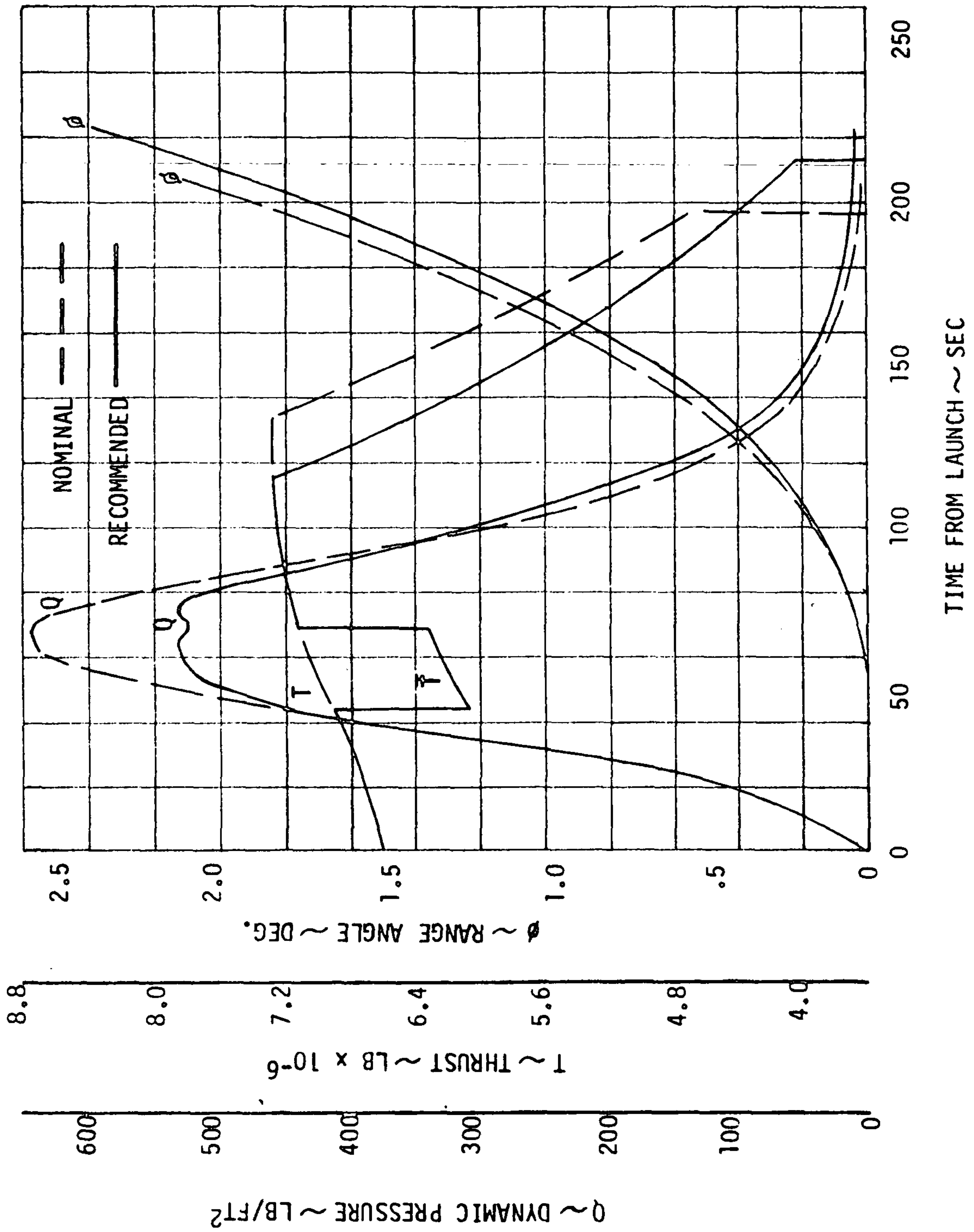
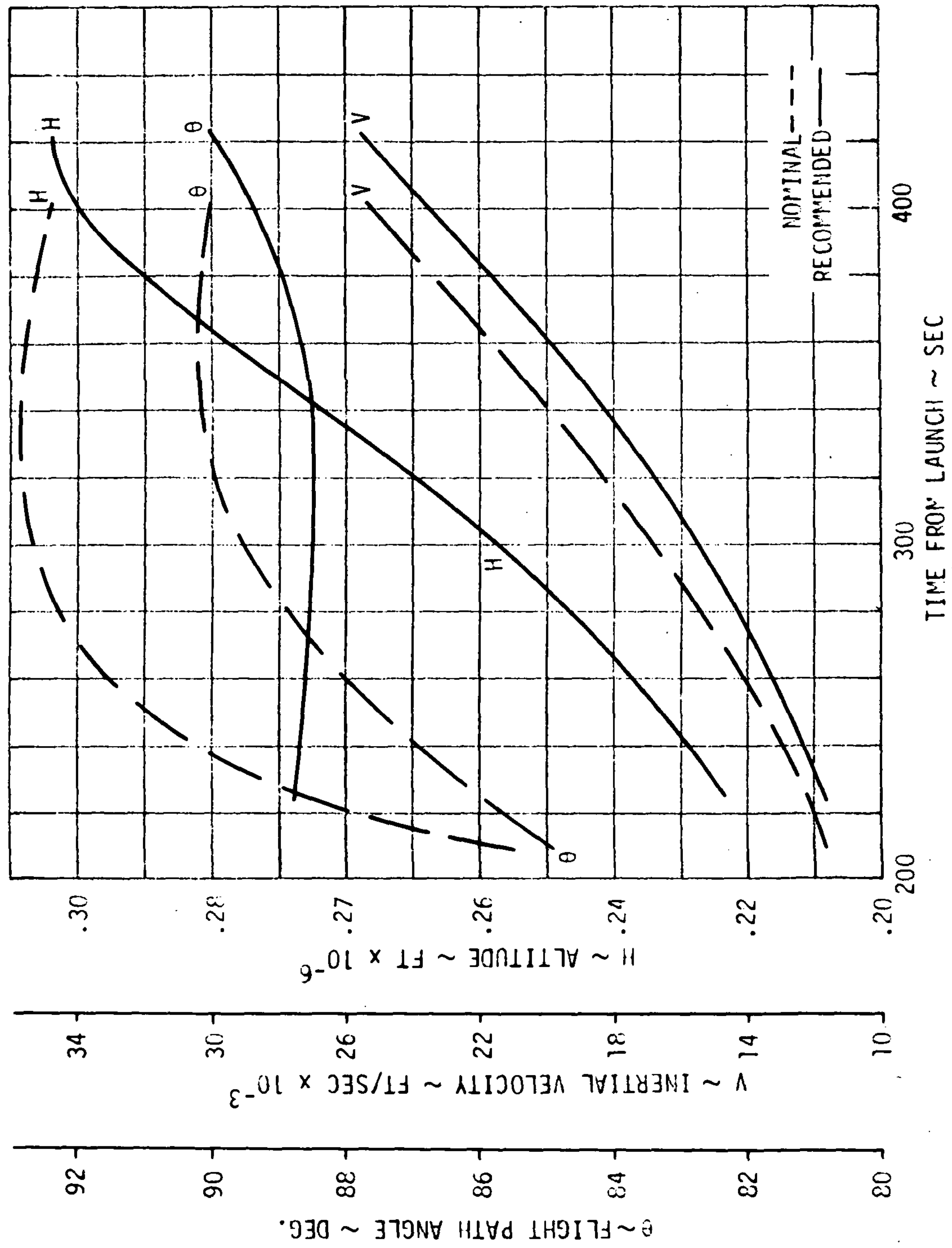


FIGURE 3.3-66



FLIGHT PARAMETERS FOR
FIRST MATED FLIGHT
ORBITER FLIGHT

FIGURE 3.3-67

test flight. This trajectory results in the following deviations from nominal:

- Ascent maximum dynamic pressure is reduced by 20%
- Ascent longitudinal acceleration is reduced by 15%
- Separation dynamic pressure increases from 5 psf to 10 psf
- Booster entry temperature is decreased by 5.5%
- Booster entry loads are reduced by 30%

Three candidate orbits were considered for the mission. Two of these (48° and 34.3° inclination) were selected for consideration primarily because they allow downrange Booster landing which in turn allows a softer Booster entry. The 29.5° inclination was selected for consideration because it allows Orbiter return to the launch site at the end of the first revolution with low crossrange and also uses the earth rotation to maximum advantage in reducing the severity of Orbiter entry conditions.

Figure 3.3-68 compares the three candidate orbits in terms of several parameters of interest. The payload data includes the effect of flying the ascent trajectory described above.

By selecting the 48° inclined orbit and off loading 75,000 lbs of flyback propellants, the Booster entry temperature is further reduced by 2.8% and the Booster entry loads by 3.5%. This orbit also provides good first rev MSFN tracking and very good tracking for the first seven orbits.

Accordingly, the 48° inclination, 100 nm orbit has been tentatively selected for the first vertical mission. The altitude was selected to provide a lifetime of about eight days consistent with the philosophy of an open ended mission. Figures 3.3-69 and 3.3-70 show the ground tracks for the mission.

With respect to Orbiter entry, the primary concern is the demonstration of a safe entry rather than maximum acquisition of aerodynamic and testing data. For this reason, the entry trajectory has been tailored to provide the most benign

COMPARISON OF CANDIDATE ORBITS FOR FIRST VERTICAL MISSION

	INCLINATION		
	48.0°	29.5°	34.3°
Launch azimuth	50°	89°	110°
First rev tracking	BDA (1 min) MAD (2 min)	BDA (2 min) CYI (1 min)	ANG (2 min) ACN (3 min) CRO (3 min)
Payload	+ 5,500 lbs	-10,000 lbs	-2,500 lbs
from reference	25,000 lbs	43,000 lbs*	43,000 lbs*
First day tracking	BEST	GOOD	GOOD
Booster flyback	200 nm	450 nm	200 nm
to	Seymour Johnson AFB	KSC	GBM
Orbiter one rev	TEX	TEX	TEX
return opportunities	N.C.	KSC	

* Reference payload based on ABES in configuration for due East launch.

FIGURE 3.3-68

GROUND TRACK FOR FIRST VERTICAL MATED FLIGHT

LAUNCH DAY

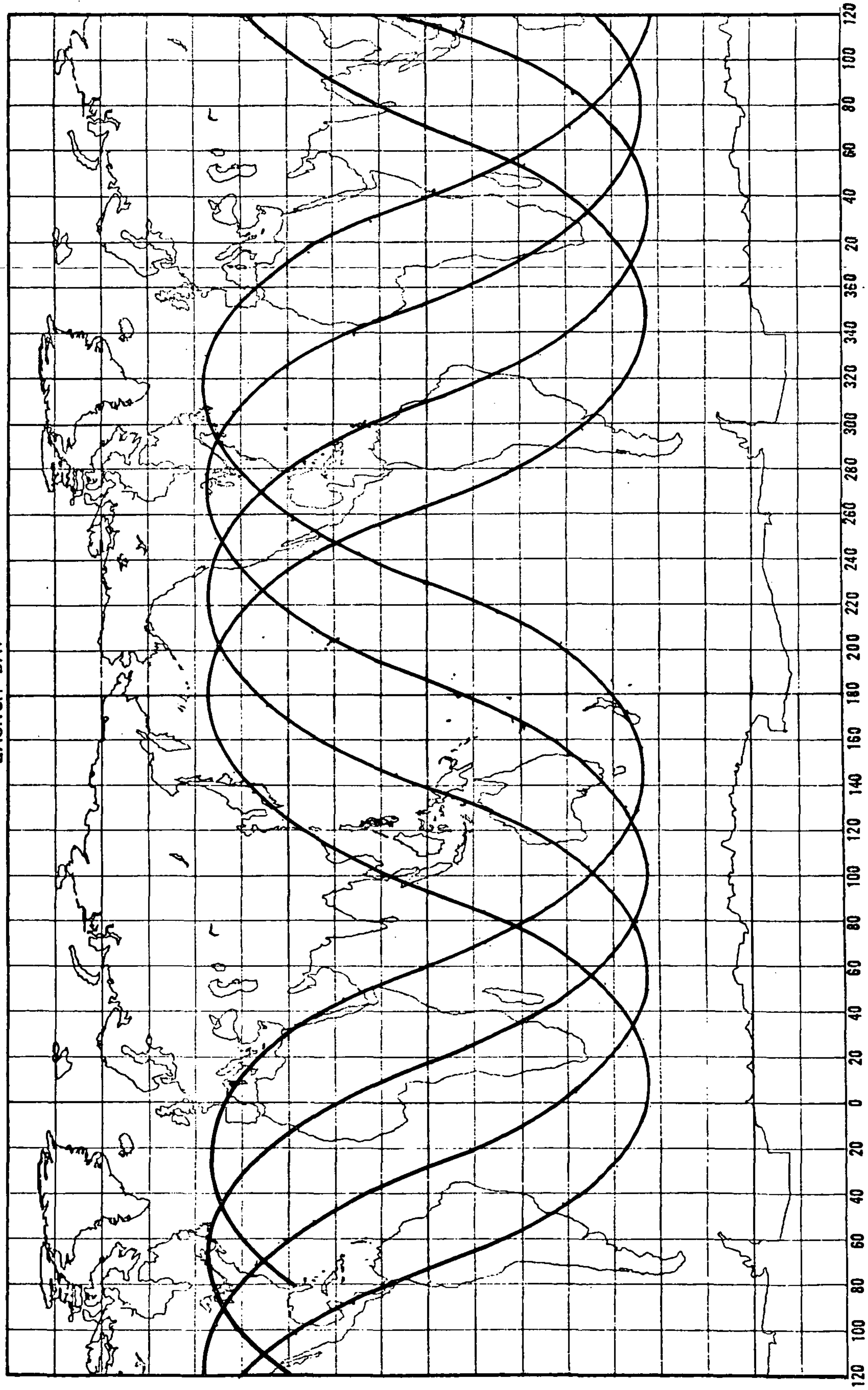
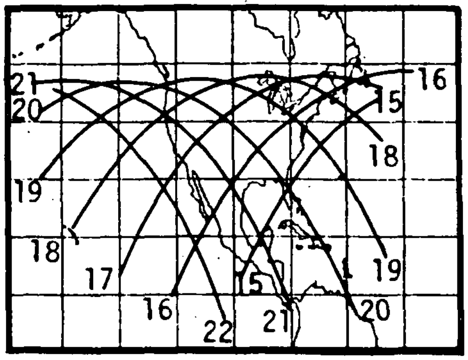
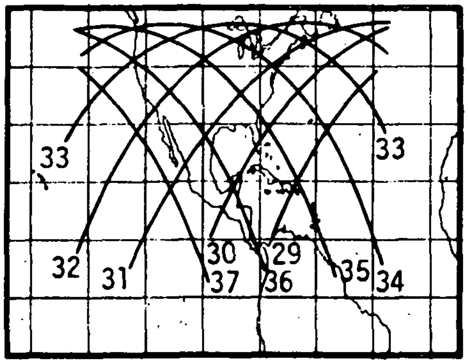


FIGURE 3.3-69

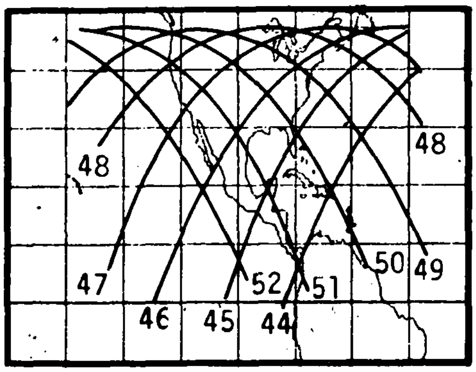
GROUND TRACKS NEAR THE U. S. FOR THE FIRST VERTICAL TEST FLIGHT



DAYS 1, 4 and 7



DAYS 2, 5 and 8



DAYS 3 and 6

FIGURE 3.3-70

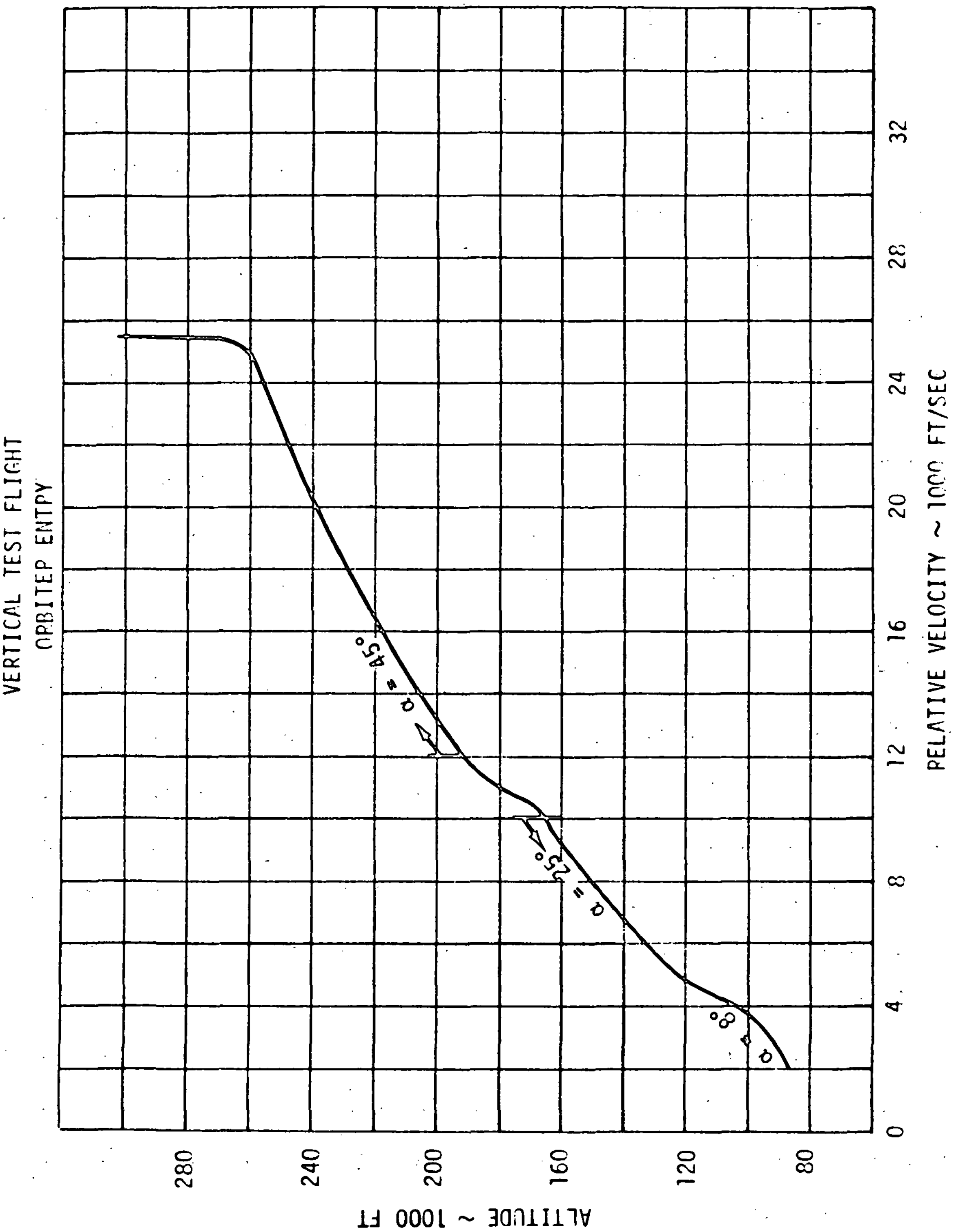
thermal environment with minimum maneuvering requirements. This is accomplished through the following approaches:

- High angle of attack during the high heating range
- Constant angle of attack through high heating range
- Lower orbit inclination than the design polar mission
- Return time and landing site selected to minimize crossrange requirement.
- Lower than nominal entry time due to use of higher angle of attack.

Entry will be from a 100 nm circular orbit, requiring a retro $\triangle V$ of 250 ft/s. A constant 45 degree bank is held during pullout. After achieving a zero flight path angle, bank angle is increased to prevent skip, then gradually decreased to near zero. After decelerating to about M=12, a gradual transition to an angle of attack of 25 degrees is made to acquire aerodynamic data. Further transition to an angle of 8 degrees is made at a Mach number of about 4. This provides an attitude near maximum L/D for maneuvering to the landing site. A velocity-altitude history of this trajectory is shown in Figure 3.3-71.

3.3.2.1.3.4 Landing - The Booster vehicle will land downrange so that flyback JP fuel quantity may be reduced while allowing safe Booster flyback to a landing site with some cruise engine anomalies. Seymour Johnson AFB, North Carolina, has been selected as the downrange site requiring a minimum of additional facilities. During cruiseback to the landing site, the vehicle will perform control aerodynamic maneuvers and other checks to verify control system integrity prior to landing. The Booster will undergo postlanding safing and inspection, and will then be pre-flighted for an airbreathing ferry flight and flown back to the launch site.

The Orbiter entry time and landing site will be determined by mission constraints and system operational status. The baseline plan envisages a VFR weather landing, at the launch site (KSC), with minimum cross range maneuvering.



VERTICAL TEST FLIGHT
ORBITER ENTRY

FIGURE 3.3-71

An additional quantity of JP fuel will be installed in the payload bay to provide an aerodynamic flight capability to correct for errors in the vehicle's entry guidance and navigation performance.

Additional operations explanations are contained in Section 3.3.2.4.

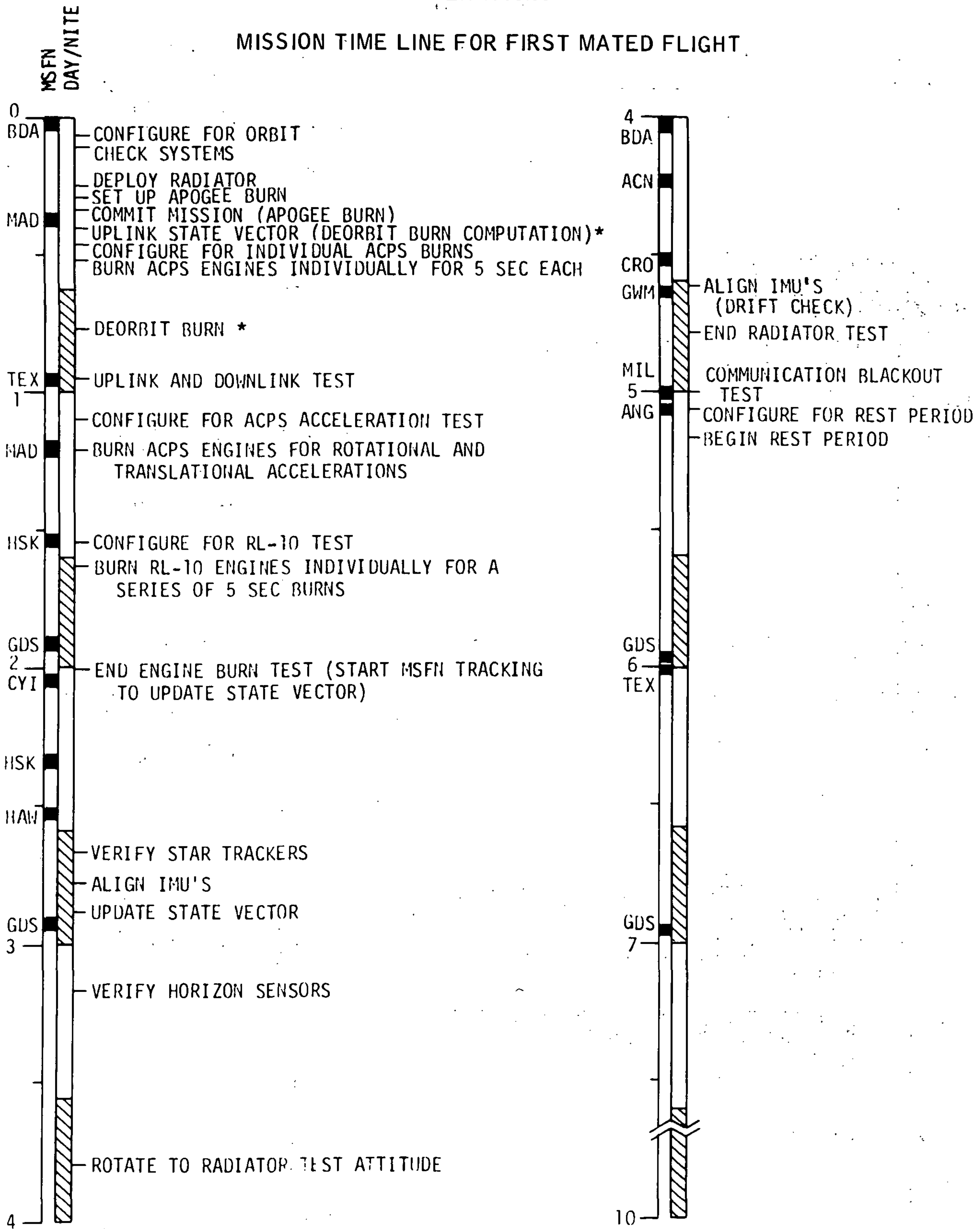
3.3.2.1.3.5 Event Timeline - Figure 3.3-72 presents a timeline for the events of the first vertical test flight beginning at insertion and ending at landing. The column at the left indicates orbit number and shows the MSFN coverage. Cross hatched areas indicates darkness periods. As mentioned earlier, the mission will be open ended with possible return at several points. Nominal return is scheduled on day six or seven when near zero crossrange is required. No tests are scheduled during the rest periods with the exception of the test to verify the on-orbit thermal system. This test will take three days of predetermined orientation. The tests shown in the timeline for the first two work periods should be completed before the thermal demonstration test is begun. Only the beginning of this test is shown in the timeline. Most of the tests performed in the first two work cycles will be performed again after the thermal demonstration test to determine degradation of the system. The timeline for these tests will be almost identical to the first two work cycles and therefore, are not shown.

3.3.2.1.4 Early Development/Operational Missions - This section presents mission descriptions for the first 10 Shuttle payload carrying missions (Figures 3.3-73 and 3.3-74). These missions were taken from NASA MSC-02542, Vol. 3, and are assumed to follow the first vertical mated test flight. As the flight test studies progress, the flight test facets of these missions will be detailed. The first four payload carrying (Missions 2-5) missions are Shuttle development flights designed to verify the crew and Shuttle capability to:

A. Operate in a space environment

OPERATIONS

MISSION TIME LINE FOR FIRST MATED FLIGHT



*ONE REV RETURN

FIGURE 3.3-72

OPERATIONS

MISSION TIME LINE FOR FIRST MATED FLIGHT (CONTINUED)

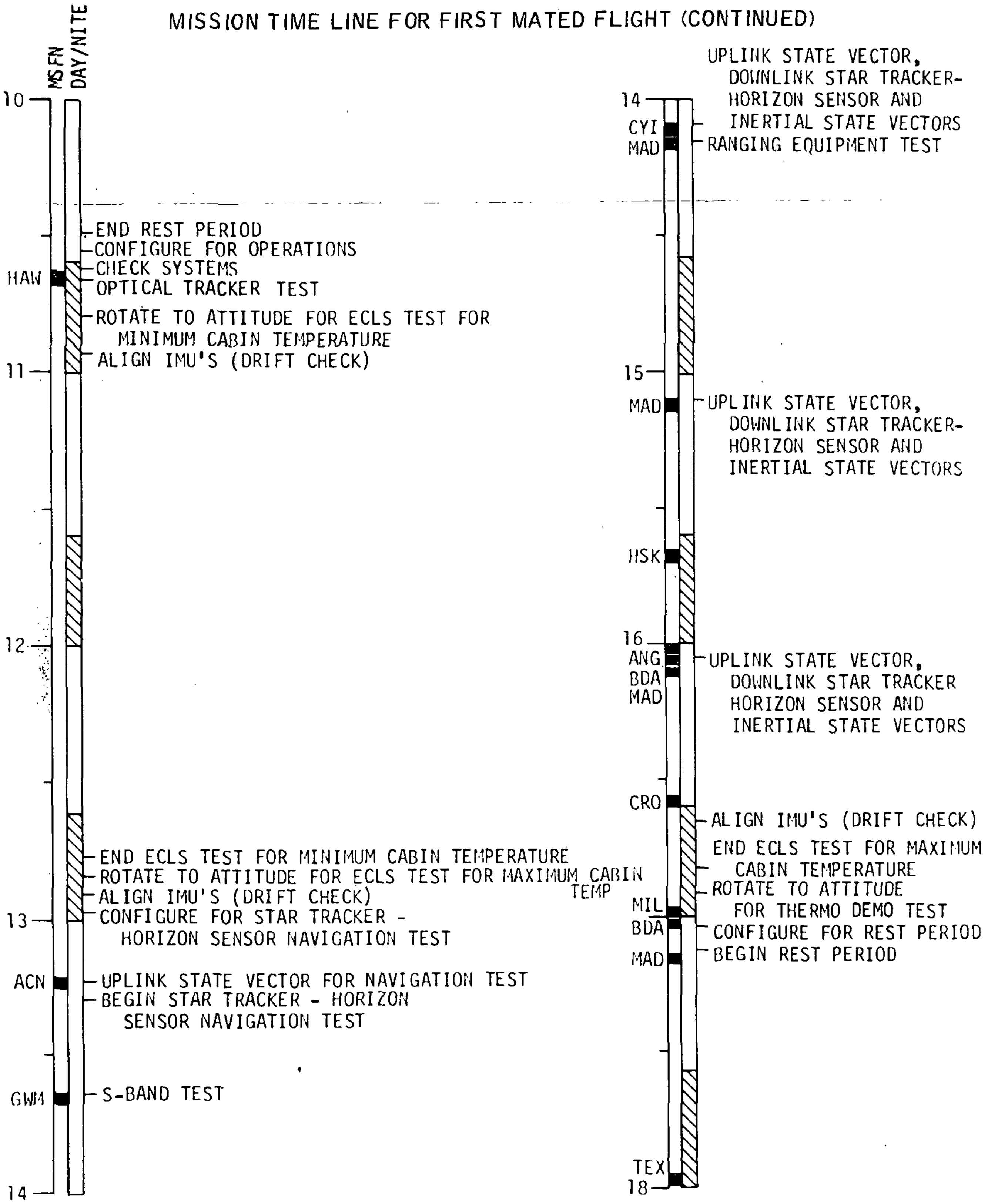


FIGURE 3.3-72 (CONT'D)

MISSION DESCRIPTIONS FOR MISSIONS 2 THROUGH 11

MISSION	MISSION DURATION DAYS	MISSION OBJECTIVES	ORBITER ORBITAL PARAMETERS		P/L FINAL ORBITAL PARAMETERS	
			INCLINATION Deg	APOGEE/PERIGEE nm	INCLINATION Deg	APOGEE/PERIGEE nm
2	5	Practice procedures for checkout, deployment, retrieval, and docking telefactor	29	256/256	N/A	N/A
		Deploy a passive meteoroid and exposure module	29	256/256	29	256/256
		Test advanced EVA equipment	29	256/256	N/A	N/A
		Test a contamination monitoring device	29	256/256	N/A	N/A
3	6	Deployment of three satellites: SATS-F, SATS-G, SESP-1001	29	245/245	29	245/245
		Verification of the Shuttle rendezvous technique (Retrieval of the meteoroid & exposure module)	29	257/254	N/A	N/A
		Improvement of the EVA and telefactor operation	29	245/245 257/254	N/A	N/A
4	7	Deployment of three satellites: SAS-E, EPS-C, SATS-H	50	199/196	50	199/196
		Rendezvous with SKYLAB A (Orbital Workshop)	50	208/207	N/A	N/A
5	4	Final Shuttle development flight Rendezvous and recovery of the non-cooperative satellite OAO-1	35	420/420	N/A	N/A
6	4	Deploy satellites: HEAO, SESP-1000	28.5	256/256	28.5	256/256

FIGURE 3.3-73

MISSION DESCRIPTIONS FOR MISSIONS 2 THROUGH 11

MISSION	MISSION DURATION DAYS	MISSION OBJECTIVES	ORBITER ORBITAL PARAMETERS		P/L FINAL ORBITAL PARAMETERS	
			INCLINATION Deg	APOGEE/PERIGEE nm	INCLINATION Deg	APOGEE/PERIGEE nm
7	4	Development of on-orbit satellite staging techniques; further Shuttle development Deployment of two geosynchronous satellites (ATS-H, earth resources satellite)	28.5	132/132	0	19322/19322
8	7	Support the deployment of an Orbit-to-Orbit Shuttle (OOS) carrying a Department of Defense (DoD) payload Secondary objectives are continued Shuttle development and improvement of on-orbit staging techniques	28.5	115/115	Undefined	Undefined
9	5	Same as Mission 8	30	125/125	Undefined	Undefined
10	7	Help develop Shuttle sortie capability and to demonstrate the capability to support non-astronaut passengers Secondary goals are to checkout the manned support module and the capability to support various scientific experiments	90	118/118		
11	3	Deploy an international cosmic ray module (or some other appropriate experiment module)	28.5	200/200	28.5	200/200

FIGURE 3.3-74

B. Deploy and retrieve satellites

C. Support extravehicular activity

D. Conduct rendezvous operations of varying complexity

These missions have very ambitious secondary objectives including complex payload operations and extravehicular activity. As the flight test aspects of the missions are defined, it may turn out that achievement of the secondary objectives is not compatible with maximizing the flight test results. In this case, these secondary objectives will be reduced in scope or eliminated. The next five (Missions 6-10), although not primarily Shuttle development flights, have secondary Shuttle development objectives. These missions are designed to:

A. Develop and improve on-orbit satellite staging techniques to permit geosynchronous missions.

B. Develop a Shuttle sortie capability

C. Verify the Shuttle capability to accommodate nonastronaut passengers.

The eleventh Shuttle mission, the first fully operational flight, is a mission to launch a cosmic ray module for use by the international scientific community.

Certain aspects of these missions may be modified as a result of changes in the vehicle since NASA MSC-02542, Vol. 3 was published. For example, the missions are based on a low crossrange Orbiter. Therefore, altitudes were chosen to reduce return phasing requirements on certain missions and return phasing maneuvers were utilized on others. While it is desirable to minimize crossrange requirements at first, flight test objectives will require increased use of crossrange on the subsequent missions.

3.3.2.1.5 Design Mission - The Space Shuttle design mission consists of delivering and retrieving payloads in a 100 nm circular orbit with an inclination of 28.5 degrees, remaining in orbit up to 7 days, and returning to the launch site. The Orbiter has the capability to deploy a payload (PL) and, if required, retrieve it. Some missions may consist only of retrieving or servicing a previously launched payload. The Orbiter can also carry an Orbit-to-Orbit Shuttle (OOS) for boosting payloads into orbits requiring a greater expenditure of energy than that afforded by the Shuttle. Because it includes most of the more interesting aspects - OOS/PL deploy, orbit maintenance, rendezvous, OOS/PL retrieval and "dead-stick" landing - the mission described here is the deployment of an OOS/PL bound for geosynchronous orbit, waiting in orbit, and then retrieving and returning with the spent OOS.

An event timeline with normal and contingency functions for the Orbiter is shown in Figure 3.3-75. Mission profiles are shown as altitude - time histories in Figure 3.3-76, and attitude - time histories in Figure 3.3-77.

The Shuttle is launched from KSC into a 50 x 100 nm, 28.5 degree inclination orbit. After main engine shutdown, residual propellants are dumped and the velocity is trimmed with the ACPS. The Orbiter is then maneuvered to a local horizontal attitude and held in the orbital rate mode. Optics hatches are opened and orbit navigation commenced. A crewman then checks the OOS. Approximately one-half rev after insertion, the orbit is circularized at 100 nm. The $\triangle V$ for this maneuver is obtained by firing one RL-10 for 59 seconds for a $\triangle V$ of 91 ft/s. Orbital rate is again established. About an hour after launch, first contact with the ground is established through the Hawaii Tracking Station. The OOS is again checked and the Orbiter maneuvered to the OOS/PL separation attitude (Orbiter back end forward). The OOS/PL is then extended, separated, and activated with the Orbiter station keeping at a safe distance. Visual and data link checks of the OOS/PL are performed after extension and again after activation. A spacing burn (10 ft/s radially down) is performed and 13 min. later, the OOS engines are ignited, transfering it to the mission orbit. One-half rev after the first spac-

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
Prelaunch	o Start APU o Initialize Powered Flight Navigation o Initialize Launch Control System Monitor o Initialize Timing Functions o Launch Configuration Checklist o Transfer from External to Internal Power		
0	LIFT OFF o Perform System Monitoring o Monitor Launch Phase Guidance o Perform Powered Flight Navigation o Perform Abort Monitor		
:03:17	Stage o Booster Engine Cut-off o Altitude = 238,740 ft (39.29 NM) o ΔV = 15,247 fps o Separation o Orbiter Engine Ignition o Continue Powered Flight Navigation o Monitor Insertion Phase Guidance o Monitor Systems Status		
:06:41	Orbiter Shutdown o Burn Time = 3.23 min. o ΔV - TBD o Orbit = 50 x 100 NM o Initiate Inertial Hold o Continue Powered Flight Navigation		
:08	Begin Dumping Residual Main Propellant		
:09:40	Complete Dump of Main Propellant		
:10	Commence Velocity Residual Trim		
:12	Trim Complete		
:12	Terminate Powered Flight Navigation		

FIGURE 3.3-75

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
:12	Maneuver to Orbiter +X on Local Horizontal Attitude (0,0,0)		
:13	Maneuver Complete o Initiate Orb Rate o Open Optics Hatch o Initiate Orbit Navigation o Post Insertion Checklist o Initiate Automatic IRU alignments		
:13	Open P/L Bay Door and Deploy ECS Radiator		
:14	Radiator Deployed		
:14	Shutdown APU		
:14	One Crew man to Docking Station		
:16	Check Restrained OOS		
:18	OOS Check Completed	:18	OOS NO-GO o Possibly Safe OOS o Possibly Deorbit and Re-enter at Early Opportunity
:19	Crew man to Cockpit from Docking Station		
:21	System Status Checks		
:23	Check Complete		
:25	IRU Align		
:30	IRU Align Complete		
:48	Trim Attitude for Circularization Burn (Burn in Orb Rate)		
:49	Initiate Powered Flight Navigation o System Preburn Checklist		
:49:42	Commence Circularization Burn o +X Orbiter Thrust o 91 FPS Total o Terminate Powered Flight Navigation after Burn o Orbit = 100 x 100 NM		
:50:12	Impulsive Circularization Burn Time		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
:50:41	Burn Complete		
:52	Trim Orb Rate		
1:03	Establish Voice/Data Link with Ground		
1:05	System Status Checks		
1:07	Check Complete		
1:07	IRU Align		
1:12	IRU Align Complete		
1:12	One Crew man to Docking Station		
1:14	Check Restrained OOS		
1:16	Check Completed	1:16	OOS NO-GO (See :18)
1:16	Maneuver to Separation Attitude (BEF)		
1:19	Maneuver Complete o Maintain Orb Rate		
1:19	Release OOS Tie Downs		
1:21	Extend OOS (Rotate OOS 90°)		
1:24	OOS Extended		
1:24	Rigidize Docking Mechanism		
1:26	Docking Mechanism Rigidized		
1:26	Check Extended OOS o Visual o Data Link		
1:28	Extended OOS Check Complete	1:28	OOS NO-GO
1:28	Deploy Command Antenna	1:28	Possibly Safe OOS
1:29	Test Antenna Gimbal and RF	1:30	Stow OOS
1:30	Antenna Deployed	1:30	Relax Docking Mechanism

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
1:30	IRU Align	1:31	Rotate OOS 90°
1:34	IRU Align Complete	1:33	Secure OOS Tie Downs o Perform "On Orbit Functions" (See 3:50) Once Each 90 Minutes o Skip to 162:16 or Possibly Deorbit and Re-enter at Early Opportunity
1:34	Separate OOS Commence Station Keeping at Safe Distance		
1:36	OOS Activation eg o OOS Orientation o OOS Attitude Hold o OOS Deploy Antenna, Etc.		
1:36	Check Separated OOS o Visual o Data Link		
1:39	Check Completed	1:39	OOS NO-GO
1:39	Initiate Powered Flight Navigation o System Preburn Checklist	1:39	Command OOS Make Ready
		1:41	Verify OOS Make Ready Successful If not Successful o Possibly Space from OOS and Destroy OOS
1:40	OOS-Orbiter Spacing Burn o 10 fps Radial Down o 10 sec Burn Time o +Z Orbiter Thrust o Terminate Powered Flight Navigation o Monitor OOS and P/L during spacing	1:41	Visual Inspection of OOS
		1:43	Engage and Latch Docking Ring
1:42	Relax Docking Mechanism	1:43	Safe OOS
1:43	Stow Docking Mechanism	1:45	Verify OOS Safe
1:53	OOS Ignition and Transfer to Mission Orbit	1:46	Stow OOS
		1:46	Relax Docking Mechanism
1:55	Maneuver to SEF o Establish Orb Rate	1:47	Rotate OOS 90°
2:13	System Status Check	1:49	Secure OOS Tie Downs Perform "On Orbit Functions" (See 3:50) Once Each 90 Minutes
2:15	Checks Complete		
2:15	IRU Align		SKIP to 162:16 or Possibly Deorbit and Re-enter at Early Opportunity
2:20	IRU Align Complete		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
2:24	Initiate Powered Flight Navigation o System Preburn Checklist		
2:25	Terminate Spacing Burn o 10 fps Radial Up o ≈10 Sec Burn Time o Terminate Powered Flight Navigation after Burn o Burn ΔV in Components		
3:50	Perform "On Orbit Functions" (Once Each 90 Minutes Except during "Sleep" mode) +0:00 System Status Checks +0:02 Checks Complete +0:02 IRU Align +0:07 IRU Align Complete +0.07 Trim Orb Rate		
09:00	Go to "Sleep" mode once each day +0:00 Begin "Sleep" Mode (Typical) +9:00 End "Sleep" Mode (Typical)		
24:00	Perform Orbit Maintenance Burns Once per Day +0:00 Target Orbit Maintenance Burns o Initial Orbit 98.5 NM Circular o First Burn raises Apogee to 101 NM o Second Burn One-Half Orbit Later Circularizes Orbit at 101 NM +0:05 System Preburn Checklist +0:07 Checklist Complete +0:08 Trim Attitude for Orbit Maintenance Burn No. 1 o Burn in Orb Rate o Initiate Powered Flight Navigation +0:10 Commence Orbit Maintenance Burn No. 1 o +X Orbiter Thrust o ΔV ≈ 4.5 fps o ≈12 Sec. Burn Time o Orbit = 101 x 98.5 NM o Terminate Powered Flight Navigation after Burn		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
	+0:11 Trim Orb Rate		
	+0:45 Target Orbit Maintenance Burn No. 2 o Update Targeting to Account for Burn No. 1 Parameters		
	+0:49 System Preburn Checklist		
	+0:51 Checklist Complete		
	+0:52 Trim Attitude for Orbit Maintenance Burn No. 2 o Burn in Orb Rate o Initiate Powered Flight Navigation		
	+0:55 Commence Orbit Maintenance Burn No. 2 o +X Orbiter Thrust o ΔV ≈ 4.5 fps o ≈12 Sec.Burn Time o Orbit = 101 x 101 NM o Terminate Powered Flight Navigation after Burn		
	+0:56 Trim Orb Rate		
147:58	OOS Burn into Circular Orbit for Rendezvous		
148:00	Maneuver to Track Attitude o Pitch Down 15°		
148:02	Initiate Rendezvous Navigation		
148:31	System Status Check		
148:33	Checks Complete		
148:33	IRU Align		
148:38	IRU Align Complete		
148:38	Target TPI Burn o wt = 130° o Continue to Retarget Burn Until Rendezvous Navigation Terminated		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
148:43	Terminate Rendezvous Navigation		
148:43	Maneuver to TPI Burn Attitude o ≈ +X on Line of Sight to Target o Pitch Up to 27.3°		
148:44	Complete Maneuver		
148:46	Initiate Powered Flight Navigation o System Preburn Checklist		
148:47	Impulsive Time of TPI Burn o +X Orbiter Thrust o ≈ 21 FPS ≈ 13.5 Sec Burn Time o Terminate Powered Flight Navigation after Burn		
148:48	Maneuver to Local Horizontal Attitude o Pitch Down 27.3°		
148:49	Maneuver Complete o Initiate Rendezvous Navigation		
148:54	Target First Midcourse Correction Maneuver		
148:56	Initiate Powered Flight Navigation		
148:57	Impulsive Time of First Midcourse Correction Burn o Nominally Zero ΔV o Burn ΔV in Components o Maintain Local Horizontal Attitude o Terminate Powered Flight Navigation after Burn		
149:04	Target Second Midcourse Correction		
149:06	Initiate Powered Flight Navigation		
149:07	Impulsive Time of Second Midcourse Correction Burn o Nominally Zero ΔV o Burn ΔV in Components o Maintain Local Horizontal Attitude o Terminate Powered Flight Navigation after Burn		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
149:09	One Crew man to Docking Station		
149:11	Maneuver to Braking Attitude o Orbiter +Z on Line of Sight to Target o Pitch Up 30° o Initiate Powered Flight Navigation o Maintain Inertial Attitude		
149:12	Monitor P/L Line of Sight Rates; Null to Zero		
149:12	Command P/L and OOS Make Ready		
149:14	Verify P/L and OOS Make Ready Successful	149:14	P/L and OOS MAKE READY NO-GO o Possibly Complete Rendezvous, Remove Package from P/L, Space Orbiter and P/L, and Destroy P/L and OOS o Possibly Discontinue Rendezvous and Destroy P/L and OOS
149:17	Terminate Rendezvous Navigation		
149:18	Initiate Braking, Null Approach Velocity to Zero		
149:26	Station Keeping o Visual Inspection of P/L and OOS		
149:30	Extend Docking Rig (Rotate Rig 90°)		
149:32	Docking Rig Extended		
149:34	Rigidize Docking Rig		
149:36	Docking Rig Rigidized		
149:40	Approach to Docking Standoff		
149:41	Engage and Latch Docking Ring o Sense Soft Dock o Maneuver to Hard Dock		
149:41	Terminate Powered Flight Navigation		
149:41	Safe P/L and OOS		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
149:42	Verify P/L and OOS Safe	149:42	P/L and OOS NO-GO Possibly Remove Package from P/L, Separate, Space Orbiter from P/L and/or OOS and Destroy P/L and/or OOS
149:43	Stow P/L and OOS		
149:43	Relax Docking Mechanism and Rotate P/L and OOS 90°		
149:47	Maneuver to "X" Axis on Local Horizontal, BEF o Roll 189°, Pitch ≈ 35° o Establish Orb Rate		
150:00	Perform "On Orbit Functions" Once Each 90 Minutes (See 3:50)		
152:00	Begin Sleep Mode		
161:00	End Sleep Mode		
162:13	Start APU		
162:15	Secure Radiator and Close P/L Bay Door		
162:15	Check Aero Control Surface Operation		
162:16	System Status Checks		
162:17	Radiator Secured		
162:18	Checks Complete		
162:18	IRU Align		
162:23	Target Deorbit Burn		
162:28	Trim Deorbit Burn Attitude		
162:29	Initiate Powered Flight Navigation o System Preburn Checklist		
162:30:06	Commence Deorbit Burn o +X Orbiter Thrust o 250 FPS o 2 Min 40 Sec Burn Time		
162:31:26	Impulsive Deorbit Burn		

FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
162:32:46	Deorbit Burn Complete o Terminate Powered Flight Navigation		
162:33	Maneuver to Entry Attitude o Establish Orb Rate		
162:36	Maneuver Complete		
162:36	Commence Entry Preps		
162:36	Begin IRU Align		
162:33	System Status Checks		
162:40	Checks Complete		
162:41	IRU Align Complete		
162:41	Trim Attitude for Entry o Angle of Attack = 30°		
162:41	Entry Preps Complete		
162:43	Terminate Orbit Navigation o Close Optics Hatches		
162:43	Begin OMS Propellant Dump o Dump through Two Pairs of Opposing YAW Jets		
162:43	Initiate Powered Flight Navigation		
162:44	Entry Interface o Altitude = 400,000 ft.		
162:47	Begin VHF Comm Blackout		
162:52	Begin Pullout		
163:00	Terminate OMS Propellant Dump		
163:09	Switch to Aerodynamic Pitch Control		
163:15	End VHF Comm Blackout		
163:15	Lock on Two VOR Stations o Update IRU		

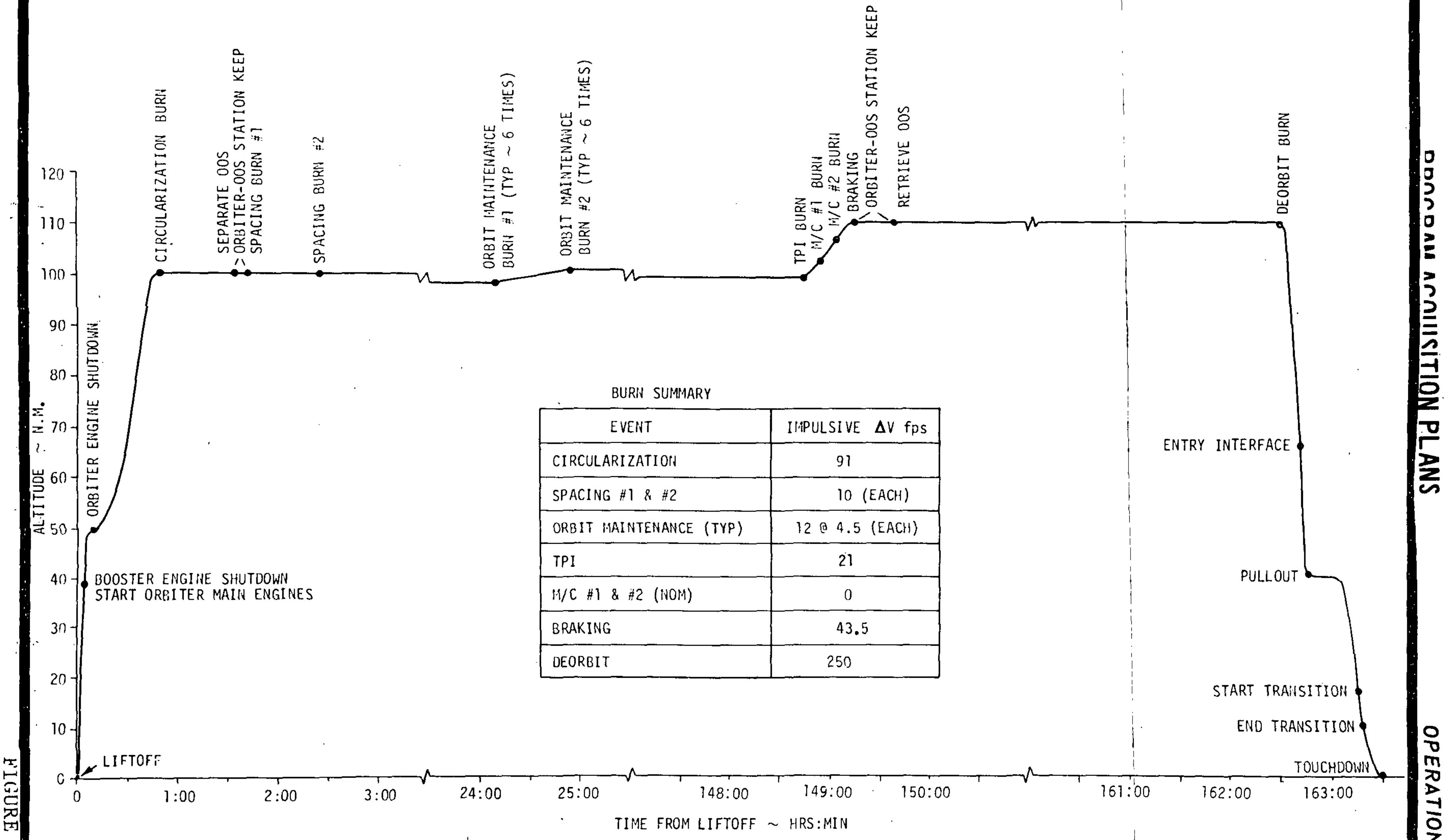
FIGURE 3.3-75 (CONT'D)

EVENT TIME LINE

TIME	FUNCTION	TIME	CONTINGENCY FUNCTION
163:20	Lock on Two DME Stations o Continue Automatic Terminal Area Guidance o Velocity < 3000 fps		
163:21	High Key o Begin Automatic Terminal Area Guidance		
163:22	Initiate Transition Maneuver		
163:23	Switch to Aerodynamic Lateral Control o Deactivate ACS Jets		
163:24	End Transition Maneuver o Continue Descent to Intercept Energy Dissipation Circle o Intercept Energy Dissipation Circle at h = 40,000 ft, M = 1.0		
163:27	Turn Toward Low Key Position o Deploy Half Speed Brakes o Airspeed = 275 KTS		
163:27	Final Pre-Landing Checklist		
163:29:40	Low Key o Altitude = 12,000 ft o Turn to Final Approach Heading		
163:30	Begin Final Approach o Computer Generated Glide Slope = 12° o Lock on Localizer o Modulate Speed Brakes and Angle of Attack as Necessary to Maintain Approach Velocity		
163:31:50	Begin Flare for Landing o Intercept ILS Glide Slope at h = 500 ft. o Lower Landing Gear		
163:32:15	Touchdown o Speed = 180 KTS o Deploy Drag Chute, Full Speed Brakes o Wheel Brakes		
163:35	Shutdown		

FIGURE 3.3-75 (CONT'D)

EASTERLY DESIGN MISSION
MISSION PROFILE



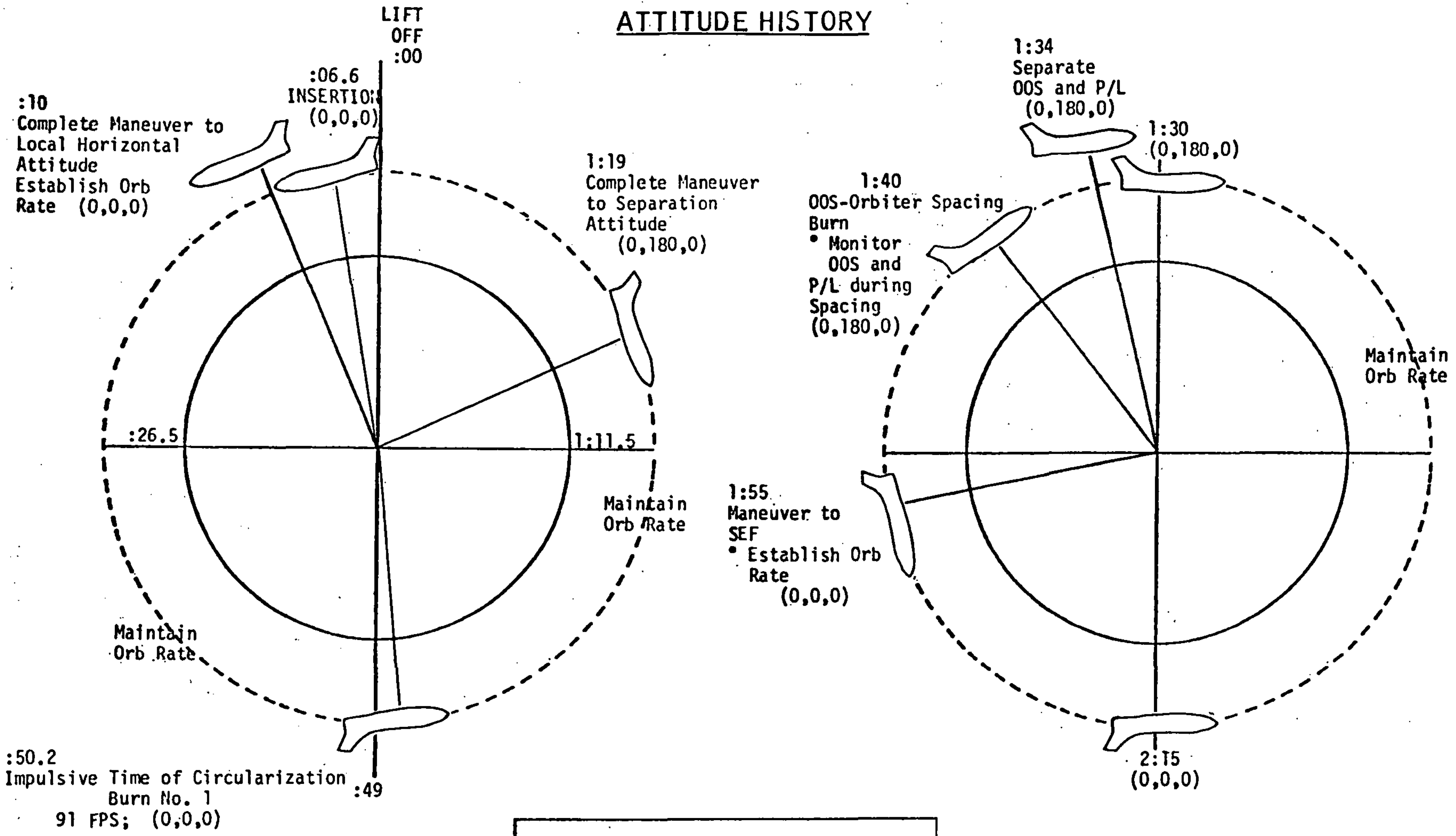
BURN SUMMARY

EVENT	IMPULSIVE ΔV fps
CIRCULARIZATION	91
SPACING #1 & #2	10 (EACH)
ORBIT MAINTENANCE (TYP)	12 @ 4.5 (EACH)
TPI	21
M/C #1 & #2 (NOM)	0
BRAKING	43.5
DEORBIT	250

FIGURE 3.3-76

EASTERLY LAUNCH DESIGN MISSION
OOS-P/L DELIVERY TO GEOSYNCHRONOUS ORBIT

ORBITER
ATTITUDE HISTORY



ATTITUDE KEY

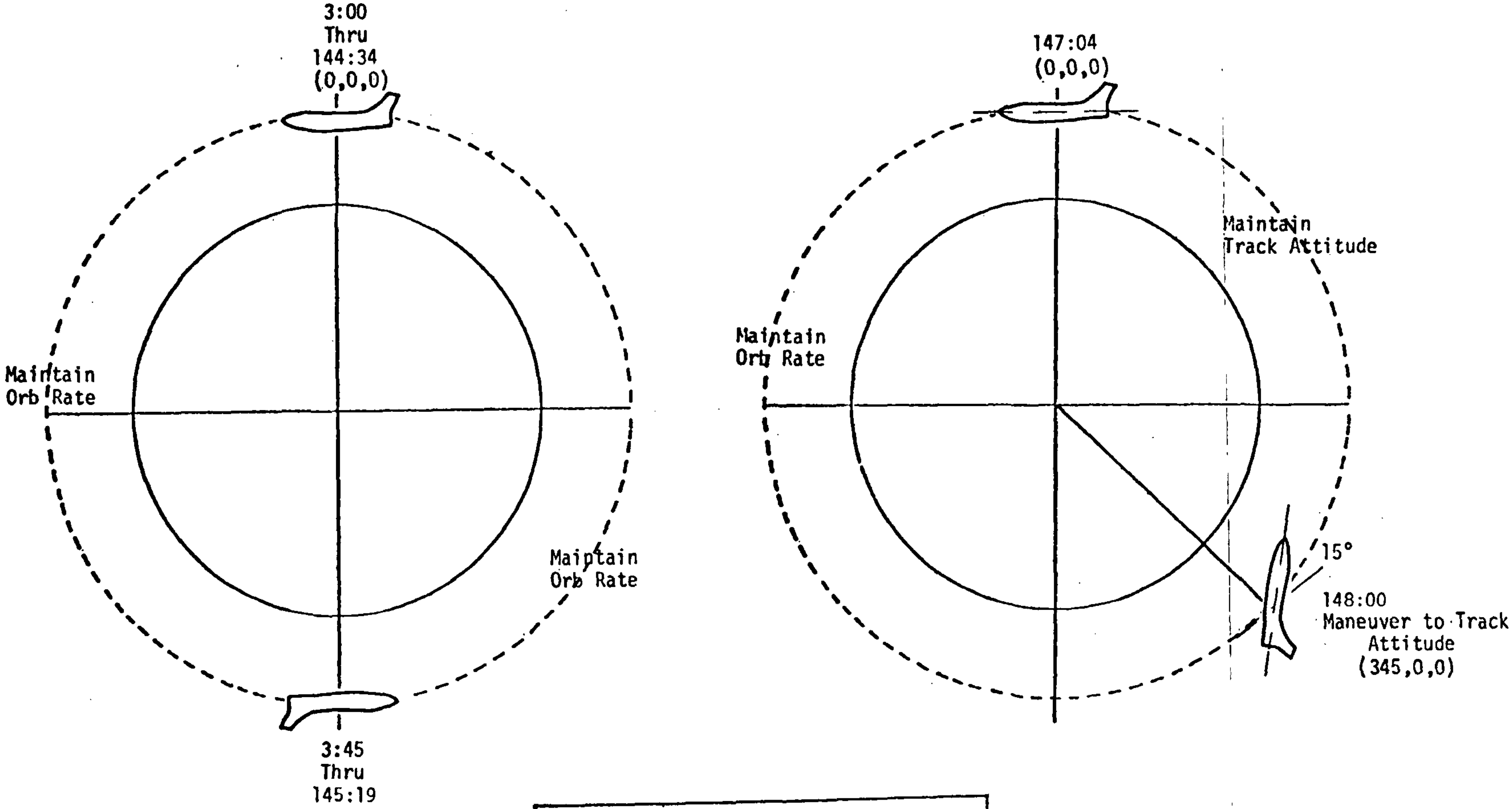
(P,Y,R) REFERENCED TO LOCAL HORIZONTAL

(0,0,0) ATTITUDE IS SMALL END IN DIRECTION OF ORBITAL MOTION (FORWARD), WINGS LEVEL, HEADS UP

SEF ≡ SMALL END FORWARD
BEF ≡ BACK END FORWARD

FIGURE 3.3-77

EASTERLY LAUNCH DESIGN MISSION
GOS-P/L DELIVERY TO GEOSYNCHRONOUS ORBIT
ORBITER
ATTITUDE HISTORY



ATTITUDE KEY

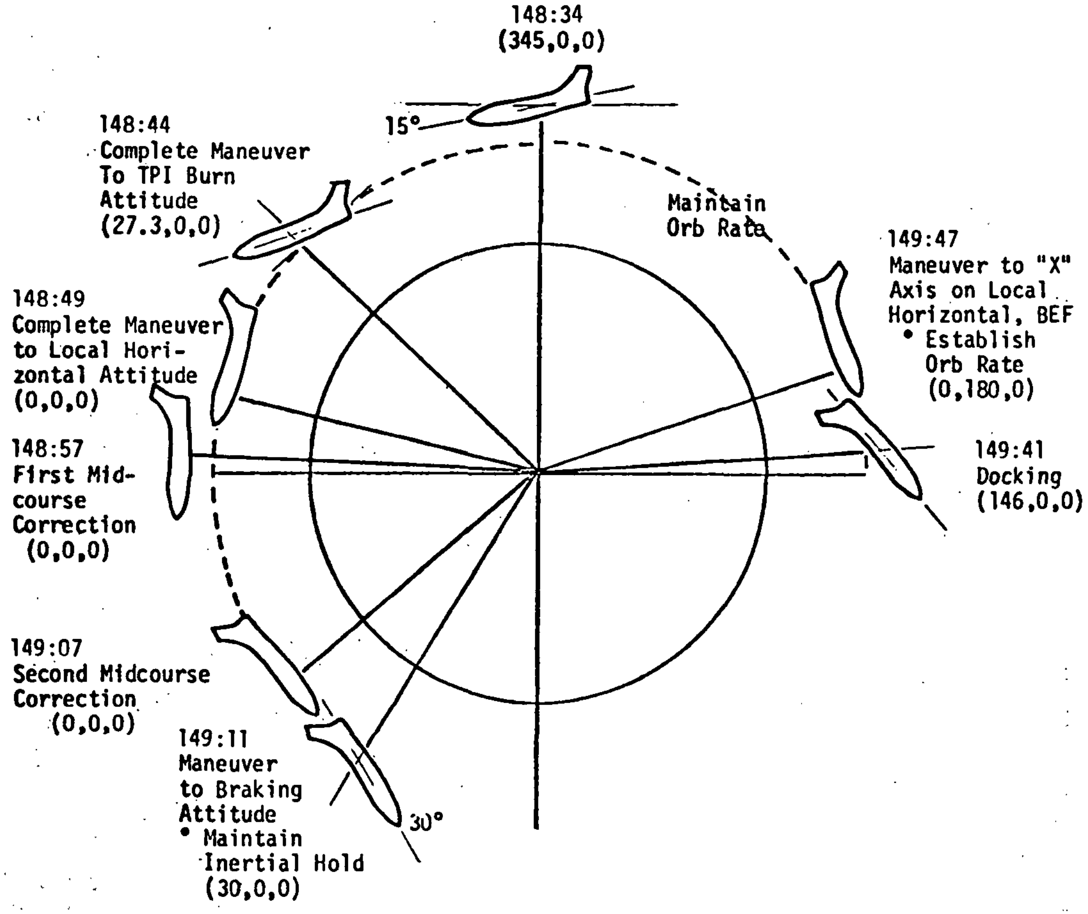
(P,Y,R) REFERENCED TO LOCAL HORIZONTAL

(0,0,0) ATTITUDE IS SMALL END IN DIRECTION OF ORBITAL MOTION (FORWARD), WINGS LEVEL, HEADS UP

SEF ≡ SMALL END FORWARD
BEF ≡ BACK END FORWARD

FIGURE 3.3-77 (CONT'D)

EASTERLY LAUNCH DESIGN MISSION
COS-P/L DELIVERY TO GEOSYNCHRONOUS ORBIT
ORBITER
ATTITUDE HISTORY



ATTITUDE KEY

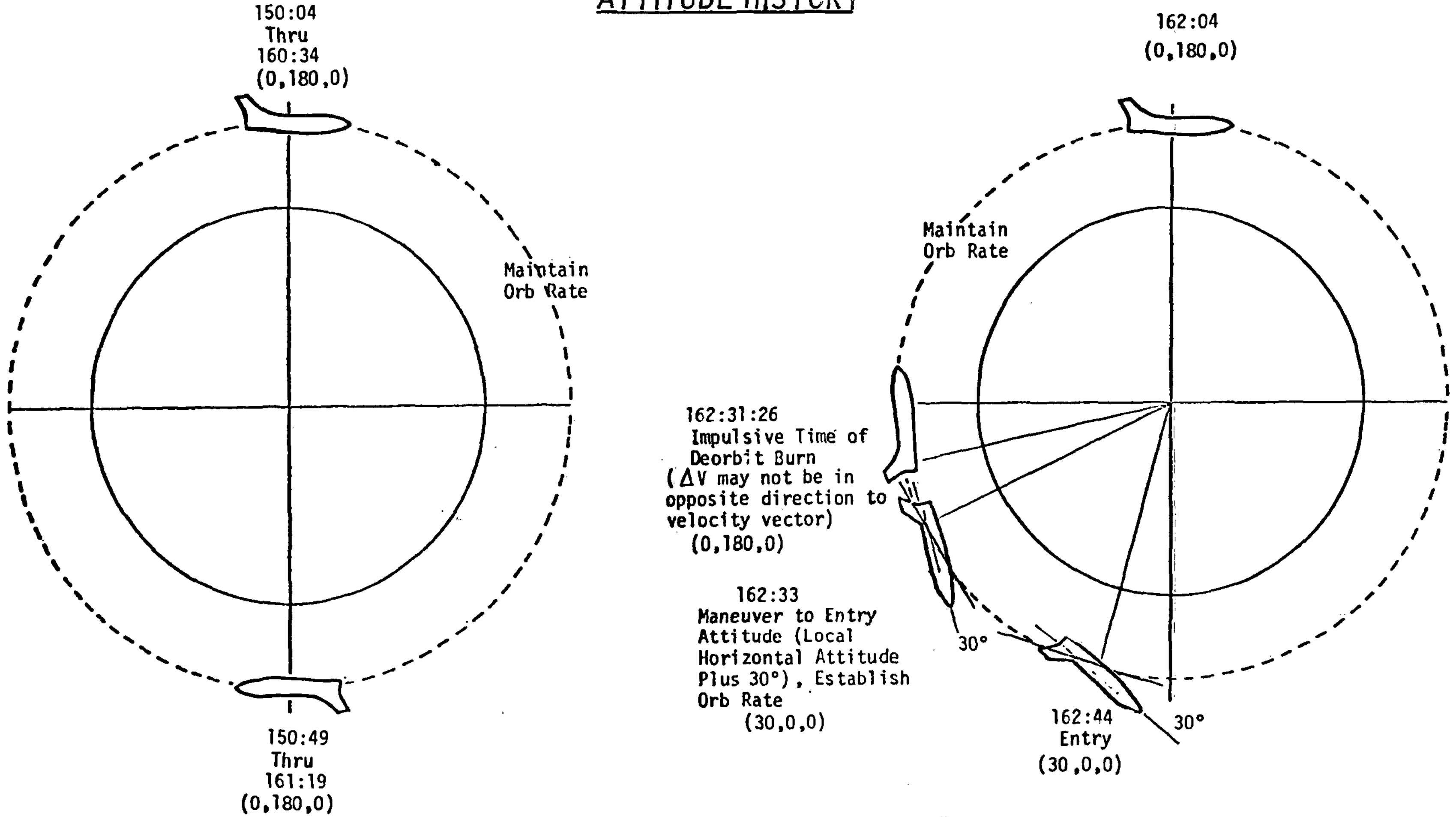
(P,Y,R) REFERENCED TO LOCAL HORIZONTAL

(0,0,0) ATTITUDE IS SMALL END IN DIRECTION OF ORBITAL MOTION (FORWARD), WINGS LEVEL, HEADS UP

SEF ≡ SMALL END FORWARD
BEF ≡ BACK END FORWARD

FIGURE 3.3-77 (CONT'D)

EASTERLY LAUNCH DESIGN MISSION
COS-P/L DELIVERY TO GEOSYNCHRONOUS ORBIT
ORBITER
ATTITUDE HISTORY



ATTITUDE KEY

(P,Y,R) REFERENCED TO LOCAL HORIZONTAL

(0,0,0) ATTITUDE IS SMALL END IN DIRECTION OF ORBITAL MOTION (FORWARD), WINGS LEVEL, HEADS UP

SEF ≡ SMALL END FORWARD
BEF ≡ BACK END FORWARD

FIGURE 3.3-77 (CONT'D)

ing burn, a second burn (10 ft/s radially up) is performed bringing the Orbiter back to its original orbit. The Orbiter then waits in orbit for the OOS to complete its mission and return for retrieval. During this time, systems checks, IRU alignments and orb rate trims are performed once per orbit (except when the crew is asleep). In addition, once per day, because of orbit decay due to drag, a pair of engine burns are performed to maintain the orbit at an average 100 nm altitude. Each burn of the pair is approximately 4.5 ft/s. After six days wait, the OOS returns to a 110 nm circular orbit and the Orbiter begins tracking it in preparation for the rendezvous sequence. The Orbiter commands the OOS to make itself ready for docking such as: assume proper attitude, excess propellant dump, ordnance jettisons, etc. A line-of-sight Terminal Phase Initiation (TPI) burn of about 21 ft/s is performed when the OOS is at 27.3 degrees elevation from the Orbiter. Two mid-course correction maneuvers are scheduled (nominal $\Delta V=0$) to correct dispersions. In order to take advantage of the higher acceleration levels available, final braking is performed with the Orbiter -Z axis on the line-of-sight to target by a crewman at the docking station. After braking, the OOS is commanded to self test to insure that it is safe for docking, is given a visual inspection, and then picked up and stowed in the cargo bay. The Orbiter then waits until the phasing is correct for return to earth.

About 6 days and 18 hours after launch, the Orbiter is configured for deorbit and the deorbit burn made with one RL-10 engine (to allow takeover with the second RL-10 in the event of a failure). It is then maneuvered to the entry attitude - wings level and 30 degree angle of attack - and maintained in this attitude with orb rate. Final entry preparations are completed, orbital navigation terminated and powered flight navigation begun. At this time, dumping of excess OMS propellant (carried for first rev abort capability) is begun by burning the propellants through two pairs of opposing yaw jets. This procedure can take up to 25 min. to complete, depending on how much propellant is excess. For this mission it takes about 17 min. Entry interface occurs 11.4 min. after completion of the deorbit burn with VHF blackout starting three minutes later and lasting about 28 min. During entry, vehicle bank angle is modulated as necessary to shape the trajectory for the desired thermal, "g" loads and crossrange characteristics. After the end of VHF blackout, position updates are automatically provided by VOR/VOR navigation aids and when velocity is below 3000 ft/s, by DME/DME. Automatic terminal area guidance begins at High Key and continues through transition to the final approach. A high energy approach is utilized until the landing flare is initiated. It should be noted that no airbreather engines are onboard the Orbiter for this mission thus precluding the possibility of "go around". A conventional ILS glide slope is then flown to touchdown, with touchdown occuring about 50 min. after entry interface.

Approximately 480 ft/s on-orbit ΔV is required to perform the nominal mission. Based on this, the baseline Delta Orbiter is capable of about a 73K payload assuming abort-to-orbit capability. Without abort-to-orbit, it is capable of 90K payload.

3.3.2.1.6 Resupply Reference Mission - The resupply reference mission consists of providing logistic support for a Space Station/Space Base in a 270 nm, 55 degree circular orbit. Logistic support will consist of periodic transportation of expendable supplies, experiments, data and passengers to and from the Space Station. The duration of each mission is up to 7 days. To avoid large out of plane dispersions, launch must occur within a few minutes of the time the target orbit plane passes through the launch site. For the resupply mission, this occurs twice per day. Since there can be up to 9 continuous days when both rendezvous launch opportunities are in darkness and up to 49 continuous days when one of the opportunities is in darkness, the Shuttle will have the capability to launch day or night. This will allow launch any day of the year as well as allow a choice of phasing conditions on any given launch day. Since the Space Station is maintained in a "repeating" type orbit, phasing at at least one of the opportunities will generally be favorable - i.e., the Shuttle will be in-plane and behind the Space Station at injection. An abbreviated sequence of events and a mission profile for a typical five revolution (M = 5) rendezvous is shown in Figures 3.3-78 and 3.3-79, respectively.

The rendezvous sequence chosen provides the flexibility necessary to account for variations in phase angle through the launch window and correcting dispersions incurred during the mission. Some specific features are:

A. The Terminal Phase Initiation (TPI) point is fixed in space and time. This provides constant lighting and phasing conditions at final rendezvous for any launch within the launch window.

B. The final phasing (NC3) and all subsequent burns are performed within range of the star tracker and S-Band ranging system. This provides angle data and range measurements as inputs for a navigated relative state used in targeting these burns.

C. The Corrective Combination (NCC) and Coelliptic Sequence (NSR) maneuvers provides the capability to correct phasing and height dispersions. This is required to provide the fixed TPI point.

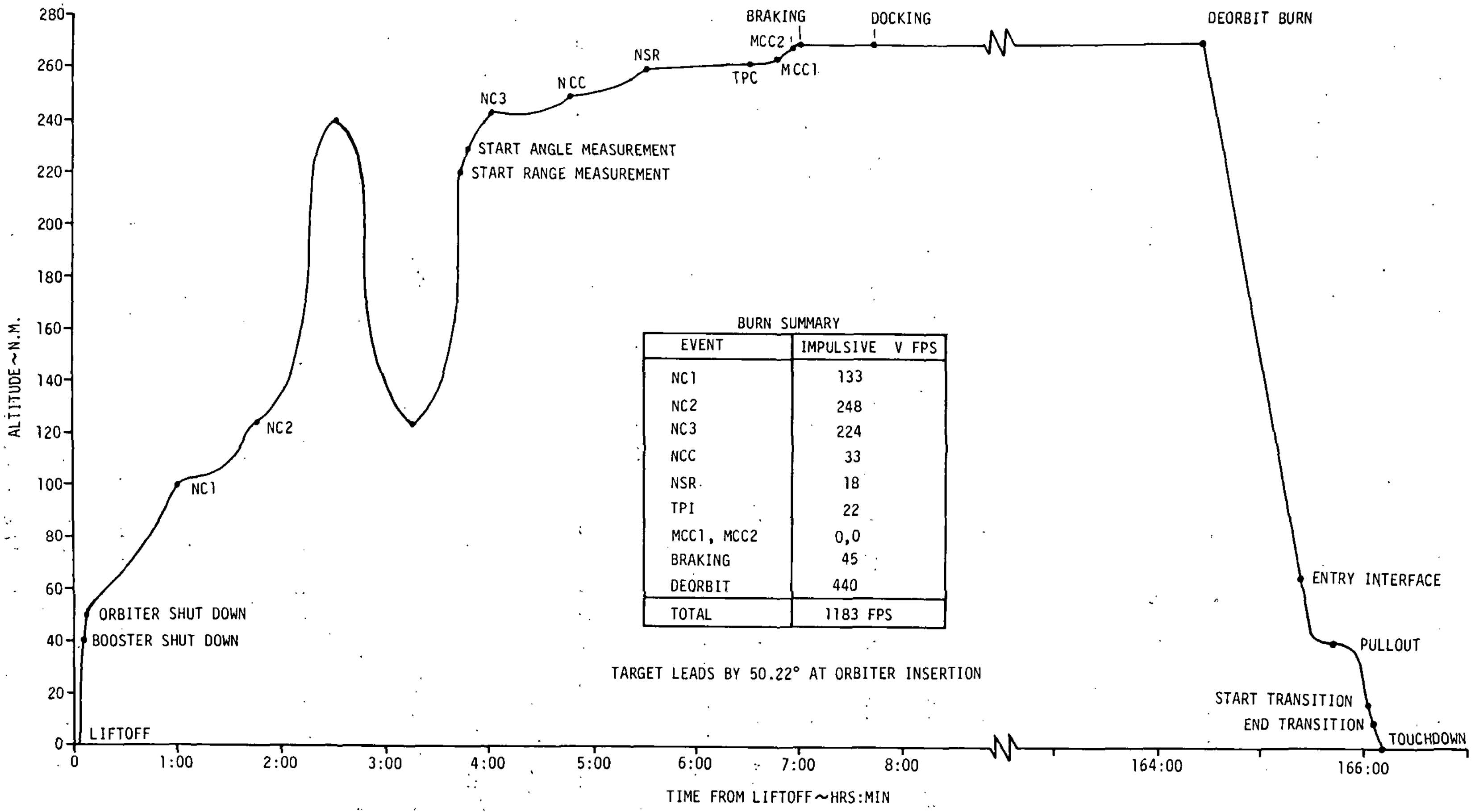
The Shuttle is launched from KSC into a 50 x 100 nm, 55 degree inclination orbit in the plane of the Space Station orbit. At insertion, the Orbiter trails the Space Station by 50.22 degrees earth central angle. When the Orbiter reaches 100 nm (first apogee), a phasing burn (NC1) is performed to raise perigee to 123 nm. This burn is necessary to raise perigee to an altitude that precludes a first revolution entry. The altitude is somewhat arbitrary, depending on the phase

RESUPPLY REFERENCE MISSION
SEQUENCE OF EVENTS

TIME OF INITIATION HRS:MIN:SEC	EVENT	ALTITUDE	ON-ORBIT TOTAL ΔV fps
	ASCENT		
-00:00:08	o Booster Engine Ignition		
00:00:00	o Lift-Off	0	
00:03:17	o Booster Engine Shut-Down	241,576 ft	Imp ΔV = 15338
00:03:19.5	o Separation	246,590 ft	
00:03:19.5	o Orbiter Engine Ignition	246,590 ft	
00:06:35.5	o Orbiter Engine Shut-Dwn/Insert	100/50 nm	
	ON-ORBIT		
00:50:23	o NC1 (Phasing)	123/100 nm	133
1:35:23	o NC2 (Phasing)	241/123 nm	248
3:42:00	o Acquire S-Band Relative Ranging (R = 400 nm)		
3:45:00	o Acquire Relative Angle Data (R = 300 nm)		
3:51:35	o NC3 (Phasing)	250/241 nm	224
4:36:35	o NCC (Corrective Combination)	260/250 nm	33
5:21:35	o NSR (Colliptic)	260/260 nm	18
6:06:35	o TPI	270/260 nm	22
6:18:27	o Midcourse Correction -1		0
6:30:19	o Midcourse Correction -2		0
6:54:38	o Deploy Cargo Container	270/270 nm	
7:19:38	o Docking	270/270 nm	10
	o On-Orbit Activities		
161:28:07	o Separation	270/270 nm	10
161:43:07	o Stow Cargo Container	270/270 nm	
161:58:07	o Position Update	270/270 nm	
	DESCENT-ORBITER		
163:17:00	o De-orbit-Initiate Burn	270/270 nm	440
163:21:08	o De-orbit-Terminate Burn		1183 TOTAL
163:22:08	o Orient to $30^\circ\alpha$		(1500) AVAIL.
163:56:08	o Entry Interface	400,000 ft	
164:26:18	o Initiate Transition Maneuver	106,000 ft	
164:28:28	o Terminate Transition Maneuver		
164:40:08	o Land (straight-in-approach)	--	

FIGURE 3.3-78

RESUPPLY REFERENCE MISSION
MISSION PROFILE



BURN SUMMARY

EVENT	IMPULSIVE V FPS
NC1	133
NC2	248
NC3	224
NCC	33
NSR	18
TPI	22
MCC1, MCC2	0,0
BRAKING	45
DEORBIT	440
TOTAL	1183 FPS

TARGET LEADS BY 50.22° AT ORBITER INSERTION

FIGURE 3.3-79

angle at insertion and the catch-up rate desired. The next burn of the rendezvous sequence is a second phasing burn (NC2) performed one-half revolution later when the Orbiter is at 123 nm, placing the Orbiter in a 123 x 241 nm orbit. The catch-up rate established is based on the condition desired at TPI. One and one-half revolutions later, when the Orbiter is at 241 nm, a third phasing burn (NC3) is performed, placing the Orbiter in a 241 x 250 nm orbit. Ranging data began 9 min. before NC3 and angle measurements 6 min. before NC3. One-half revolution later, the NCC burn changes the orbit to 250 x 260 nm and one-half revolution after that, the NSR burn places the Orbiter in a coelliptic 260 x 260 nm orbit. The NCC - NSR burns are designed to remove all dispersions so that TPI is reached at the desired time and phase angle. A line-of-sight TPI maneuver has been designed to occur when the Space Station is at an elevation angle of 27.5 degrees. It will place the Orbiter on an intercept trajectory arriving in the vicinity of the Space Station after 130 degrees of orbital travel. Two mid-course maneuvers are scheduled (nominal $\Delta V=0$) to correct any post TPI dispersions. Line-of-sight control and braking is performed with the attitude such that the -Z axis is along the line of sight in order to take advantage of the higher acceleration levels available using up firing jets.

The cargo container is rotated and locked into position 90 degrees from its original position in the cargo bay for docking to the Space Station. The Orbiter is maneuvered to the docking standoff position followed by soft and then hard docking. From this point on to the deorbit burn, the Orbiter on-orbit operations remain to be determined. Presently, there are two possible modes under consideration, namely: controlled drift mode at a significant spacing distance from the Space Station vs a docked configuration.

Seven days later, after termination of the on-orbit resupply operations, the Orbiter separates from the station and returns to the launch site. The deorbit burn places the Orbiter on a path for landing at KSC. Descent is similar to the Design Easterly Mission except that the airbreathing jet engines (ABES) must be deployed, primed and started at the maximum practical altitude (between 30,000 and 40,000 ft). After verifying satisfactory engine operation, thrust is reduced to idle, unless required to extend glide range or execute a go-around. The Orbiter lands at KSC about 1 hour and 21 minutes after deorbit.

3.3.2.1.7 Polar Reference Mission - The Polar Reference Mission consists of launching the Orbiter into an injection orbit of 50 x 100 nm, with a 90 degree inclination and circularizing at apogee by the orbital maneuvering propulsion system. A variety of payloads will be delivered, serviced and/or retrieved. The Orbiter remains in orbit for 7 days prior to returning to the launch site. Some missions, such as twilight orbits launched during the winter months will be launched at night.

A timeline and mission sequence of events from liftoff to landing is shown in Figure 3.3-80. On-orbit activities will vary with each specific mission and are presently undefined. The ΔV allocations are for translation maneuvers only and the total available is based on abort requirements. It is estimated to be 715 ft/s allowing 375 ft/s for on-orbit activities. Additional propellant is carried for attitude control and entry ACPS. Figure 3.3-81 illustrates the major mission events.

3.3.2.1.8 Booster Mission - The Booster mission is essentially the same for all the various types of missions. It can be segmented into the following basic mission phases:

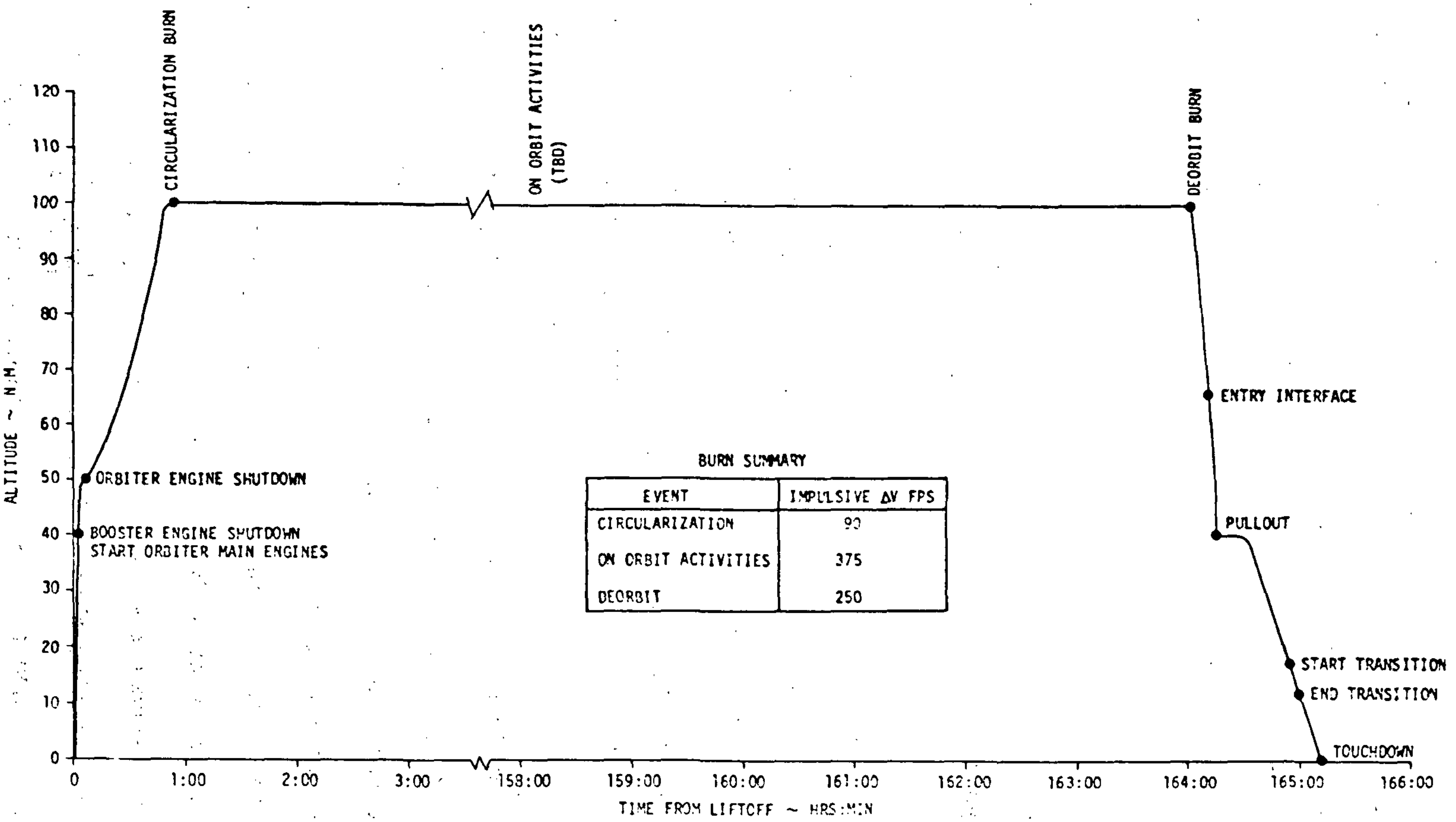
A. Powered ascent
B. Booster/Orbiter separation
C. Coast to apogee
D. Entry/transition

SOUTH POLAR REFERENCE MISSION
SEQUENCE OF EVENTS

TIME OF INITIATION HRS:MIN:SEC	EVENT	ALTITUDE	ON-ORBIT TOTAL ΔV (ft/s)
	ASCENT		
-00:00:08	o Booster Engine Ignition		
00:00:00	o Lift-Off	0	
00:03:18	o Booster Engine Cut-Off	246,341 ft	Imp ΔV = 15491
00:03:20.5	o Separation	251,359 ft	
00:03:20.5	o Orbiter Engine Ignition	251,355 ft	
00:06:39.5	o Orbiter Engine Shut-Dwn/Insert	50/100 nm	
	ON-ORBIT		
00:50:20	o Circularize	100/100 nm	90
	o On-Orbit Activities (TBD)		375
	o Orbit Decay Correction - One pair of corrections per day		
	DESCENT-ORBITER		
164:04:30	o De-Orbit-Initiate Burn	-10/100 nm	250
164:06:49	o De-Orbit-Terminate Burn		
164:07:30	o Maneuver to $30^{\circ}\alpha$		
164:18:14	o Entry Interface	400,000 ft	
164:56:14	o Initiate Transition Maneuver	106,000 ft (approx)	
164:58:14	o Complete Transition		
165:06:29	o Land (straight-in-approach)		
			TOTAL ON-ORBIT ΔV = 715

FIGURE 3.3-80

SOUTH POLAR REFERENCE MISSION
MISSION PROFILE



BURN SUMMARY

EVENT	IMPULSIVE ΔV FPS
CIRCULARIZATION	90
ON ORBIT ACTIVITIES	375
DEORBIT	250

FIGURE 3.3-81

E. Cruiseback -(flyback to launch or alternate site)

F. Landing

A typical Booster sequence of events is shown in Figure 3.3-82 and a typical profile in Figure 3.3-83.

During powered ascent, the mated Booster/Orbiter configuration rises vertically until sufficient velocity is reached to begin the pitch program. Once the initial pitch maneuver is completed, the Booster flies a gravity turn trajectory (Zero lift flight). This flight profile, minimizes the velocity losses due to gravity and reduces vehicle structural bending moments as the vehicle proceeds through the region of maximum dynamic pressure. During this mission phase, the Booster computers are guiding the vehicle, managing all vehicles systems, and cycling through the abort planning loop. Abort guidance will take over control of the vehicle pitch command if the crew "g" level limits or subsystem failure limits are exceeded. Booster abort modes are discussed in Section 3.3.2.5.2, but it is noteworthy that whether or not there is an abort, the Booster must essentially deplete the main engine cryogenic propellants by thrusting before it is capable of cruising or landing (thrust to weight consideration when flying with the ABES).

Once Booster engine cutoff has occurred, Booster/Orbiter separation can be effected by either of the separation systems found on the Booster or the Orbiter. If the trajectory is nominal, separation occurs immediately after Booster cutoff. If the mission is in an abort mode, the mated configuration may be required to coast to apogee to reduce the "g" loading and dynamic pressure at separation.

Once separation has been successfully completed, the Booster coasts to apogee where it assumes the entry attitude (trim angle of attack of 60 degrees). The Booster maintains this angle of attack to minimize heating rates until an altitude of about 141,000 ft is reached. At this altitude, angle of attack is lowered to 48 degrees to reduce the entry "g" loads. Between approximately 80,000 ft and

BOOSTER EVENT TIMELINE

TIME	FUNCTION
-:00:08	Booster Engine Ignition • Initiate Powered Flight Navigation • Verify Engine Operation
0	LIFT OFF
:00:06	Clear Tower
:00:12	Initiate Roll and Pitch Maneuver
:00:24	Initiate Zero Lift Flight
:01:10	Max Q (642 psf)
:02:10	Initiate Closed Loop Guidance
:03:17	Booster Engine Cut-off • Burn Time = 3.45 min • Altitude = 238,740 ft • Downrange = 220 N.M. • ΔV = 15,247 fps
:03:19.5	Booster-Orbiter Separation • Zero Degree Angle of Attack • Wings Level • Open Propellant Dump Valves
:04:10	Booster Apogee • Maneuver to Entry Angle of Attack = 60° • Wings Level
:05:15	Begin Communications Blackout
:05:30	Switch over to Aerodynamic Control • Verify Effective Aero Control • Deactivate ACS Jets
:06:05	Begin Angle of Attack Modulation to Limit "g" Loads • Max "g" Load = 4.25 • Minimum Angle of Attack = 48°
:06:20	Begin Bank Angle Modulation to 90° • 10 Sec Ramp – Then Hold at 90° • Constant Angle of Attack
:06:20	End Communications Blackout
:06:20	Loss of Communication with Launch Site • Elevation Angle = 0° • Switch to Communication with Relay Aircraft
:07:10	Begin Rollout to Bank Angle = 30° • Constant Angle of Attack • Mach No. = 2.8 • Establish voice link with Escort Aircraft
:07:25	Begin Transition Maneuver • Modulate Angle of Attack to 10° (20 Sec ramp) • Constant Bank Angle = 30° • Mach No. = 2.0
:07:46	End Transition Maneuver • Continue Turn to 173° at 30° Bank Angle • Reduce Bank Angle to 0° (10 Sec) to Complete 180° Turn • Open Jet Engine Doors
:08:30	Begin Jet Engine Start Sequence • Altitude = 45,000 ft • Continue Descent to Cruise Altitude
:09:30	Begin Cruise Phase • Altitude = 25,000 ft • Continue Descent to Cruise Altitude
:12:20	Stabilize powered flight at Cruise climb conditions • Altitude = 16,600 ft • Establish visual contact with Escort Aircraft • Adjust thrust level to cruise airspeed • Navigation cross checks with Escort Aircraft • Continue Powered Flight Navigation • Transfer JP-4 to Aft Tanks
:13:00	System Status Checks
:15:00	Checks Complete
1:08:00	Establish Communications with Landing Site • DME/DME Position Checks • Update IMU and Program for Cruise to Terminal Area
1:39	Start Letdown • Altitude = 20,400 ft • Reduce Power • Dump Excess JP-4
1:40:30	Enter Terminal Area • Intercept Localizer • Approach Checklist
1:45:12	Terminate Descent • Reduce to Approach Speed
1:46:20	Outer Marker – Intercept Glide Slope • Begin Final Approach • Descend on Glide Slope
1:47:55	Decision Height • Go Around – GO/NO-GO • Verify Gear Down
1:48:15	Flare to Landing Attitude
1:48:18	Touch Down • Idle Power
1:53:00	Shutdown

FIGURE 3.3-82

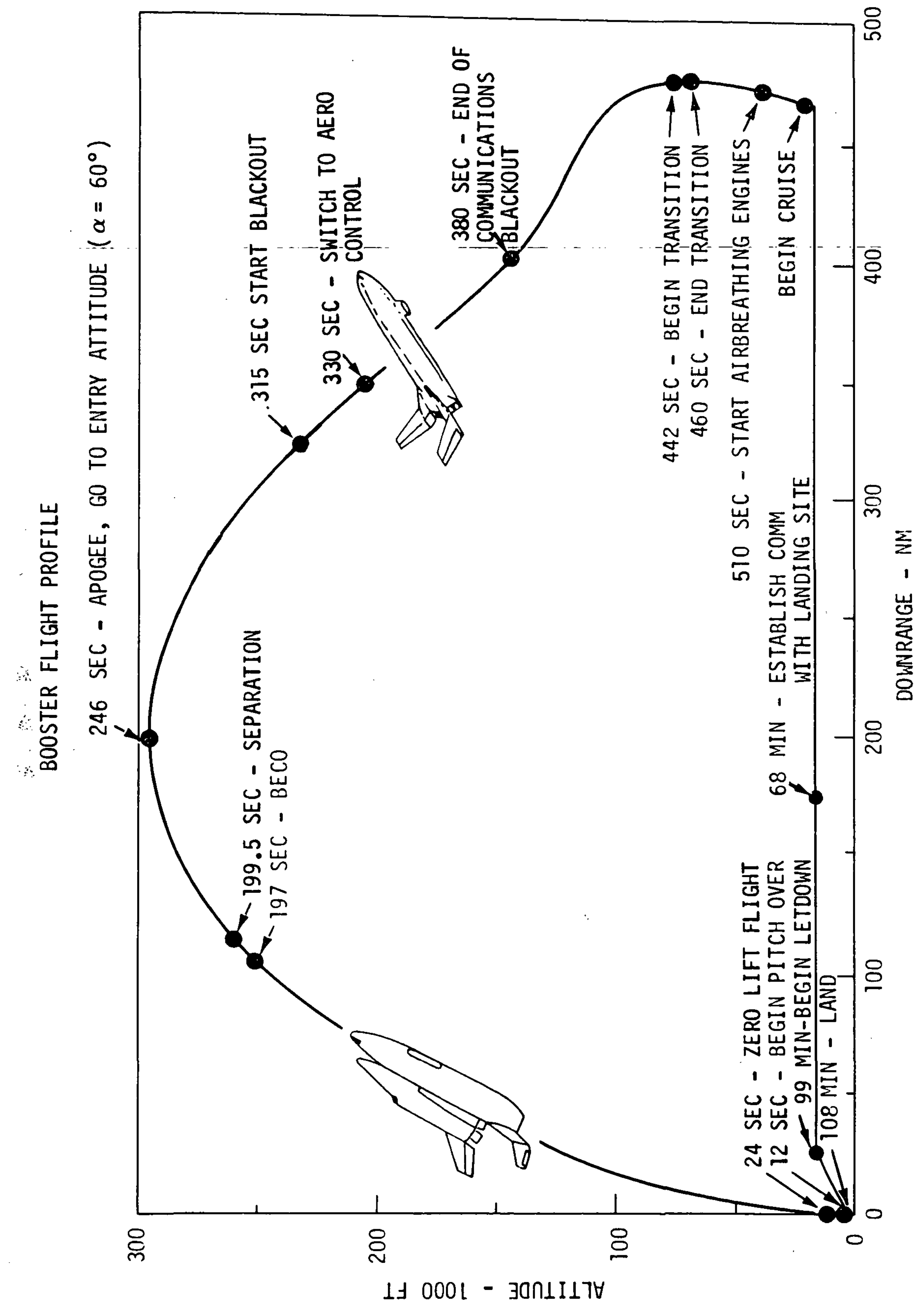

BOOSTER FLIGHT PROFILE
246 SEC - APOGEE, GO TO ENTRY ATTITUDE (α = 60°)
315 SEC START BLACKOUT
330 SEC - SWITCH TO AERO CONTROL
380 SEC - END OF COMMUNICATIONS BLACKOUT
442 SEC - BEGIN TRANSITION
460 SEC - END TRANSITION
510 SEC - START AIRBREATHING ENGINES
BEGIN CRUISE
199.5 SEC - SEPARATION
197 SEC - BECO
68 MIN - ESTABLISH COMM WITH LANDING SITE
24 SEC - ZERO LIFT FLIGHT
12 SEC - BEGIN PITCH OVER
99 MIN-BEGIN LETDOWN
108 MIN - LAND
ALTITUDE - 1000 FT
300
200
100
0
DOWNRANGE - NM
0
100
200
300
400
500

FIGURE 3.3-83

72,000 ft, the angle of attack is further reduced to 10 degrees. This angle is maintained until the ABES are started and the cruise angle of attack of 6 degrees is assumed. In addition to the angle of attack variations, the Booster begins a banking maneuver at about 125,000 ft (90 degree bank) to minimize downrange distance and hence minimize the cruiseback distance to the landing site. The 90 degree bank is held to about 90,000 ft where a gradual reduction is made to 30 degrees (at about 82,000 ft) and then maintained. Starting about 30,000 ft, the bank angle is further reduced, reaching 0 degrees at the nominal cruise altitude. The ABES inlet door is opened and engine start sequence begun at about 45,000 ft. All engines are up to power before the cruise altitude is reached. When the vehicle reaches the optimum cruising altitude, ABES power is adjusted accordingly and the vehicle assumes a direct heading to the launch site. The flight profile described has been designed to turn the Booster 180 degrees from the ascent flight path to a direction approximately toward the launch site and to maintain the entry "g" load below 4.25 at all times.

During the entry, there is a VHF communications blackout period beginning shortly after the beginning of the entry phase and lasting for about 65 seconds. By the end of blackout, direct communications with the launch site has been lost. The Booster then relays communications through and receives radar vectors around weather areas from an escort aircraft located in the vicinity of the transition. This aircraft will be equipped with the usual complement of over water comm/nav aids such as HF radio, LORAN, radar, etc. The escort aircraft will rendezvous with the Booster using any or all of the currently used aircraft rendezvous techniques (e.g., visual, radar, UHF homing or air-to-air DME). After rendezvous, normal aircraft station keeping is performed by use of visual contact. The escort aircraft can use its radar to pick the best route around or through the weather and to vector the Booster along the best course, similar to current military practice.

Cruiseback to the launch site is the nominal return mode of the Booster. However, in the operational phase, Booster downrange landing and aerial refueling offer payload advantages. Figure 3.3-84 presents a summary of the effect of downrange landing and aerial refueling options on payload to orbit for the Eastern Test Range (ETR) launch site. Three Booster downrange landing sites which were considered for launch azimuths between 0 and 180 degrees from ETR in generating this figure are:

- Nassau, Bahamas
- Cherry Point MCAS, North Carolina
- Kingston, Jamaica

Subsequent studies have shown that Seymour-Johnson AFB, North Carolina (about 55 nm west of Cherry Point MCAS) has superior runway characteristics and will replace Cherry Point as a downrange site. This will not significantly affect the results shown in Ref. Figure 3.3-84. Further discussion of alternate Booster return modes is provided in DN-I-East-TI-20, "Downrange Landing and Alternate Return Modes vs Cruise Back".

3.3.2.2 Mission Operations System Description - The recommended mission operations system is divided between onboard and ground control functions, and resulted from an onboard vs ground trade study (see IM-1-East-MO-2," Space Shuttle Autonomy (GAFSO)"), the mission requirements, and other studies performed during Phase B. This approach for both Orbiter and Booster is viable and cost effective. The early Shuttle flights will utilize the full up Manned Space Flight Network to take advantage of its demonstrated performance. As confidence in the Shuttle vehicle performance is attained, the requirement for full up MSFN coverage will diminish to the point that only voice communication and periodic telemetry data

KSC OPTIONAL CRUISE PERFORMANCE

- Reference Vehicle MP-8
- 1500 FPS OMS Loading & Orbiter ABES in at all Azimuths

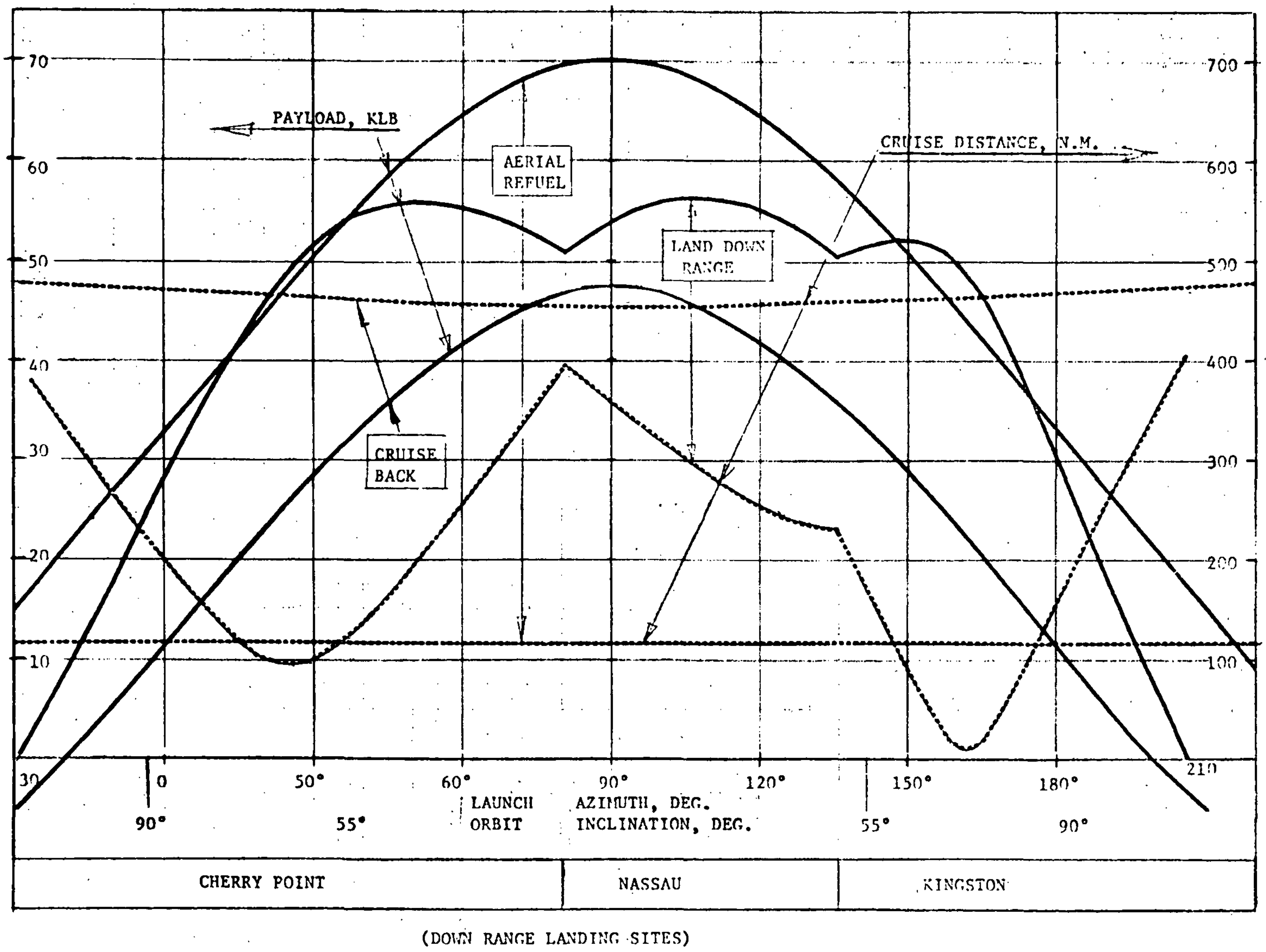


FIGURE 3.3-84

transmissions will be required. At this point, transition to a Tracking and Data Relay Satellite (TDRS) system will occur if such a system is available and, if not, transition to a limited MSFN will take place until a TDRS system is available.

The Shuttle mission operations will provide considerable change in the relative ground/flight crew responsibilities for overall management of the mission when compared to previous manned programs. The Shuttle flight crew and vehicle systems will have increased responsibility for the following reasons:

- Onboard functions are more cost effective
- System redundancy level provides higher probability of success
- Automation provides increased onboard capability
- Flight crew functions are vehicle operation related, not payload or experiment oriented.

During vertical flight test and early operational flights, ground support will be similar to that of previous programs but, once confidence in the Shuttle systems is attained, the requirement for ground support will diminish. The Booster has no uplink capability and the downlink will be removed at the end of the vertical flight test period. The Orbiter has both uplink and downlink, through flight test and operationally, but the downlinked data will be substantially reduced at the end of the vertical flight test period.

The ground mission operations functions are much less for the Booster than for the Orbiter primarily because of its relatively short mission life. Therefore, most of the mission operations discussed here focus on the Orbiter; however, many of the statements are applicable to the Booster as well.

3.3.2.2.1 Onboard - Once the vertical flight test program is completed and operational confidence has been attained, the onboard mission operations system will perform, with minor ground support, the functions of trajectory control, systems management, mission planning, flight progress monitoring and evaluation, and flight crew/passenger status monitoring. It will also perform certain aspects of communications control and payload management. The approach to performing these functions is discussed in Section 3.3.2.3. This section will describe the key features of the system from an operational point of view and will also provide a brief description of the avionics elements.

The key features of this system are a high level of redundancy, a high degree of autonomy, and a high level of automation. The avionics system provides four levels of redundancy for safety functions, three levels for mission success functions, and one or two levels for convenience functions. While this obviously provides a very high probability of crew safety and mission success, it also enhances the operational capability of the vehicle in several other ways. This considerably reduces the procedure development and crew training time required for each mission. Another important aspect of redundancy is that it makes it practical to have a high level of autonomy by assuring a high probability that essential functions can be performed onboard even in the event of multiple failures. This leads to significant operational benefits as discussed below.

Autonomy is a second key feature of the onboard operations system. By providing the capability to perform most functions onboard, ground mission support can be dramatically reduced while also increasing vehicle flexibility. As currently envisioned, the ground will provide only an information and interface function including such tasks as supplying weather predictions for the landing site, providing solar flare information, providing coordination of air traffic control matters, and providing consultation on procedural, systems and flight planning problems. All major functions will be achieved onboard. This approach allows a substantial reduction in the requirements for ground tracking, communications, and data processing. Once operational status is attained, it allows an estimated operations savings of $80M per year over a low autonomy system (see IM-I-East-MO-2, "Space Shuttle Autonomy (GAFSO)"). An autonomous onboard system is also a more operationally flexible system. Since ground support is not required for critical functions, there is no need to constrain the event to occur within ground communications periods. Also, since ground tracking is not required, there is no tracking limitation on mission orbits.

The high degree of autonomy requires a simplified and well organized method of subsystem management and mission control. The onboard system is designed to perform routine functions automatically, leaving the flight crew free for the more important monitoring and decision making functions. The computer will be used for data gathering and data processing; the flight crew will analyze the pertinent computer results or options, then decide whether to proceed (or which option to proceed with), and then execute the function automatically. For example, upon crew request, a maneuver sequence to achieve return phasing and deorbit for landing at a crew selected site will be computed and displayed to the crew. After review and approval of the plan, the crew will proceed to execute the plan utilizing the computer and associated controls. Another example is systems management. Noncritical configuration sequencing is performed automatically and computer software is used to vote redundant systems where three or more units are available, to conduct reasonableness tests on subsystems, and to perform limit checks on parameters. The results of this sequencing and testing is displayed to the crew. The crew has the option to override selection of redundant systems and make any abort decisions based on this information. Upon crew initiation of an abort plan, an abort sequence is performed. Other specific areas in which automation is provided include ascent guidance, orbital and rendezvous navigation, entry guidance and landing.

The guidance and navigation subsystem will maintain current estimates of the vehicle's position, velocity, and attitude so that appropriate maneuvers can be performed. It is comprised of four gimballed Inertial Measurement Units (IMU), four IMU processors, four optical trackers, and four horizons sensors. The IMU is an all attitude system. The optical tracker serves the dual purpose of tracking stars for IMU alignment and the rendezvous target for rendezvous navigation updates. The horizon sensors provide angle data for IMU alignment and orbital navigation. Other communications and navigation equipment includes S-band ranging systems, DME receivers, VOR receivers, and landing aids systems (localizer, glide slope, radar altimeter).

During the ascent phase of flight, the IMU is the sole source of navigation information. Guidance of the Shuttle vehicle is under control of the Booster until separation at which time each vehicle provides its own guidance. No external navigation aids are employed during this portion of the mission. During the orbital phase, the optical tracker and horizon sensors are used for attitude and navigation update information. The horizon sensors continually track the earth's horizon during all orbital phases (except maneuver phases) and supply horizon angular information relative to the navigation base. The optical tracker periodically tracks selected stars under computer control. Subsequent processing of this information by the central computer provides the desired navigation information. To support the first orbital maneuvers, this processing or orbit navigation data begins immediately after orbit insertion. For rendezvous, the optical tracker is used to obtain angle to the target information. Range to the cooperative target is obtained via S-band ranging which is provided by the communications subsystem. For the reentry phase, IMU information is the primary source of navigation data although it is augmented by horizon sensor and optical tracker data prior to entering the atmosphere and by VOR/DME information after entry. In order to control the growth of errors in the altitude channel during reentry, altitude is determined by comparing measured drag with a model of drag stored in the computer. Accuracy of this technique is sufficient to limit the altitude channel errors. Landing is accomplished by using conventional aircraft landing aids.

The flight control subsystem provides for flight path control and the execution of maneuvers (determined from automatic guidance commands or crew derived commands) by controlling and stabilizing vehicle attitude. Its primary functions are to (1) enhance the inherent stability characteristics of the Shuttle, (2) provide an autopilot capability, (3) provide the crew a manual flight path control capability during orbital and aerodynamic phase of flight, (4) allow manual mode control, and (5) provide inputs to crew displays. The following flight control capabilities are provided:

Mission Phase	Control Description
Booster Ascent	Booster TVC control (all axes)
	Booster elevons aid in roll control during high Q
	Automatic rate command system using rate gyro feedback with attitude feedback through the steering equations
	Orbiter engines and surfaces held in trim position
Booster Entry	ACS for entry orientation
	ACS controls bank angle using yaw and roll to 200K ft altitude
	ACS and aero for angle of attack to 200K ft altitude
	Surface control only after 200K ft altitude
	Automatic or manual control

Mission Phase	Control Description
	Manual capability for attitude hold/rate command in bank (using roll stick deflections) and pitch, angle of attack
Booster Cruise and Landing	Aero surfaces and JP_4 engines used Automatic or manual cruise and landing Manual modes Roll, yaw, pitch rate command with augmentation Autopilot modes Altitude hold Heading hold Velocity control Approach and landing
Orbiter Ascent	TVC control (all axes) Surfaces held in trim position Automatic rate command system using rate gyro feedback with attitude feedback through the steering equations
On-Orbit Attitude	Manual modes Acceleration Pulse Rate command/attitude hold Automatic modes Attitude hold at guidance derived or keyboard inserted attitude
On-Orbit Translation	Manual Mode Acceleration Automatic Mode ΔV increment

Orbiter Entry	ACS controls bank angle and angle of attack to 75K ft ACS and aero surfaces used for transition Automatic or manual control Manual capability for attitude hold/rate command in bank (using roll stick deflections) and pitch, angle of attack
Orbiter Cruise and Landing	Control similar to that for Booster cruise and landing

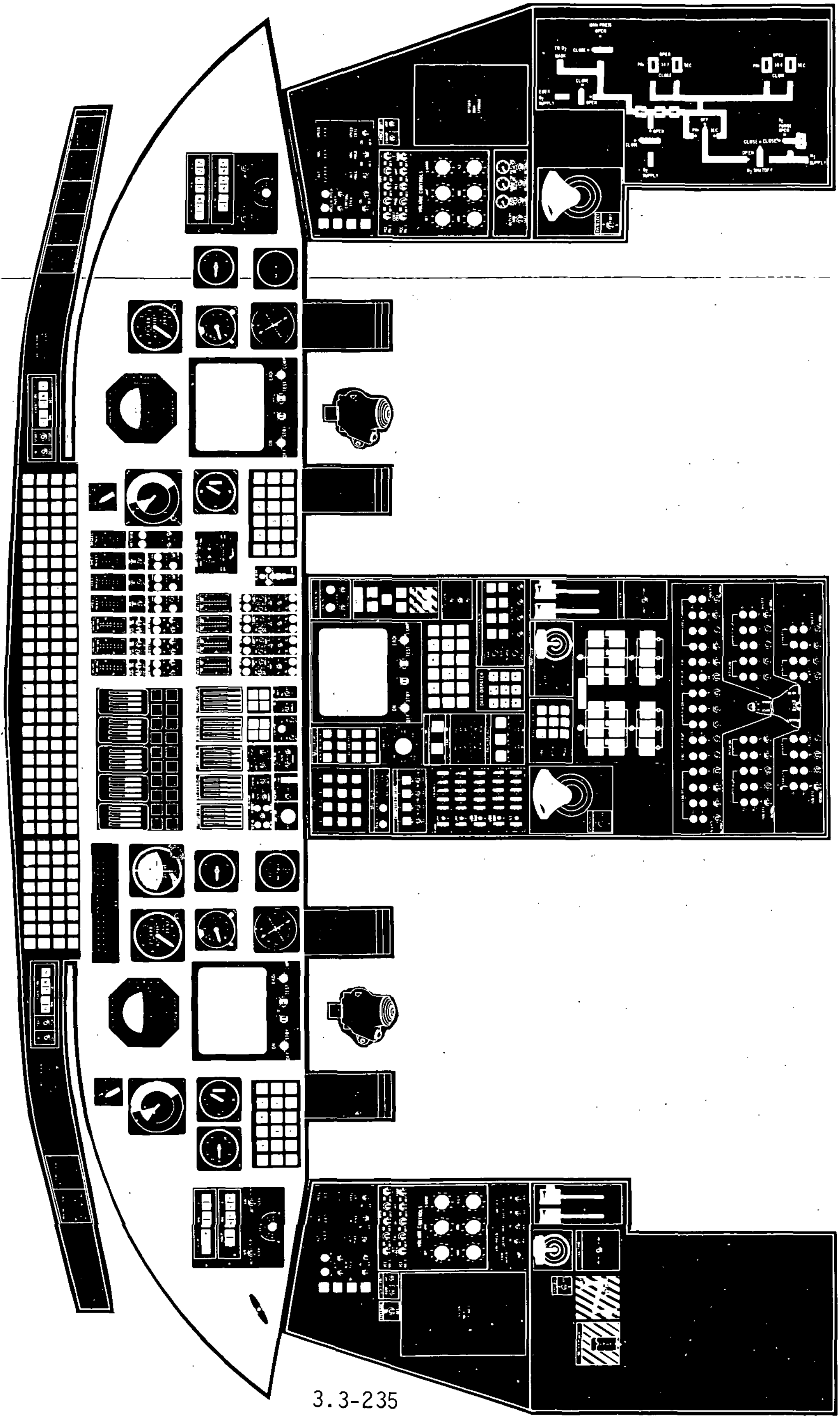
The Orbiter communications system provides the communication links required between the Orbiter, Booster, ground and Space Station. It provides the capabilities for (a) two-way voice communications between the ground and the Orbiter, between the Orbiter and Space Station, between the Orbiter and Booster, and beween pilot, copilot and passengers, (b) ground tracking of the Orbiter, (c) ground to Orbiter data or command link, (d) an Orbiter to ground data link, and (e) an Orbiter rendezvous ranging link.

The navaid functions are to provide onboard position updating after entry, and to allow the Orbiter to maneuver to and the Booster to fly to the desired landing site. The navaids are also used for enroute navigation during ferry flights. During landings, the navaids provide azimuth, elevation and the guidance signals which are required for an automatic landing capability. The navaid equipment furnishes raw measurement data including (a) slant range and bearing angle to VOR/DME ground stations during aerocruise, (b) altitude measurement above the terrain (Radar altimeter) from an altitude of 2,500 feet to touchdown, (c) a measure of vertical and lateral deviation from the standard Instrument Landing System (ILS) glide slope and localizer, respectively. Transmission and reception is accomplished via a unified S-Band subsystem and UHF transceiver subsystem. The S-Band subsystem provides orbital communications including telemetry, tracking, command, and voice. The UHF subsystem is used for direct voice communications to the landing airport, MSFN, EVA crewmen, and air traffic control center equipment.

The data management subsystem performs (1) onboard computation, (2) data acquisition and distribution, and (3) data storage. The onboard computation function includes solving the equations necessary to navigate, guide and control the vehicle, data processing for subsystems such as the star tracker and horizon sensor, vehicle checkout and fault isolation, vehicle configuration control and mission planning. The data acquisition and distribution function involves control of the data transfer, providing the data transfer media and remote data interfacing. The scope of the data acquisition and distribution includes data between the Orbiter and the Booster, and payload as well as intravehicle data. The data storage function includes keeping a record of mission events and events times for execution, a record of preflight established procedures to assist the pilot in carrying out the mission and a record of selected data for ground maintenance of the vehicle.

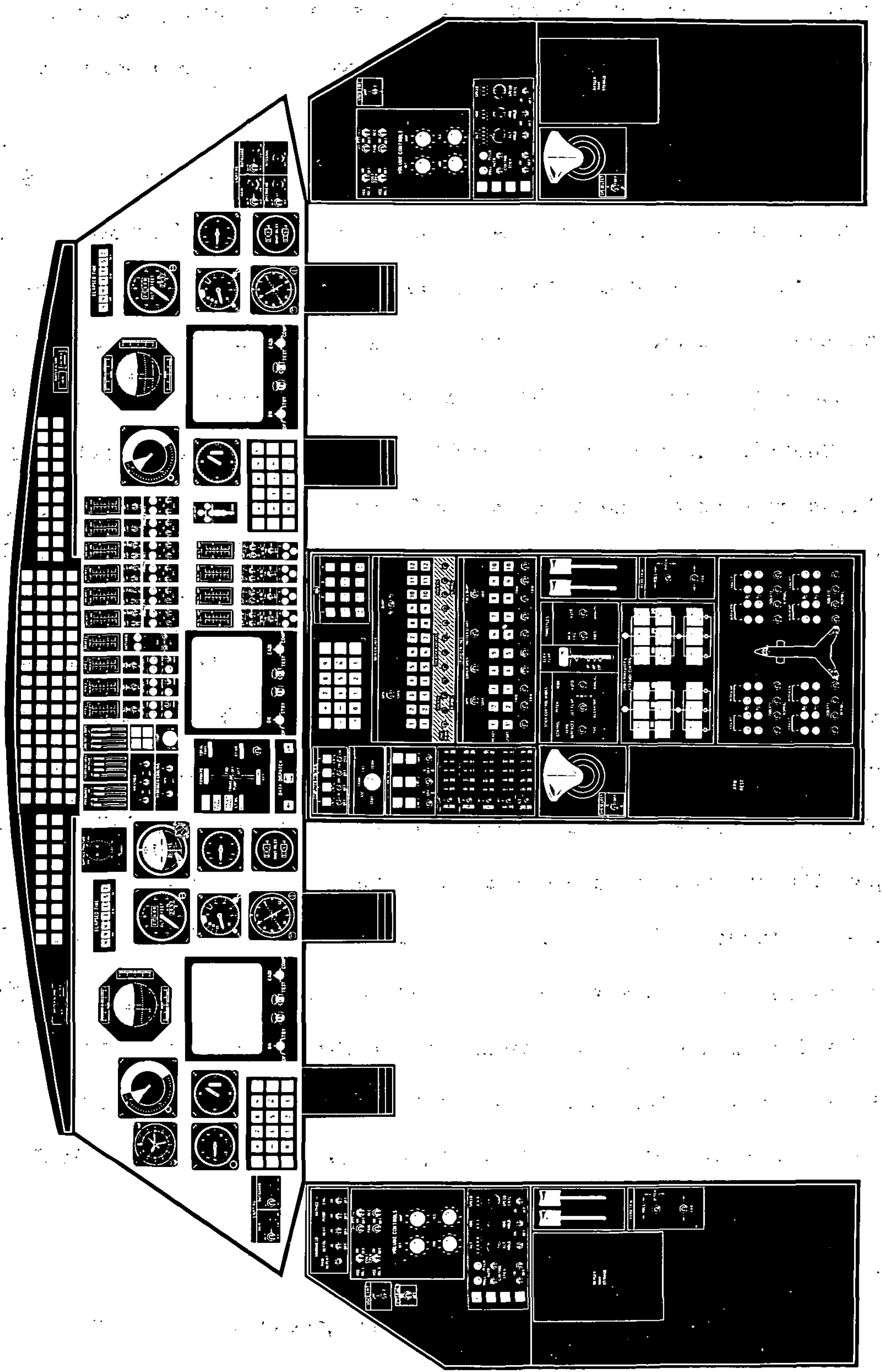
The crew station displays and controls provide the flight crew with an interface to the operational subsystems of the Orbiter and Booster. The two crewmen are in a side-by-side arrangement and the displays and controls are duplicated where necessary to provide vehicle operational control from either crew position as shown in Figures 3.3-85 through 3.3-86. The equipment is arranged in five major panels and a center console. As can be seen, there is a very high degree of commonality between the Booster and Orbiter instrument panel arrangement. Not so obvious is the fact that the most of the individual instruments are common to both vehicles.

3.3.2.2.2 <u>Network Description</u> - The baseline Space Shuttle network was



SPACE SHUTTLE ORBITER INSTRUMENT PANEL

FIGURE 3.3-85



SPACE SHUTTLE BOOSTER INSTRUMENT PANEL

FIGURE 3.3–86

selected by assessing the Shuttle communications requirements, selecting a preliminary baseline network configuration and evaluating the communications coverage afforded by that net to demonstrate adequacy.

3.3.2.2.2.1 Shuttle Communications Requirements - Because of the Shuttle's high level of autonomy, communications requirements are based primarily on assuring crew and vehicle safety and mission success. Safety and success functions performed on the ground and their impact on communications are shown in Figure 3.3-87. This figure indicates that communications necessary to the safety and success of a Shuttle mission can be provided with a few, strategically placed, ground stations or with one data relay satellite. The possible exception to this is communications related to solar flare monitoring. This area will require further study.

3.3.2.2.2.2 Baseline Network Configuration - Communications and backup orbit determination for the baseline Space Shuttle is provided by a six station limited MSFN and existing aircraft cruise and landing aids. The MSFN sites proposed for the Shuttle are the presently existing sites listed in Figure 3.3-88. MSFN station capabilities required are - USBS T/M, command and voice, plus VHF voice. The top block of Figure 3.3-89 illustrates this concept. The communications circuits needed to interconnect the MSFN stations with Goddard Space Flight Center (GSFC) and the Ground Mission Operations Center (GMOC) will be supplied by NASA Communications Division (NASCOM). Shuttle flight operations are expected to require the existing four 3-KC voice/data lines between GSFC and each MSFN site.

These lines will be utilized as follows:

A. One Line, air/ground voice

B. One Line, network coordination and air/ground voice backup

C. Two Lines, with 4.8 kbps modems for command and telemetry data.

In addition, one teletype (TTY) circuit is required for each site in use for

COMMUNICATIONS REQUIREMENTS

(FUNCTIONS PERFORMED ON GROUND)

FUNCTION	REASON	COMMUNICATION REQUIREMENT
SAFETY FUNCTIONS		
o LANDING SITE WEATHER MONITOR o LANDING SITE ASSISTANCE	PROVIDE FOR SAFE LANDINGS	CONTACT ONE OR TWO ORBITS PRIOR TO DEORBIT TO PRIMARY OR ALTERNATE LANDING SITE
o SPACE WEATHER MONITOR	SOLAR FLARE RADIATION WARNING	VARIABLE WITH SOLAR FLARE TYPE AND INTENSITY AND WITH ORBIT ALTITUDE AND INCLINATION. TWO TO TEN HR. FROM OPTICAL OBSERVATION UNTIL PARTICLES REACH VICINITY OF EARTH
SUCCESS FUNCTIONS		
o OBJECTIVE UPDATE	DIRECTION FOR CHANGING/ UPDATING MISSION OBJECTIVE	INFREQUENT AND UNPREDICTABLE. BY PRE-PLANNING FOR CONTINGENCY SITUATIONS, GAPS UP TO 8 HR. PROBABLY TOLERABLE
o TARGET SATELLITE STATE VECTOR	OBTAIN EPHEMERIS OF PASSIVE TARGET SATELLITE	TARGET SATELLITE STATE VECTOR OBTAINED PRIOR TO LIFT-OFF. UPDATES NOT CRITICAL-SEND WHEN COMM AVAILABLE
o INTERFACE TO OTHER AGENCIES	GENERAL INFORMATION NECESSARY TO THE MISSION	INTERFACE DURING AEROCRUISE AND LANDING PROVIDED BY LANDING AIDS. OTHER TIMES UP TO 8 HR GAPS O.K.
o CONTINGENCY SUPPORT TO CREW	PROVIDE CONSULTATION OR SUPPLEMENTAL INFORMATION AS REQUESTED BY CREW	INFREQUENT AND UNPREDICTABLE. ON-CALL SUPPORT PROVIDED ONLY FOR NON-TIME CRITICAL SITUATIONS

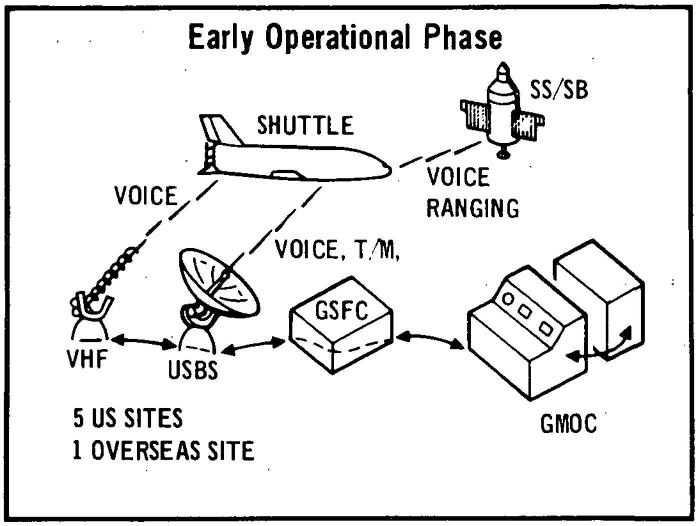
FIGURE 3.3-87

SHUTTLE MSFN REQUIREMENTS

STATION	S-BAND		VHF VOICE (BACK-UP)
	30' DISH	85' DISH	
OPERATIONAL PHASE SITES			
Merritt Island (MIL/MLA)	X		X
Hawaii (HAW)	X		X
Corpus Christi (TEX)	X		X
Goldstone (GDS)		X	X
Bermuda (BDA)	X		X
Canary Islands (CYI)	X		X
TEST AND DEVELOPMENT PHASE SITES			
Madrid (MAD)		X	X
Honeysuckle Creek (HSK)		X	X
Carnarvon (CRO)	X		X
Guam (GWM)	X		X
Ascension Islands (ACN/ASC)	X		X
SHIP (T&D PHASE ONLY)			
USNS Vanguard (VAN)	X		X

FIGURE 3.3-88

OPERATIONS
MISSION CONTROL CONCEPT



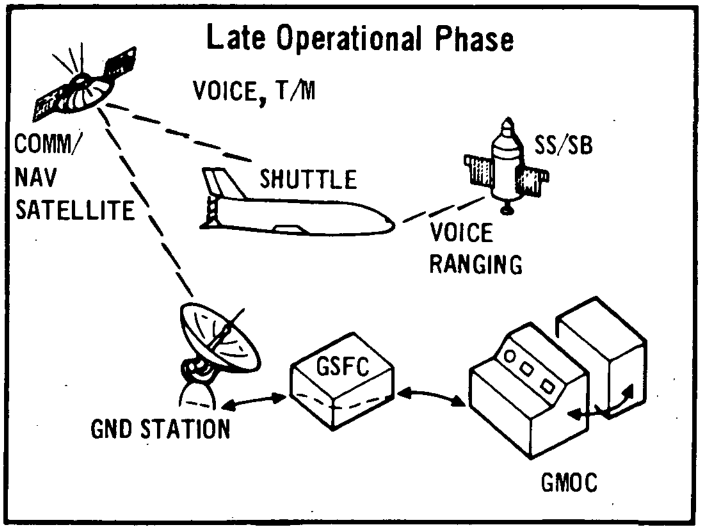


FIGURE 3.3-89

Shuttle/station contact predictions, acquisition messages and other miscellaneous traffic. All data is formatted at GSFC and routed, together with voice, over two wide band trunk lines between GSFC and the GMOC.

The limited MSFN described presumes a network configuration dictated by Shuttle requirements. If a "National Space Net" (presumably an optimized combination of existing NASA communications networks) is implemented and is available during the Shuttle operational period, it would be utilized instead of the limited MSFN network.

A communication/navigation satellite system will also satisfy all safety and mission success functions as well as provide for convenience, reporting and morale functions. This system is adequate for solar flare monitoring communications. Minimal requirements for such a system are one comm satellite in geosynchronous orbit, one ground station and the necessary landlines between the ground station/GSFC/GMOC. This is illustrated on the bottom of Ref.Figure 3.3-89. Use of a comm/nav satellite would eliminate the requirements for any MSFN coverage; however, aerocruise and landing aids are still required. Transition from the limited MSFN to a comm/nav satellite would have little effect on GMOC and on-board functions.

3.3.2.2.2.3 Coverage from Baseline Network - The coverage presented in this section corresponds to the limited MSFN configuration assumed to be used during the Shuttle early operational phase. The six operational sites provide sufficient coverage to perform all safety and mission success functions. A coverage summary for various orbit inclinations for low and high altitude is shown in Figure 3.3-90. Although this figure indicates some rather large gaps in coverage, they are worst case situations and most are either unlikely to occur or the mission can be designed around them with little or no loss in capability. The only gap of any significance is the Hawaii-south to Canary-north gap at low altitude and low

Worst case contact gaps in order of length for 6-station MSFN, 5° elevation angle criterion

h	i	From		To		Gap	
nm	deg	Sta	pass[a]	Sta	pass[a]	revs	hrs
100	30	HAW	s	CYI	n	5.7	8.4
	60	HAW	s	CYI	n	3.6	5.3
		TEX	s	HAW	s	3.0	4.4
		CYI	n	MIL	n	3.0	4.4
		HAW	n	BDA	s	2.3	3.4
		CYI	s	BDA	s	2.0	2.9
	90	GDS	s	BDA	n	5.6	8.3
		GDS	n	CYI	s	4.3	6.3
		HAW	n	BDA	s	4.2	6.2
		CYI	n	MIL	n	3.0	4.4
		HAW	s	CYI	n	1.6	2.3
	120	HAW	n	CYI	s	3.3	4.8
		CYI	s	BDA	s	2.9	4.3
		GDS	n	HAW	n	2.9	4.3
		CYI	n	BDA	n	2.0	2.9
		GDS	s	CYI	n	1.6	2.4
400	90	HAW	n	CYI	s	1.2	2.1
	120	HAW	n	CYI	s	2.2	3.7

[a] Northbound or Southbound

FIGURE 3.3-90

inclination. This gap will occur once per day. However, none of the gaps significantly affect mission safety or success functions (except perhaps solar radiation warning).

The functions having the greatest impact on coverage requirements are those concerned with landings, both emergency deorbit and landing and normal landings. In most cases, coverage is sufficient to declare an emergency and obtain clearances within 2 or 3 orbits prior to entry. Emergencies requiring an immediate deorbit appear to be so remote that stations to fill the gaps solely for this reason are unwarranted. These gaps will not exist with TDRS. A normal landing requires voice contact one or two orbits prior to deorbit for obtaining weather; opening flight plans, etc. Coverage is sufficient at any inclination to satisfy this function for CONUS landings. All other functions are less time critical and are easily satisfied with the coverage provided. Cruise and landing aids are local in nature and are provided by existing aircraft aids at airports suitable for Shuttle landings. Additional MSFN sites are used in the flight test phase and initial operational phase. This provides the coverage required to verify proper vehicle system operation, additional state vector updates and additional crew consultation service until the Shuttle has been adequately flight tested.

Preliminary work on solar radiation monitoring indicates that it is highly desirable to have ground flare observation data as well as onboard radiation measurement data available to determine whether an abort is required. To effectively utilize both pieces of data, communications are required at reasonable frequency. Indications are that ground observation of the flare precedes the potential danger period by 2 - 10 hours, so that contact gaps no larger than 2 hours might be desirable. However, the problem is complicated by the facts that 1) there is a very low probability of such an occurrence, 2) there is a low probability of large gaps, and 3) there are some remedial measures which can be taken onboard based on onboard observations of radiation build-up. These remedial measures could include maneuvering to favorable attitudes, donning water vests, or even aborting the mission. Thus the question of the adequacy of the limited MSFN network for solar flare monitoring requires further study; however, the TDRS system is certainly adequate.

3.3.2.2.3 Ground Mission Operations Center - The Ground Mission Operations Center (GMOC) will be an integral part of a Mission Control Center (MCC). It is envisioned that by the time the Shuttle becomes operational, an MCC will have evolved such that few (if any) consoles will be dedicated to a particular program. In order to define the minimum support which must be provided by an MCC for Shuttle operations, specific functions have been assigned to individual consoles and the consoles so identified are collectively referred to as the GMOC. The primary objective of the GMOC will be to provide appropriate mission/flight support for the Space Shuttle. The support required for the first orbital flights will be of similar magnitude to that experienced on early manned programs. The transition to the approach recommended will take place over 1 - 2 year period. The operational support is consistent with an overall program concept of autonomous Space Shuttle operations coupled with minimal ground support and turnaround time at the lowest possible operating costs. To this end, both the Space Shuttle systems and GMOC systems design considerations necessarily become interdependent; however, program goals require that onboard operational autonomy receive primary emphasis. Therefore, the baseline GMOC is defined as providing for only limited information and interface activities during Space Shuttle operations. A primary intent of GMOC functions is to coordinate and control communications, to interface with all outside supporting agencies, and to provide consultation as requested by the flight crew.

3.3.2.2.3.1 GMOC Functions - The baseline GMOC functions for Shuttle missions are categorized as follows:

A. Information Functions

1. Provide flight dynamics/mission plan status and maneuver sequence status. This information will be obtained from position and status reports from the crew via voice or telemetry and will be utilized primarily in connection with the ground coordination activities of the GMOC.
2. Receive and store telemetry data on vehicle systems.
3. Provide information on vehicle systems on request from the crew for assistance. The necessary systems engineers can be called in as required for consultation over the comm link and to examine particular data dumps in order to perform their analysis and advise the crew accordingly.

B. Interface Functions

1. Provide coordination of flight planning air traffic control matters and related advisory information for Space Shuttle flights.
2. Provide the vehicles with solar flare and landing weather information.
3. Provide the interface for range safety or other data required by the test range.
4. Provide for any required data transfer with NORAD and also with the Space Station Operations Center (if a separate entity).
5. Coordinate and control the communications network in accordance with the nominal, backup or alternate mission plans.

C. Other Support Functions

1. Provide contingency malfunction and medical support. Spacecraft malfunction and medical problems which cannot be determined or

isolated onboard will require auxiliary support from the ground. This support would be on call to the GMOC on an as-required basis.

2. Provide for coordination with in-flight experiment support as required.

3.3.2.2.3.2 GMOC Functional Interfaces - The following sections briefly describe the primary GMOC functional interfaces which are presented in Figure 3.3-91.

A. GMOC/Space Shuttle Interfaces - The GMOC will maintain voice communication with the Space Shuttle throughout its mission. A baseline assumption is that gaps of several orbits and minimal per orbit coverage can be tolerated in the voice communications link. Voice communications and telemetry data can be transmitted during orbital phases whenever the Orbiter is within line-of-sight of any of the MSFN sites. During landing cruiseback or ferry flights, the Booster or Orbiter will talk directly or relay via escort aircraft to the ARTCC or tower, or to the GMOC via landline connections.

B. GMOC/Test Range Interface - A communications link will be required between the GMOC and Range Safety for coordinating range support requirements, scheduling, etc.

C. GMOC/Shuttle Support Facility - The GMOC will advise the Space Shuttle Ground Operations Facility on Space Shuttle operations and systems/vehicle status as required. In addition, the GMOC can, if desired, process and record system/subsystem telemetry parameters from the onboard data bus. These data may be used by the support facility in the investigation and analysis of critical malfunctions or failures.

D. GMOC/NORAD Interface - At present, aircraft clearance into ADIZ areas under control of the Air Defense Command are usually coordinated with NORAD through the responsible Air Route Traffic Control Center (ARTCC). Because of the specialized nature of Space Shuttle operations, it is

GMOC FUNCTIONAL INTERFACES

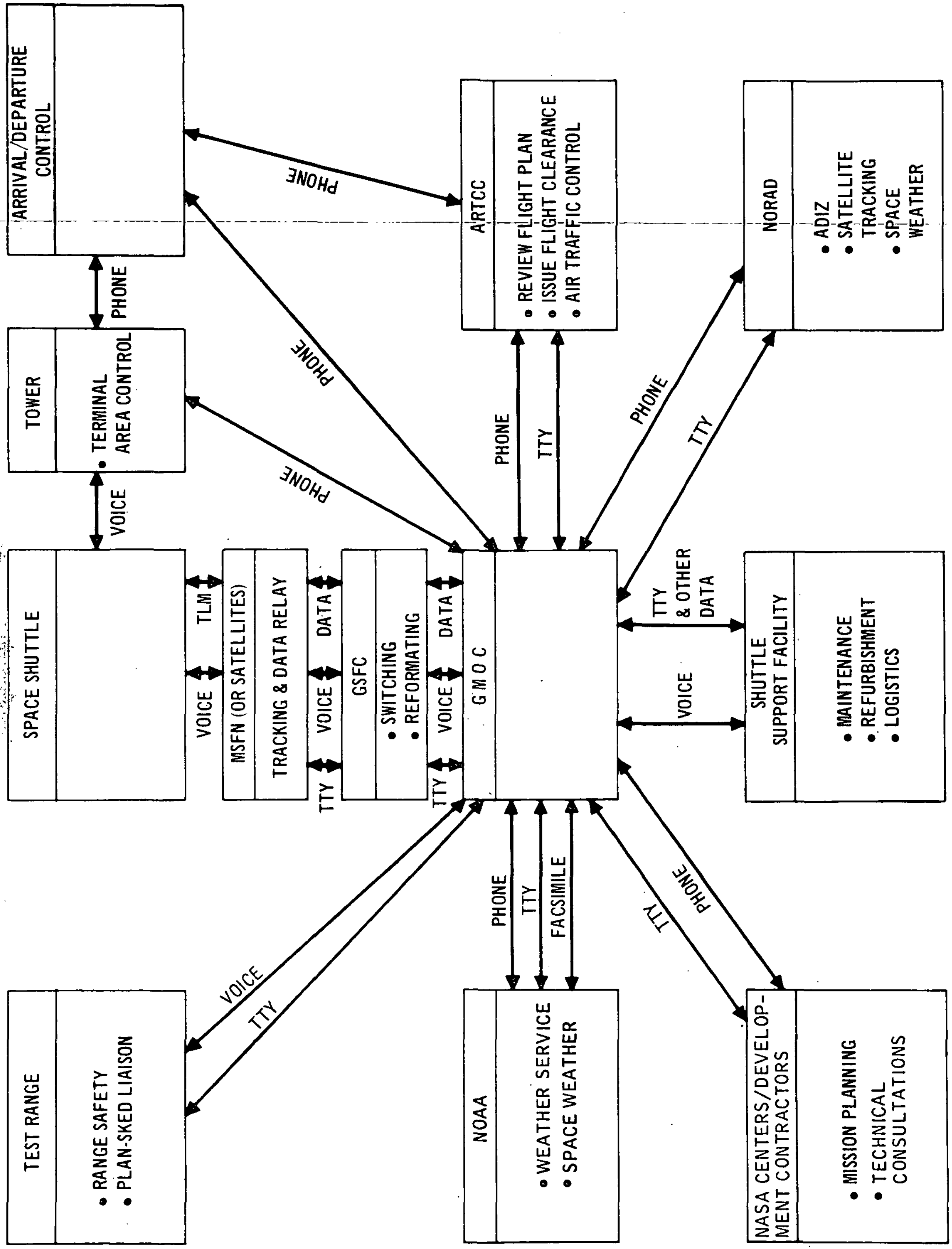


FIGURE 3.3-91

expected that direct communications with NORAD will become a firm requirement and thereby provide for effective coordination of all GMOC-NORAD matters. NORAD may also provide supplemental space weather and satellite tracking information to the GMOC.

E. GMOC/Air Traffic Control Interface - The GMOC-ARTCC and other air traffic control related interfaces shown in Ref.Fig.3.3-91 are those which would exist under current concepts of air traffic control exercised under the Federal Aviation Administration (FAA). All elements of air traffic control would apply to Space Shuttle aircraft flight in its ferry (point-to-point) mode of operations. A portion of the elements will still apply in other Space Shuttle modes of operation in domestic and international controlled air-space. It is expected that the GMOC will be required to act as "base operations" in coordinating the flight plan, flight plan deviations and clearance activities between the Space Shuttle vehicles and ARTCC until direct communication can be achieved. The GMOC will be required to provide continuing update of Space Shuttle flight planning information as changes occur and real-time advisory information on Space Shuttle flight progress to the appropriate ARTCC for proper execution of its air traffic control function. Contingency plans for international landing clearance must be activated by the GMOC if required.

Actual air traffic control of Space Shuttle flight operations in controlled airspace will be exercised by ARTCC assisted by Arrival and Departure Control organizations in terminal airport control zones. Finally, airport towers and associated ground support facilities will be employed in controlling the Shuttle to its final landing approach and landing. These additional interfaces are also shown in Ref.Fig.3.3-91.

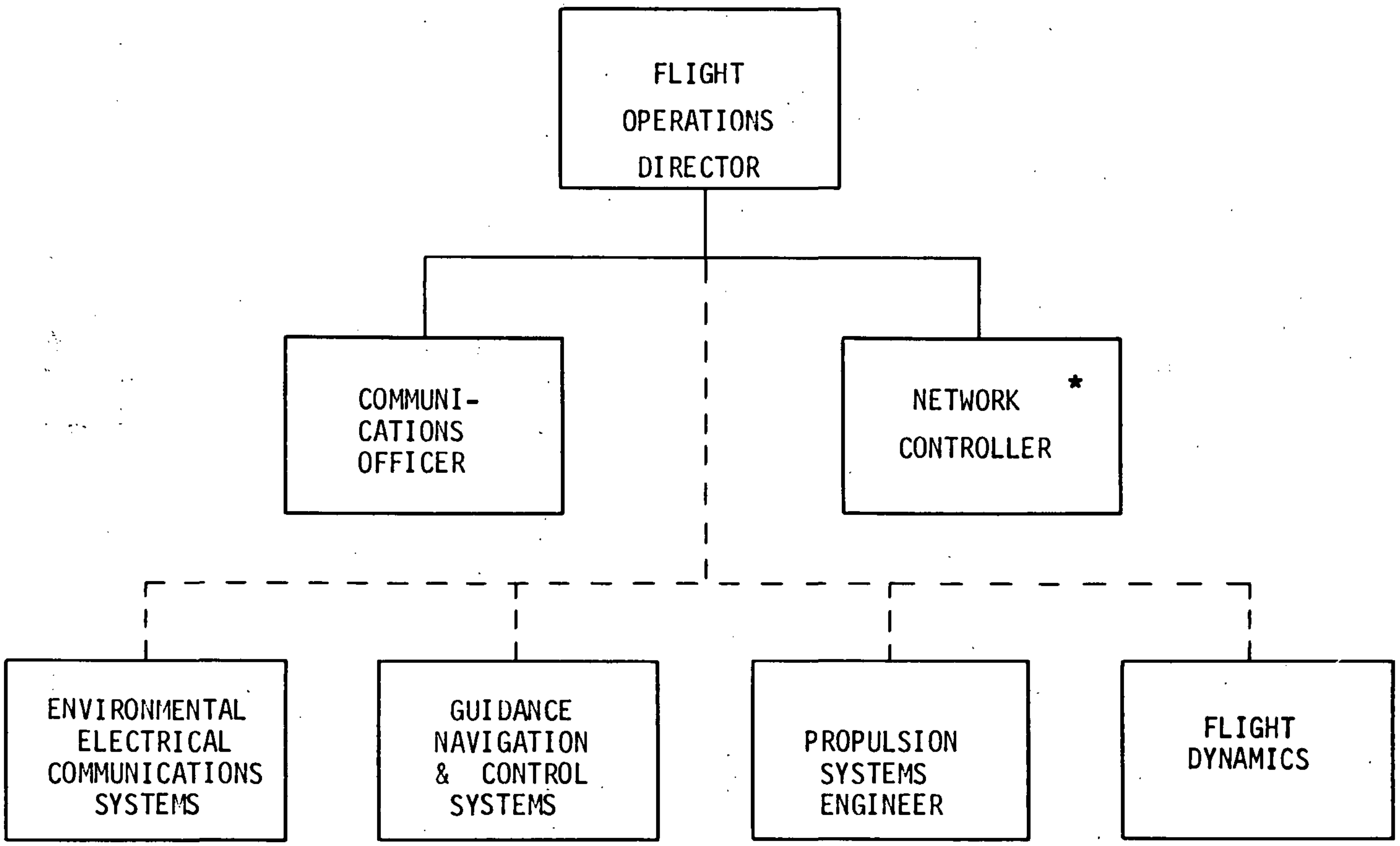
F. GMOC/National Oceanic and Atmospheric Administration (NOAA) - This interface will exist for atmospheric and space weather information. The National Weather Service will be the primary source of weather information for flight planning weather briefings and for continuous monitoring of present and forecast weather incident to all Space Shuttle operations. The Environmental Research Laboratory continually monitors for solar flares. Data on flare area, intensity and frequency will be determined and transmitted to the GMOC for analysis.

G. GMOC/Development Contractor/NASA Center Interface - Any use of MSFN will require coordination with GSFC and other supporting agencies for site configuration, station handover and handback, message formatting and communications backup. Those NASA centers directly involved with spacecraft design relating to hardware operation will be available for technical consultation during the mission.

3.3.2.2.3.3 Facility Organization - An initial estimate of the organization and staffing required for the GMOC is shown in Figure 3.3-92. The GMOC will be an organizational composite of existing MCC functions and will include portions of the Mission Operations Control Room (MOCR), Communications, Command, and Telemetry Systems (CCATS), the Real-Time Computer Complex (RTCC), and Staff Support Rooms (SSR). Manning of the organizations defined here will be on as-required basis. The Flight Operations Director and Communications Officer are the only "full-time" positions currently envisioned. (It is assumed that Network Controller support would be available when required.).

A. Flight Operations Director - This officer, as the representative of NASA management, shall be aware of the status and progress of Space Shuttle

GMOC ORGANIZATION STRUCTURE



* TIME SHARED WITH OTHER MCC PROGRAMS

FIGURE 3.3-92

operations and exercise command decision responsibility in GMOC operations and activation of contingency plans, as required. He will be provided with a console capable of viewing any of the displays at other console stations and have access to communications with all other GMOC consoles and primary external interface elements.

B. Communications Officer - This officer will be responsible for all launch and orbital voice communications to the Space Shuttle crew. It is expected that he will be a former or potential Space Shuttle pilot with training and experience requisite to acting in liaison in all matters related to Space Shuttle/GMOC support operations. He will assist the Flight Operations Director and participate in flight coordination activities, as required. He will be provided with a console capable of viewing any of the displays at other operating consoles and communications terminal equipment consistent with his tasks.

C. Network Controller - This officer will support the Shuttle Flight Operations Director on a time-shared basis. He will be responsible for the detailed operational control and failure analysis of the communications network. He will be responsible for management of the mission data flow and for monitoring all communication systems as required.

D. Vehicle Systems Engineers (4) - At a minimum, engineers in the following categories will be available (on call) to support Shuttle operations as required.

(a) Environmental, Electrical, and Communications (EECOM)
(b) Guidance, Navigation and Control (GNC)
(c) Propulsion Systems Engineer (PSE)
(d) Flight Dynamics Officer (FDO).

It is envisioned that these engineers would man non-dedicated consoles on a time-shared basis with other programs to provide the requested support.

3.3.2.2.4 Flight Test Considerations - The Shuttle flight test program will consist of a horizontal flight program and a vertical mated flight program. The horizontal flight program will not require mission operations support since horizontal flight activities will be conducted primarily to verify basic airplane mode flying characteristics. Existing facilities at KSC and EAFB will be utilized for decision making, data processing, reduction and computation.

The vertical mated flight program and early operational flights will require extensive ground mission operations support. The mission operations requirements will be similar to that of previous manned space programs. This is in contrast to the minimum ground support required once Shuttle is operational. Complete MSFN coverage will be required for state vector update, telemetry uplink, telemetry downlink, and ground monitoring of the flight. The Flight Test Ground Mission Operations Center (FT/GMOC) will be a fully manned, dedicated facility providing flight dynamics, systems monitoring, and flight planning support to the onboard systems.

"Full up" ground mission operations support will be required for the first five vertical mated test flights. Although it is expected that this support will diminish gradually during early operational flights as confidence is gained in the Shuttle systems to perform autonomously, a "full up" MSFN and GMOC will be maintained for support as necessary during the first two years.

3.3.2.2.4.1 Onboard - The onboard mission operations system will perform the functions of trajectory control, systems management, mission planning, flight progress monitoring and evaluation, and flight crew status monitoring during the development flights just as it will during operational flights. However, ground mission operations will "back up" all of these functions, until the vertical flight test program and early operational flights have demonstrated onboard systems capability to perform these functions. For example, the first vertical test mission is designed to test the navigation subsystem, among other things. Onboard and ground navigation data will be compared by ground operations and as long as the ground verifies the onboard navigation, the system will perform autonomously. If the ground does not concur, then ground navigation data will be utilized to perform necessary trajectory control functions. Similarly, then, each subsystem will be monitored and to the degree that the subsystem is meeting performance specifications, the onboard systems will fly the mission. This means that during the development flights, ground operations will share the flight control responsibilities with the onboard operations. As confidence is gained through the test program, in each subsystem and finally the total system, responsibility for flight control will rest solely with the flight crew/onboard systems and operational status will be attained.

3.3.2.2.4.2 Network Description - Communications and state vector update for the Shuttle development flights will be provided by the Manned Spaceflight Network (MSFN) and existing aircraft cruise and landing aids.

All MSFN stations will be required and full station capability will be utilized - USBS tracking, telemetry, command uplink, and voice, plus UHF voice.

The vertical flight test missions will be constrained to provide necessary MSFN coverage for state vector update and ground monitoring.

The communications circuits needed to interconnect the MSFN stations with GSFC and the GMOC will be supplied by NASCOM. These required circuits are:

A. Four 3-kc voice/data lines between GSFC and <u>each</u> MSFN site in use utilized as follows:

   (1) One line, air/ground voice

   (2) One line, network coordination and air/ground voice backup

   (3) Two lines, 4.8 kbps modems for telemetry and command data.

B. Two teletype (TTY) circuits for <u>each</u> site for low speed tracking data, acquisition messages, and other miscellaneous data.

A tracking ship will be required during launch to provide telemetry and tracking information from launch through insertion.

3.3.2.2.4.3 <u>Ground Mission Operations Center</u> - The Ground Mission Operations Center required to support vertical flight test and early flight operations (FT/GMOC) will be a fully manned, dedicated facility functionally similar to the Apollo and Skylab MCC configuration. In addition to the routine communications and facility interface functions which will be retained for the operational phase of the program, the FT/GMOC will provide continuous backup to onboard systems management and flight dynamics functions. It will also provide for the recording and display of flight test peculiar instrumentation data.

<u>FT/GMOC Functions</u> - The FT/GMOC functions for mated vertical test flights and early operational flights are categorized as follows:

A. <u>Operational Functions</u> - The FT/GMOC will perform all of the GMOC functions presented in 3.3.2.2.3.1. That support designated as "on call" or "as requested" will be provided on a continuously manned basis during the flight test phase.

B. <u>Backup Functions</u>

   (1) Provide systems management to include:

- Systems Monitoring
- Fault Isolation and Corrective Action
- Configuration and Consumables Management

(2) Provide flight dynamics support to include:

- Targeting Computations
- Abort Monitoring
- State Vector Update and Orbit Determination

(3) Provide mission planning support to include:

- Update prelaunch mission plan
- Perform nominal and alternate rendezvous planning and scheduling
- Provide nominal and alternate deorbit plans

(4) Provide flight progress monitoring

(5) Provide crew status monitoring

C. Flight Test Functions - Provide recording, processing, and monitoring of data obtained from test flight instrumentation.

FT/GMOC Functional Interfaces - The FT/GMOC functional interfaces will be the same as those presented in Reference Figure 3.3-92 and described in 3.3.2.2.3.2. In addition, state vector update will be provided via the telemetry uplink and it is expected that tracking information during launch through insertion will be obtained from the test range via landline for driving vehicle dynamics displays in the FT/GMOC.

Facility Organization - The FT/GMOC will consist of a central Mission Operations Control Room (MOCR) and several Staff Support Rooms (SSR's) assisted by supporting areas including the Communications, Command and Telemetry Systems (CCATS) area and the Real-Time Computer Complex (RTCC). The position functions in each of the areas are identified in Figures 3.3-93, 3.3-94 and 3.3-95.

MOCR AND SSR ORGANIZATIONAL STRUCTURE

FLIGHT TEST

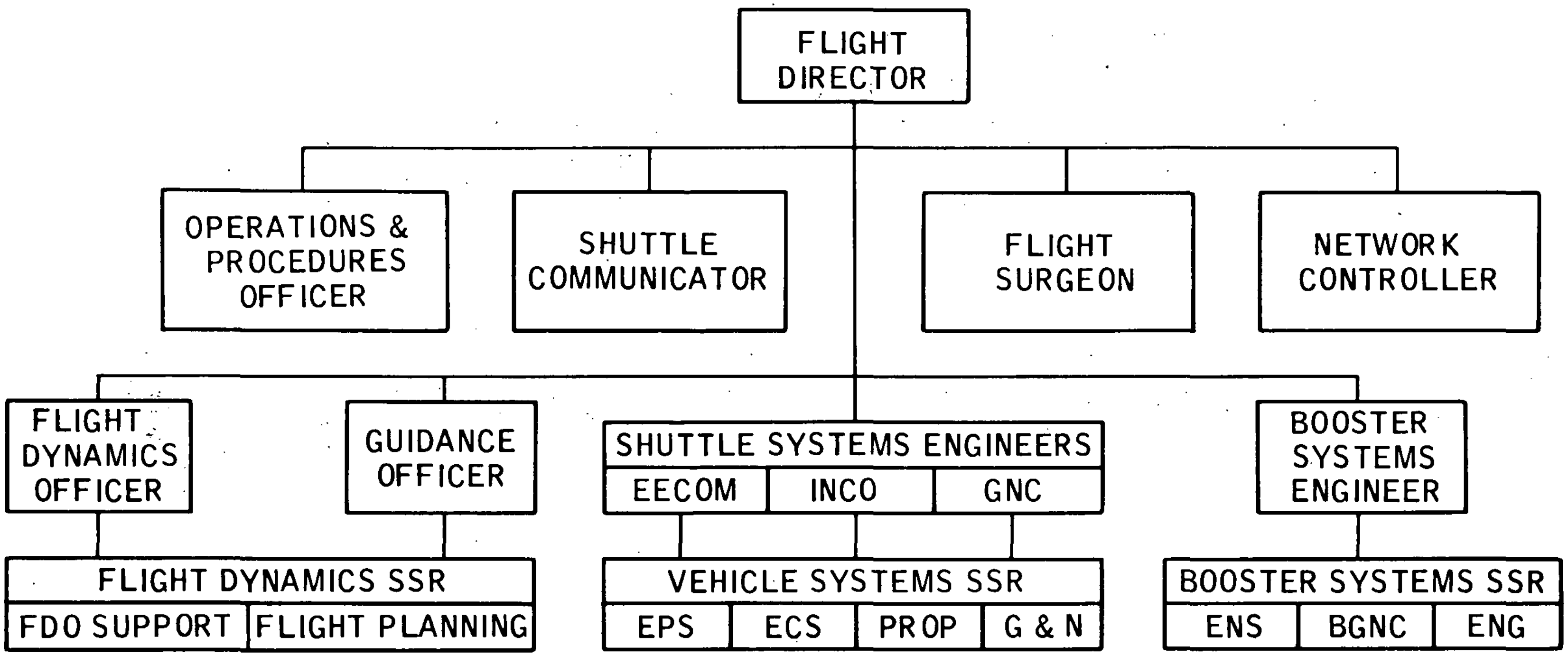


FIGURE 3.3-93

CCATS OPERATIONAL ORGANIZATION
FLIGHT TEST

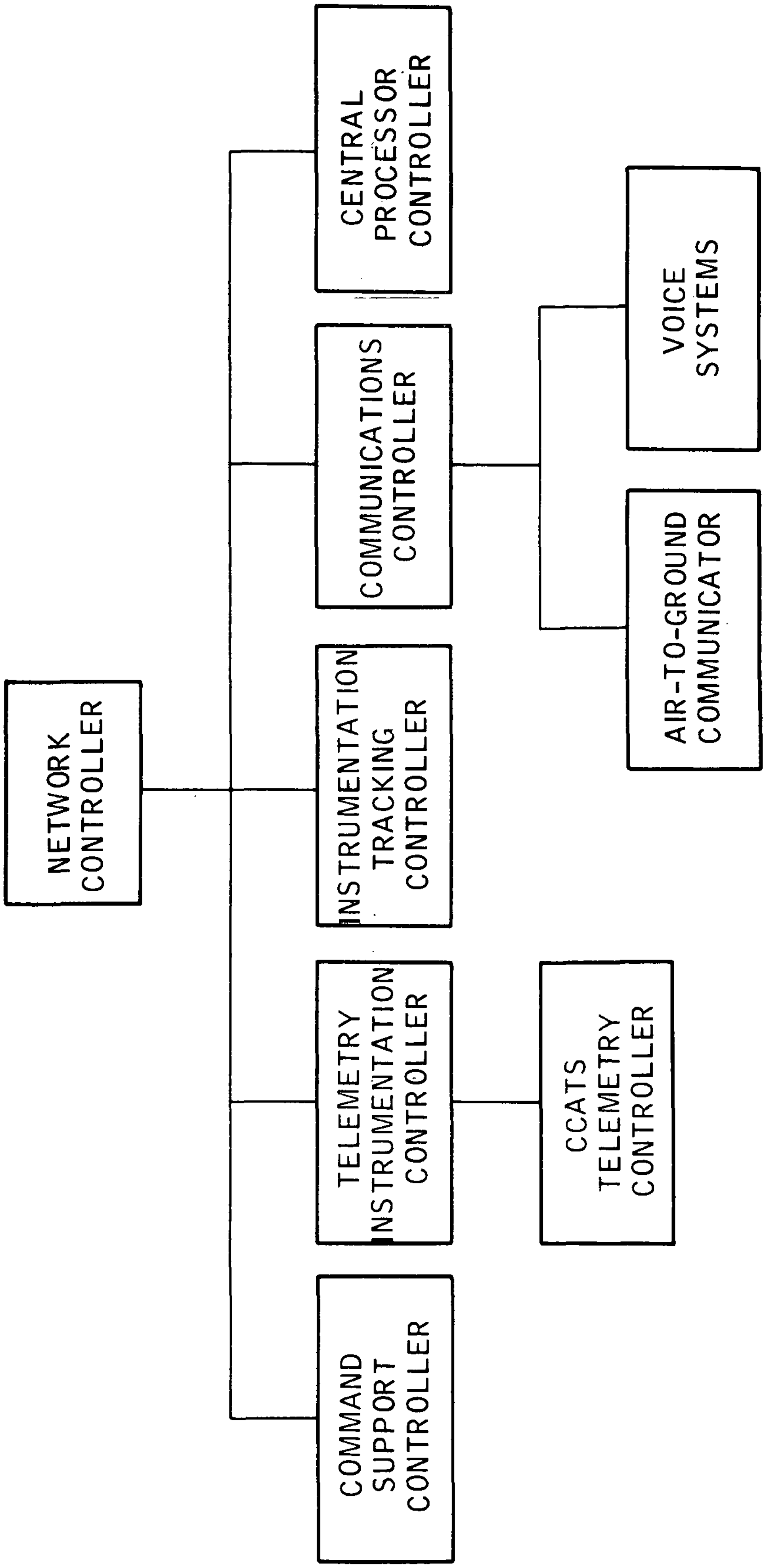


FIGURE 3.3-94

RTCC OPERATIONAL ORGANIZATION
FLIGHT TEST

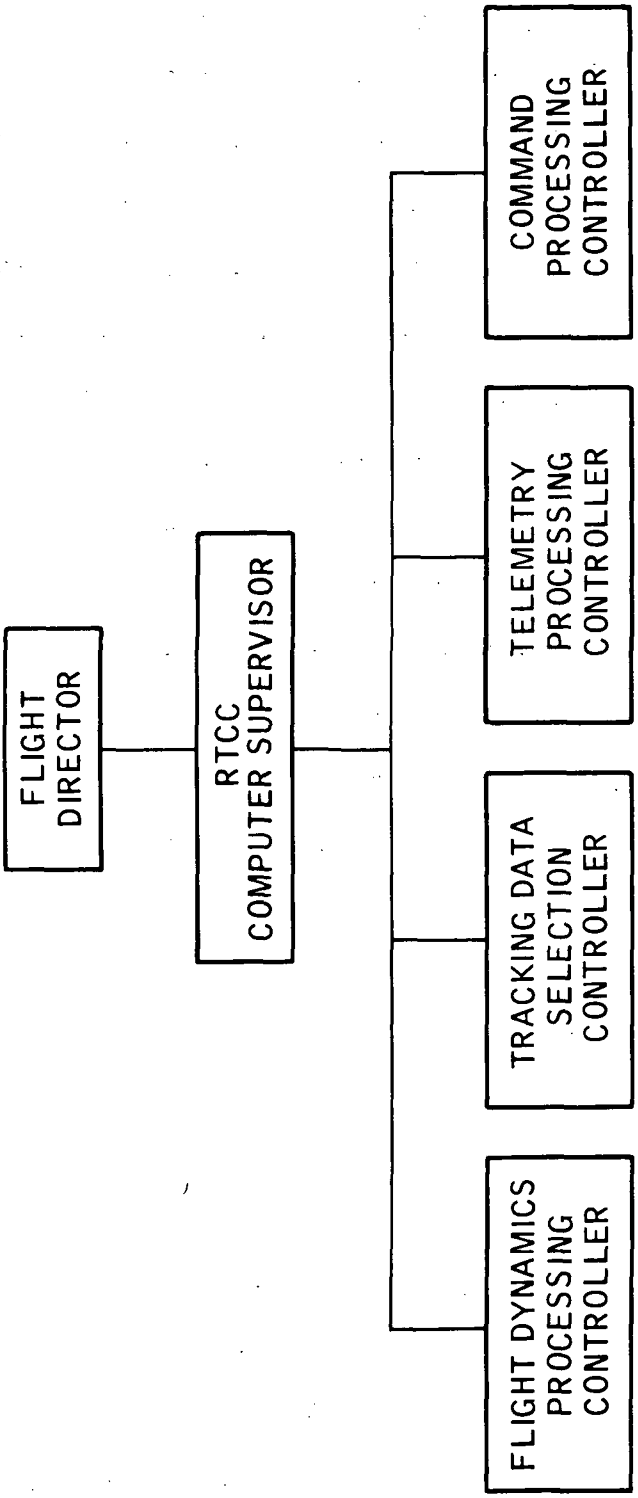


FIGURE 3.3-95

3.3.2.3 Mission Control Functions - Overall responsibility for the conduct of the Shuttle mission is vested in the Shuttle Command Pilot. He is responsible for insuring that mission objectives, or acceptable alternatives are met, if possible. The ground will have the capability to provide advice or consultations on procedural questions and systems or flight planning problems which may arise. The ground will coordinate and control the communications network in order to maintain voice and telemetry communication and interface with all outside agencies providing flight services. The ground will evaluate flight progress and flight crew status inputs via the voice link for mission progress assessment. In order to provide these capabilities, a Ground Mission Operations Center (GMOC) will be established. The GMOC will collect and store telemetry data. Data will be processed only upon crew request to provide advice or consultation.

All mission control functions are accomplished by flight crew analysis of the mission trajectory, vehicle systems, and flight plan through the use of the onboard trajectory, vehicle systems, and flight plan through the use of the onboard computer and display systems. The capability will exist, onboard, to achieve all functions necessary for:

- Trajectory control
- Vehicle systems management
- Real-time mission planning
- Flight progress monitoring and evaluation
- Crew and passenger status monitoring
- Communication control of onboard equipment.

The following sections outline the specific mission control functions and procedures that are accomplished during the ascent, rendezvous, orbital, deorbit and entry, and aerocruise and landing phases.

3.3.2.3.1 Trajectory Control - Trajectory control activities are those actions or functions necessary to predict and control the Shuttle's orbital path from liftoff to landing.

A. Ascent Phase - During the ascent phase of flight, the Inertial Measuring Units (IMU's) are the sole source of navigation information. Guidance of the mated vehicle is under control of the Booster. Ascent guidance equations will be programmed and stored in the central computers. As currently configured, no external navigation aids will be employed during this portion of the mission. A breakdown of the onboard and ground trajectory control functions follows:

Onboard

- Perform targeting computations based on ground supplied data (prelaunch)
- Align, calibrate, and verify inertial reference (prelaunch)
- Perform powered flight guidance, navigation and control
- Monitor several independent sources of trajectory data, compare with nominal and limit values to determine when an abort is required
- Make abort decisions
- Perform abort targeting

Ground

- Provide target trajectory data for prelaunch targeting computations
- Provide erasable load.

B. Rendezvous Phase - For rendezvous, the star tracker will be used to obtain relative angle information with respect to the target vehicle. Range to the cooperative target will be obtained via S-band ranging which is provided by the communications subsystem. The capability for planning and execution of the rendezvous maneuver sequence will exist onboard. Onboard and ground trajectory control functions follow:

Onboard

- Perform rendezvous navigation utilizing outputs of tracking systems
- Perform catchup targeting for adjusting the phase angle and orbital characteristics with respect to the target, Terminal Phase Initiation (TPI) targeting to place the Orbiter on an intercept course with the target, midcourse targeting to keep Orbiter on an intercept course, and targeting computations to brake the Orbiter into a station keeping mode with respect to the target.
- Perform powered flight navigation during thrusting maneuvers
- Perform automatic guidance and control of maneuvers with provision for crew manual takeover if necessary
- Perform inertial reference realignment, if necessary
- Perform station keeping navigation
- Maintain Orbiter in desired placement with respect to target during station keeping
- Perform docking and undocking maneuvers

Ground

- Provide solar flare monitoring data
- Coordinate and control communications network rendezvous progress via voice during MSFN station passes
- Provide target state vector for passive rendezvous
- Provide consultation with respect to systems, computational or procedural discrepancies upon request.

C. Orbital Coast Phase - The star tracker and horizon sensors will be used for attitude and navigation update information during the orbital coast phase of the mission. The horizon sensors will continually track the earth's horizon during all orbital phases (except maneuver phases) and supply horizon angular information relative to the navigation base. The star tracker will periodically track selected stars under computer control during all orbital phases. Subsequent processing of this information will provide the desired navigation information. To support the first orbital maneuvers, this processing of orbit navigation data must begin immediately after orbit insertion. This phase applies only to the Orbiter. Onboard and ground trajectory control functions follow:

Onboard

- Perform orbital navigation incorporating data from horizon scanners and optical trackers
- Perform pointing and acquisition for each navigational instrument
- Perform automatic realignment of the inertial reference using sequential star sightings
- Calibrate inertial reference using measured trend data
- Perform automatic vehicle attitude control

Ground

- Provide solar flare monitoring data
- Coordinate and control communications network
- Provide consultation with respect to systems, computational or procedural discrepancies.

D. Deorbit and Entry - The Orbiter deorbit and entry phase and Booster entry phase will be under control of the guidance computer. Inertial Navigation System information will be the primary source of navigation data being augmented in the Orbiter only by horizon sensor and star tracker data prior to entering the atmosphere and by the VOR/DME information when available. In order to control the growth of errors in the altitude channel during reentry, altitude will be determined by comparing measured drag with a model of drag stored in the computer. Accuracy of this technique is sufficient to limit the altitude channel errors. Onboard and ground functions during this phase are as follows, (deorbit functions are not applicable to Booster):

Onboard

- Perform entry targeting (Orbiter only)
- Realign inertial reference (Orbiter only)
- Maneuver and maintain Orbiter in desired deorbit thrust attitude
- Maneuver and maintain Booster and Orbiter in desired entry attitude
- Perform powered flight navigation during deorbit maneuver (Orbiter only) and entry (Booster and Orbiter)
- Perform orbital coast navigation when appropriate (Orbiter only)
- Perform automatic guidance and control of Orbiter deorbit maneuver and Booster and Orbiter entry
- Control transition maneuver from entry attitude to cruise attitude

Ground

- Coordinate and control communications network

E. Cruise and Landing Phase - This phase is applicable to both the Booster and Orbiter. It starts after the transition phase and terminates at the final airport landing. This phase includes both powered and unpowered cruise flight. Cruise navigation makes use of conventional VOR/DME navigation aids and barometric altimeter inputs. Landing aids include ILS and radar altimeter during flare. Onboard and ground trajectory control functions are as follows:

Onboard

- Perform powered flight cruise and landing navigation with airways and landing navigational aids
- Perform guidance and control in conjunction with ground advisories to perform necessary maneuver for attaining approach corridor
- Provide ATC data for ground controller
- Monitor for crew manual takeover during cruise, approach and landing
- Provide approach corridor guidance utilizing approach and landing sensors
- Provide throttle and aerodynamic interface control

Ground (ARTCC, ATC)

- Monitor cruise
- Provide ground aids for approach and landing
- Monitor other aircraft for area sterilization and collision avoidance
- Monitor landing and taxi
- Provide escort aircraft for weather radar data and communications

3.3.2.3.2 Systems Management - Systems management is the process of (1) monitoring the vehicle system/subsystems, (2) performing test and checkout of the systems/subsystems, (3) isolating abnormal situations and performing corrective action, and (4) configuring the vehicle as desired and maintaining cognizance of the configuration.

Responsibility for systems management will be onboard as provided for in the integrated avionics system design. Ground support of systems management will be provided on an on-call basis. The systems analysts will process the pertinent telemetry data that has previously been recorded and stored. These data combined with voiced information will provide the basis for a non-real-time evaluation of non-time critical events.

Systems Monitoring - Systems monitoring is required to maintain a watch on the health of the various vehicle systems and provide a means of distributing systems information to those who need to know. All vehicle systems are monitored on a regular schedule and their performance evaluated to detect abnormal situations. If an abnormal situation is detected, the monitor selects pertinent information, routes it to the proper alarm or display, insures that critical information does not go unnoticed, updates the onboard information files and logs the event.

The systems monitoring procedure is fully automated and operated by the onboard computer. Safety critical failures (actual or impending) will trigger visual and audible signals in the Emergency Caution and Warning (EC&W) system and request a recognition signal from the crew. Visual displays are programmed to present only that data necessary to support current crew activity and to monitor failures critical to the current mission phase or requiring crew corrective action. In addition, dedicated instruments, displays and alarms for selected safety parameters are driven by redundant sensors independent of the computer.

The ground will keep track of the onboard systems, primarily via voice contact with the crew. Systems data will be downlinked during MSFN station passes and stored in the GMOC for processing and display when so desired to support a crew request for assistance. In this manner the ground will have necessary vehicle status and performance discrepancy data in order to consult with the crew and to notify the Shuttle Ground Operations Support Facility of systems problems.

Test and Checkout - These functions include routine system tests, checks or operations necessary to maintain the vehicle systems operating at normal efficiency as well as special tests and/or checks prior to critical mission phases. If an abnormal indication is received, the computer is so informed and it notifies the systems monitor for display and proceeds with fault isolation and corrective action.

Each subsystem is checked out prior to operation. Selected subsystems and components supporting critical functions are checked out on a periodic basis. In general, the checkout function will be automated and will employ normal monitoring routines and subsystem self-test capability. In test modes requiring system stimulus, the crew will be alerted by alarm or display and the stimulus initiated (or not inhibited) by crew action at their discretion. If normal test modes are non-operating, the application of external stimuli on a non-interference basis is permitted. Preflight checkout will be performed using onboard built-in test equipment when feasible.

Fault Isolation and Corrective Action - Diagnostic and fault isolation routines will be performed by the computer to a level necessary to identify and initiate corrective action. The routines will be called up by the computer, or on command from the crew, when the systems monitoring and/or test and checkout functions indicate a discrepancy. Corrective action may be initiated by the crew or automatically. In general, the malfunction analysis will consist of voting between redundant units at the LRU level. Corrective action in most cases will entail automatic switch-over to redundant LRU's or subsystems. Multiple failures may require crew selection of alternate operating modes.

Identity of a failed unit will be logged in the GMOC from voice communication with the crew. The Shuttle Support Facility will be alerted for possible refurbishment preparation requirements. Upon crew request to investigate a problem, systems analysts will be called into the GMOC to support failure analysis and recommend corrective action.

Configuration Management - Configuration Management involves putting a system to the use for which it is intended, causing it to function in the intended manner and providing for normal utilization of system resources. In addition, it provides for verifying that a system is configured correctly and analyzes the usage rates of the system resources.

Configuration Management is controlled onboard by the computer. Mission rules, timelines, and procedures stored in the onboard computer will be compared to the crew and vehicle activity. If the configuration or flight mode does not correspond to the stored program data, the crew will be alerted by alarms and/or displays. If a time critical safety hazard exists, a preprogrammed alternate configuration will be initiated automatically by the onboard computer prior to crew notification. The actual consumables usage rates are compared against the flight plan nominal usages and future usage requirements by the onboard computer. If abnormal usage is detected which will compromise later mission events, the crew is notified so alternate plans can be initiated.

The GMOC has no responsibility for configuration management. However, the ground will maintain a log of the vehicle systems status and record T/M data for processing if requested by the crew.

3.3.2.3.3 Mission Planning - In-flight mission planning is required to enable the crew to change the nominal sequence of events in order to compensate for non-nominal happenings. Three distinct types of mission plans (other than the nominal) are recognized: (1) Backup plans - the mission objective(s) remains the same but the approach to performing the mission changes, (2) Alternate plans - the original mission objective(s) can no longer be met and different objective(s) are substituted together with an approach to performing the mission, (3) Abort plans - no mission objective can be accomplished and the Shuttle must return to earth.

Onboard mission planning is primarily computational with specific inputs and guidance from the crew. These computations will determine what type of non-nominal plan is possible, then formulate a new plan, recognizing all imposed constraints and reschedule the mission events corresponding to the new plan. Specific ground and onboard mission planning functions are:

Onboard

A. Using the insertion state vector and rendezvous target parameter, perform rendezvous planning and scheduling of each phase.

B. Provide backup rendezvous plans and a decision on the utilization of backup rendezvous plans when needed as a result of alarms received from rendezvous systems, violation of rendezvous constraints, or changes in mission parameters.

C. Schedule IMU alignments and sensor calibrations consistent with the mission schedule of burns and events and changes in the mission plan.

D. Maintain an estimate of the vehicle mass and inertial properties throughout the mission using RCS and main engine burn data and cargo loading data.

E. Select an abort strategy consistent with abort mission rules and schedule the abort function including mission sequencing after the abort maneuver.

F. Generate a deorbit/entry plan and schedule each deorbit maneuver utilizing an onboard state vector, the desired landing site coordinates and reentry guidance.

G. Provide backup deorbit plans and a decision on the utilization of backup deorbit plans when alarms are received from deorbit systems, deorbit constraints are violated, or deorbit parameters change.

H. When required, prepare alternate mission plans with support from ground.

Ground

A. Using updated ground constraints, target state vector, landing site coordinates, mission objectives and constraints, prepare preliminary trajectory plan for the entire mission during prelaunch to insure that the mission objectives will be met.

B. Provide crew consultation with respect to possible computational or procedural discrepancies as required.

C. Determine network coverage based on current mission plan and schedule communications with the Shuttle.

D. Maintain landing site weather and status information and select landing site alternates as required to meet non-nominal mission plans.

E. Provide objectives for alternate missions in the event the primary mission objectives cannot be met. Support flight crew in preparing alternate mission plan.

F. Provide target state vector and mission constraints for alternate mission.

3.3.2.3.4 Flight Progress Monitoring and Evaluation - Flight progress monitoring and evaluation is accomplished by comparing actual events or trends with those specified by the current mission plan. If events occur as scheduled and if forecast trends (i.e., consumables usage, trajectory, system configuration, etc.) are as planned, all is well. If events and trends are not as planned, an alternate mission may be planned, or as a last resort, the mission terminated.

Flight progress monitoring and evaluations rest primarily with the crew and their avionics interface. If an event does not occur as scheduled, it will be noted by the computer and flashed to the crew for action. The crew will monitor and evaluate flight progress in order to insure the safety and integrity of the crew and vehicle and to successfully accomplish the mission objectives. The ground will monitor flight progress in order to keep abreast of events as they occur, maintain current displays and consult with the crew on mission planning.

3.3.2.3.5 Flight Crew/Passenger Status Monitoring - For the logistics resupply mission, medical monitoring by the GMOC will be limited to voice contact with the flight crew for a status report on any health irregularities observed by either the flight crew or passengers. Onboard monitoring for this mission will be based on how the crew feels rather than on biomed instrumentation. In the event of a serious health problem, the most likely response would be to an abort return to Earth or docking with the Space Station. Crew members will receive some first aid training to carryover until a doctor can be reached just as commercial airline flight crews currently do.

For the 7 to 30 day missions, the problem is quite different. Development of symptoms to a point where an emergency exists will be more gradual and could go unnoticed by visual observers. Obviously, the greatest danger during the Shuttle mission would occur if one of the pilots is in trouble. Of concern also is the possibility of circulatory or physical deconditioning of passengers which might reduce their ability to withstand the reentry acceleration stress. The larger crew size including passengers, longer duration missions, greater autonomy, and the shirtsleeve environment all indicate decreased monitoring of the spacecraft personnel medical state from the ground. It appears likely that individually carried medical monitors and recorders can be developed which measure important body and environment conditions such as heart rate, respiratory rhythms, temperature, etc. and issue an audiovisual alarm if certain thresholds are approached for each individual. Recordings will be available to assist postmission diagnosis. The alarms will alert the individual and other space team members to the need for remedial action. An adequate in-flight emergency medical kit to deal with recognize problems is implied.

An automatic alarm system for monitoring the spacecraft environment will be contained in the systems management software/hardware configuration. This will be supplemented by the normal MCC solar flare monitoring function to provide advisory data to the crew of impending cosmic particle onset and/or geomagnetic storm activity.

The ECLS, food and water supplies (normal and emergency rations), personal hygiene and waste management arrangements and activity schedules aboard the Shuttle will still be of interest to the medical personnel. Data requirements for evaluating performance of the equipment during the development phase for medical interests will most likely coincide with the desires of equipment designers so that no additional in-flight data load will be imposed. Greater emphasis will be placed on obtaining performance data through realistic ground simulations with less reliance upon flight telemetered data.

On the longer duration missions, exercise equipment will be needed to maintain physical condition to be able to cope with reentry and recovery stresses. Diet planning and control procedures will be needed for prevention of poor morale or critical food shortages.

Data transmission from the Orbiter will be handled by voice communications since the crew will be trained in symptom description and in obtaining onboard medical measurements requested by a ground consultant, such as body temperature, blood pressure, pulse rate, etc. On the longer duration missions, voice status reports by the crew and passengers on the state of their health will be communicated to the ground on a periodic basis.

3.3.2.3.6 Communications Control - The baseline Shuttle communications system provides the necessary communication links between the Orbiter, Booster, ground and Space Station. This system includes capabilities for:

A. Two-way voice between:
  - Ground and Orbiter
  - Ground and Booster
  - Orbiter and Booster
  - Orbiter and Space Station

B. Orbiter to ground data link

C. Ground to Orbiter data or command link

During orbital phases, voice/data communications between the Orbiter and ground is accomplished via the MSFN stations making up the Shuttle mission operations communications net. Voice and data are carried on the Unified S-Band System

(USBS) and voice only can be carried by the UHF transceiver subsystem. All communications are limited to MSFN station passes, which could vary between two to ten minutes per station depending on orbit altitude and station location relative to the Orbiter ground track. In addition, up to six orbit gaps between passes can occur. Telemetry data is formatted and can be read out by the Orbiter during a station pass. The MSFN station will record the data, reformat it, and send it to GSFC for relaying to the GMOC - some in near real-time and some on a delayed playback basis. Command or uplink data, if any, is handled similarly but in reverse order.

During the cruise and landing phases, voice communications between the Orbiter or Booster and ground is via the UHF transceiver system with direct links to the Air Route Traffic Control Centers (ARTCC) and airport towers.

Communications control functions are primarily concerned with operation of the communications equipment, scheduling MSFN station passes and coordination with outside agencies. Each user is responsible for operating his own equipment, (e.g. power on/off, channel selection, monitoring, etc.). In addition, the ground is responsible for coordinating with the MSFN for station passes and with the FAA for filing of flight plans and obtaining landing clearances. During the cruise and landing phase, the onboard crew will talk directly to ARTCC and airport tower. The crew is responsible for closing their flight plan.

When a TDRS is available, all Orbiter/ground communications will be routed through it. The TDRS Central Control Facility (assumed at GSFC) will provide all necessary ground data handling. Shuttle will simply be another user of the system.

3.3.2.3.7 Payload Management - The variety of payloads available for Shuttle delivery requires the vehicle and the ground based mission support to perform certain functions to activate, monitor, deploy, separate and transfer control of the payload.

The Orbiter shall:

A. Deploy the payload from the stowed position to a position for separation
B. Monitor the payload for safety during prelaunch through deployment
C. Provide activation signals for those systems needed prior to separation
D. Verify with the ground via voice that the payload is ready for separation, if required
E. Separate the payload
F. Perform post separation activities as required
G. Move away from the payload
H. Station keep as required
I. Provide orbital retrieval
  (a) Sensors for rendezvous
  (b) Mechanism for capture
  (c) Provide hard points for tie down
  (d) Provide signals for powering down
  (e) Monitor secured payload

The ground based mission support or the payload itself shall:

A. Verify the payload is ready for separation, if required
B. Activate payload propulsion stages, as required
C. Monitor the payload for systems performance after activation
D. Control experiments/data
E. Terminate performance, as required

3.3.2.3.8 EVA Operations - The vehicle provides for these operations using the Airlock and a Portable Life Support System and tether. Pending pressure level finalization, prebreathing is assumed to be required. EVA activities will be performed by Cargo Handler crew members only, in order to minimize special training and hazards exposure of the flight crew. A UHF communications link between the EVA crewman and the Orbiter is provided. A typical EVA timeline is shown in Figure 3.3-96. The vehicle commander shall be responsible for assessment of EVA operations and the termination thereof if required. No ground support is required for EVA operations.

3.3.2.3.9 Flight Test Considerations - Responsibility for the conduct of the Shuttle development missions will be shared by onboard and ground operations until sufficient missions have been flown to demonstrate that the onboard systems are capable of flying autonomously. This does not mean that during the development missions the onboard systems will share functions with the ground; i.e., a portion performed by ground operations and a portion by onboard operation. Rather, it is envisioned that the onboard systems will be primary for all functions but the ground will process telemetry and tracking data in order to evaluate systems performance and to provide backup solutions and data should an onboard system not meet performance specifications. Ground operations will have the capability to provide state vector updates; evaluate vehicle systems performance; perform trajectory control, mission planning and flight planning; perform flight crew status monitoring; assess mission progress; coordinate and control the communications network; and interface with outside agencies providing flight services.

In order to provide these capabilities, a Flight Test Ground Mission Operations Center (FT/GMOC) will be established and manned during each development mission. The FT/GMOC will collect and routinely process all T/M and tracking

PRELIMINARY EVA OPERATIONS TIMELINE
USING PLSS TYPE EQUIPMENT

PRE EGRESS PREP	
o PRE BREATH 0^2	3 HRS*
o AIRLOCK PREPARATION	20 MIN
o EQUIPMENT PREPARATION	25 MIN
o DONNING LCG AND SUIT	20 MIN
o DONNING PLSS	25 MIN
o COMM CHECK	10 MIN
o INGRESS TO AIRLOCK	5 MIN
o FINAL SYSTEM PREP	25 MIN
o PRESSURE INTEGRITY CHECK	5 MIN
o CLOSE CABIN HATCH	5 MIN
o AIRLOCK DEPRESS	15 MIN
o OPEN TOP HATCH	5 MIN
o EGRESS	10 MIN
TOTAL =	3 HRS, 30 MIN

EGRESS OPERATIONS	
o DURATION	2.5 TO 3 HRS
TOTAL =	2.5 TO 3 HRS

POST EGRESS	
o INGRESS	5 MIN
o CLOSE HATCH	5 MIN
o REPRESS AIRLOCK	5 MIN
o OPEN CABIN HATCH	5 MIN
o DOFF PLSS	20 MIN
o DOFF PRESSURE SUIT	15 MIN
o RECHARGE PLSS	10 MIN
o STOWAGE OF PLSS AND SUIT	20 MIN
TOTAL =	1 HR, 25 MIN

*TOTAL TIME DEPENDENT UPON TYPE OF PRESSURE SUIT AND INITIAL CABIN PRESSURE. PRE BREATHING DONE IN PARALLEL WITH OTHER ACTIVITIES.

FIGURE 3.3-96

data necessary to verify proper vehicle systems and trajectory operation.

Mission control functions are accomplished onboard by flight crew analysis of the mission trajectory, vehicle systems, and flight plan through the use of the onboard computer, data management systems, and display systems. The capability will exist, both onboard and in the FT/GMOC, to achieve all functions necessary for:

- Trajectory control
- Vehicle systems management
- Mission planning
- Flight progress monitoring and evaluation
- Crew status monitoring
- Communications control

3.3.2.3.9.1 Trajectory Control - Trajectory control activities are those actions or functions necessary to predict and control the Shuttle's orbital path from liftoff to landing.

A. Ascent Phase - A breakdown of the onboard and ground trajectory control functions during the ascent phase follows:

Onboard

- Perform targeting computations based on ground supplied data (prelaunch).
- Align, calibrate, and verify inertial reference (prelaunch).
- Perform powered flight guidance, navigation, and control.
- Monitor several independent sources of trajectory data; compare with nominal and limit values and the ground to determine when an abort is required.
- Make abort decisions.
- Perform abort targeting.

Ground

- Provide target trajectory data for onboard targeting computations.
- Perform backup targeting computations.
- Provide erasable load.
- Perform abort monitoring.
- Monitor and maintain independent computations of launch trajectory using ship radar and telemetry data.
- Perform backup abort targeting.

B. Rendezvous Phase - The capability for planning and execution of the rendezvous maneuver sequence will exist onboard and in the FT/GMOC. Onboard and ground trajectory control functions are as follows:

Onboard

- Perform rendezvous navigation utilizing outputs of tracking systems.
- Perform catchup targeting for adjusting the phase angle and orbital characteristics with respect to the target, Terminal Phase Initiation (TPI) targeting to place the orbiter on an intercept course with the target, midcourse targeting to keep orbiter on an intercept course, and targeting computations to brake the orbiter into a station keeping mode with respect to the target.
- Perform powered flight navigation during thrusting maneuvers.
- Perform automatic guidance and control of maneuvers with provision for crew manual takeover if necessary.
- Perform inertial reference realignment, if necessary.
- Perform station keeping navigation.
- Maintain orbiter in desired placement with respect to target during station keeping.
- Perform docking and undocking maneuvers.

Ground

- Provide MSFN state vector updates as a backup to onboard navigation.
- Perform rendezvous targeting based on MSFN tracking for comparison with onboard targeting parameters.
- Monitor and evaluate rendezvous via voice, telemetry and tracking data received during MSFN station passes.
- Provide target state vector for passive rendezvous.
- Monitor rendezvous maneuvers.
- Provide consultation with respect to computational or procedural discrepancies.

C. Orbital Coast Phase - Onboard and ground trajectory control functions during the orbital coast phase are as follows:

Onboard

- Perform orbital navigation incorporating data from horizon scanners and optical trackers.
- Perform pointing and acquisition for each navigational instrument.
- Perform automatic realignment of the inertial reference using sequential star sightings.
- Calibrate inertial reference using measured trend data.
- Perform automatic vehicle attitude control.

Ground

- Provide external data for calibration of navigation sensors.
- Provide state vector updates as backup to star/horizon navigation.
- Provide consultation with respect to computational or procedural discrepancies.

D. Deorbit and Entry - Onboard and ground functions during the deorbit and entry phase are as follows, (deorbit functions are not applicable to booster):

Onboard

- Perform entry targeting.(Orbiter only)
- Realign inertial reference (Orbiter only).
- Maneuver and maintain Orbiter in desired deorbit thrust attitude.
- Maneuver and maintain Booster and Orbiter in desired entry attitude.
- Perform powered flight navigation during deorbit maneuver (Orbiter only) and entry (Booster and Orbiter).
- Perform orbital coast navigation when appropriate.
- Perform automatic guidance and control of Orbiter deorbit maneuver and Booster and Orbiter entry.
- Control transition maneuver from entry attitude to cruise attitude.

Ground

- Provide Orbiter with MSFN state vector updates prior to deorbit.
- Perform entry targeting as backup.
- Monitor deorbit maneuver.
- Monitor entry down to communications blackout.

E. Cruise and Landing Phase - Cruise and landing aids include VOR/DME, ILS and radar altimeter during flare. Onboard and ground trajectory control functions during cruise and landing are as follows:

Onboard

- Perform powered flight cruise and landing navigation with airways and landing navigational aids.
- Perform guidance and control in conjunction with ground advisories to perform necessary maneuver for attaining approach corridor.
- Provide ATC data for ground controller.
- Monitor for crew manual takeover during cruise, approach, and landing.

- Provide approach corridor guidance utilizing approach and landing sensors.
- Provide throttle and aerodynamic interface control.

Ground (ARTCC & ATC)

- Monitor cruise
- Provide ground aids for approach and landing.
- Monitor other aircraft for area sterilization and collision avoidance.
- Monitor landing and taxi.
- Provide escort aircraft for weather radar data and communications.

3.3.2.3.9.2 Systems Management - The onboard systems management functions will be the same as those described in 3.3.2.3.2.

Although a systems management capability will be provided both onboard and on the ground, primary responsibility for systems management will be onboard as provided for in the integrated avionics system design. During mated vertical test and early operational flights, ground support of the systems management functions will be provided in the FT/GMOC to backup the onboard capability until such capability has been satisfactorily demonstrated and verified.

A. Systems Monitoring - The ground will back up the onboard systems by voice contact with the crew and by monitoring downlinked data. Onboard display will be duplicated in the FT/GMOC as required and will be driven by the ground computer as a backup to the onboard system.

B. Test and Checkout - The ground will back up this function through voice communication and monitoring downlinked telemetry data.

C. Fault Isolation and Corrective Action - The ground will back up the fault isolation and corrective action functions through voice communications and by monitoring downlinked telemetry data. Additional malfunction analysis and consultation regarding corrective or alternate procedures will be provided to back up the onboard function on a continuous basis. Typically, the ground backup to onboard redundancy voting logic might consist of ground comparison of nominal and actual parameters of the unit under test.

D. Configuration Management - The FT/GMOC will back up the configuration management function through voice communication, monitoring downlinked telemetry data, and through ground computations.

3.3.2.3.9.3 Mission Planning - Inflight mission planning by ground mission operations will be required to provide backup or contingency mission plans and for comparison with onboard derived plans. Specific ground and onboard mission planning functions are:

Onboard

- Using the insertion state vector and rendezvous target parameter, perform rendezvous planning and scheduling of each phase.
- Provide backup rendezvous plans and a decision on the utilization of backup rendezvous plans when needed.
- Schedule IMU alignments and sensor calibrations consistent with the mission schedule of burns and events and changes in the mission plan.
- Maintain an estimate of the vehicle mass and inertial properties throughout the mission using RCS and main engine burn data and cargo loading data.
- Select an abort strategy consistent with abort mission rules and schedule the abort function including mission sequencing after the abort maneuver.
- Generate a deorbit/entry plan and schedule each deorbit maneuver utilizing an onboard state vector, the desired landing site coordinates, and reentry guidance.

- Provide backup deorbit plans and a decision on the utilization of backup deorbit plans when alarms are received from deorbit systems, deorbit constraints are violated, or deorbit parameters change.

Ground

- Using updated ground constraints, target state vector, landing site coordinates, mission objectives and constraints, prepare preliminary trajectory plan for the entire mission during prelaunch to insure that the mission objectives will be met.
- Perform independent nominal and backup rendezvous and deorbit planning and compare with onboard plans.
- Maintain an independent updated flight plan.
- Determine network coverage based on current mission plan and schedule communications with the Orbiter.
- Maintain landing site weather and status information and select landing site alternates as required to meet non-nominal mission plans.
- Provide objectives for alternate missions in the event the primary mission objectives cannot be met. Support flight crew in preparing alternate mission plan.

3.3.2.3.9.4 Flight Progress Monitoring and Evaluation - Flight progress monitoring and evaluation is accomplished onboard and in the FT/GMOC by comparing actual events or trends with those specified by the current mission plan. If events occur as scheduled and if forecast trends (i.e., consumables usage, trajectory, system configuration, etc.) are as planned, all is well. If events and trends are not as planned, an alternate mission may be planned, or as a last resort, the mission terminated.

If an event does not occur as scheduled, it will be noted in the FT/GMOC and by the onboard computer and flashed to the crew for action. The ground and crew will monitor and evaluate flight progress in order to insure the safety and integrity of the crew and vehicle and to successfully accomplish the mission objectives. Ground monitoring of flight progress will allow the FT/GMOC to keep abreast of events as they occur, maintain current displays, and consult with the crew on mission planning.

3.3.2.3.9.5 Flight Crew Status Monitoring - For the short duration development missions, medical monitoring by the FT/GMOC will be limited to voice contact with the flight crew for a status report on any health irregularities observed by the flight crew. Onboard and ground monitoring will be based on how the crew feels rather than on biomed instrumentation. In the event of a serious health problem, the most likely response would be to abort and return to Earth.

For the 7-day missions, it appears reasonable that individually carried medical monitors and recorders could be used. Data requirements for evaluating performance of the equipment during the development phase will most likely coincide with the desires of the equipment designers so that no inflight data load will be imposed. Greater emphasis will be placed on obtaining performance data through realistic ground simulations with less reliance upon flight telemetered data.

The ECLS system, food and water supplies, personal hygiene, waste management arrangements, and activity schedules will be of interest to ground medical personnel.

The FT/GMOC will monitor telemetry data on the environmental life support systems as a backup the spacecraft environmental automatic alarm system.

3.3.2.4 Landing Operations

3.3.2.4.1 General - The Space Shuttle vehicles shall normally land at the launch site, subject to emergencies and terminal area weather. Alternate landing sites for the Orbiter and Booster are required to provide for these contingencies. The Booster may land downrange on certain missions where cruise fuel is partially off-loaded to provide increased payload. The increase in payload can be used for heavy payload missions or to increase the Orbiter's on-orbit $\triangle$V capability to reduce reaction times for Space Station rescue missions. Also, expected bad weather at the launch site at Booster return time might cause the loss of a favorable launch window for a Space Station rescue mission unless downrange landing is utilized.

The vehicles shall be capable of night landing. Night launch typically results in night landing for Booster return, Orbiter ascent aborts (return to launch site) and Orbiter first revolution returns to launch site. Also, night landing capability increases mission flexibility by allowing use of all return opportunities.

The vehicles shall be capable of automatic transition, approach and landing. However, manual reversion will be possible at any time. Landing will be performed under VFR weather conditions at the onset of the program to provide the crew maximum visual cues to assess the performance of the automatic system. Landing in IFR weather shall be initiated after confidence has been established in the total deorbit and landing systems.

3.3.2.4.2 Orbiter Landing Operations

3.3.2.4.2.1 Orbiter Energy Management Phase - Before deorbit, the Orbiter crew will receive destination weather, NOTAMs and landing runway information.

They will insert landing runway touchdown coordinates into the onboard computers.

After deorbit, position updates will be automatically provided to the area navigation system from conventional VOR/VOR navigation aids until velocity is below 3000 ft/s (completion of transition). These updates will have begun after the vehicle passes the communications black-out regime. When the velocity is below 3000 ft/s, updates are provided from DME/DME navigation aids.

Automatic terminal area guidance will begin over High Key. High Key is approximately Mach 5, 100 nm from Low Key at 125,000 ft altitude. During transition, angle of attack is slowly lowered from 30 to 8 degrees. Guidance commands continue to be supplied to direct the vehicle inbound to the energy dissipation circle. Figure 3.3-97 shows a typical profile. The vehicle will be flown at near maximum L/D, thereby conserving energy until close to the airport.

The energy dissipation circle is approximately 70,000 ft radius from the Low Key. Normally this circle will be intercepted at approximately Mach 1 and 40,000 ft altitude.

The airbreathing jet engines, for those missions where they are installed, will be deployed, primed and started at the maximum practical altitude (between 30,000 and 40,000 ft). After determining satisfactory engine operation, thrust will be reduced to idle, unless required to extend glide range or execute a go-around.

When the vehicle can complete the approach at 70 percent of maximum L/D it is turned toward the Low Key position. Speed brakes are deployed to one-half and angle of attack is reduced to yield 70 percent of maximum L/D (approximately 6 degrees).

If no energy dissipation were required, the vehicle would head to the Low

ORBITER TERMINAL AREA GUIDANCE

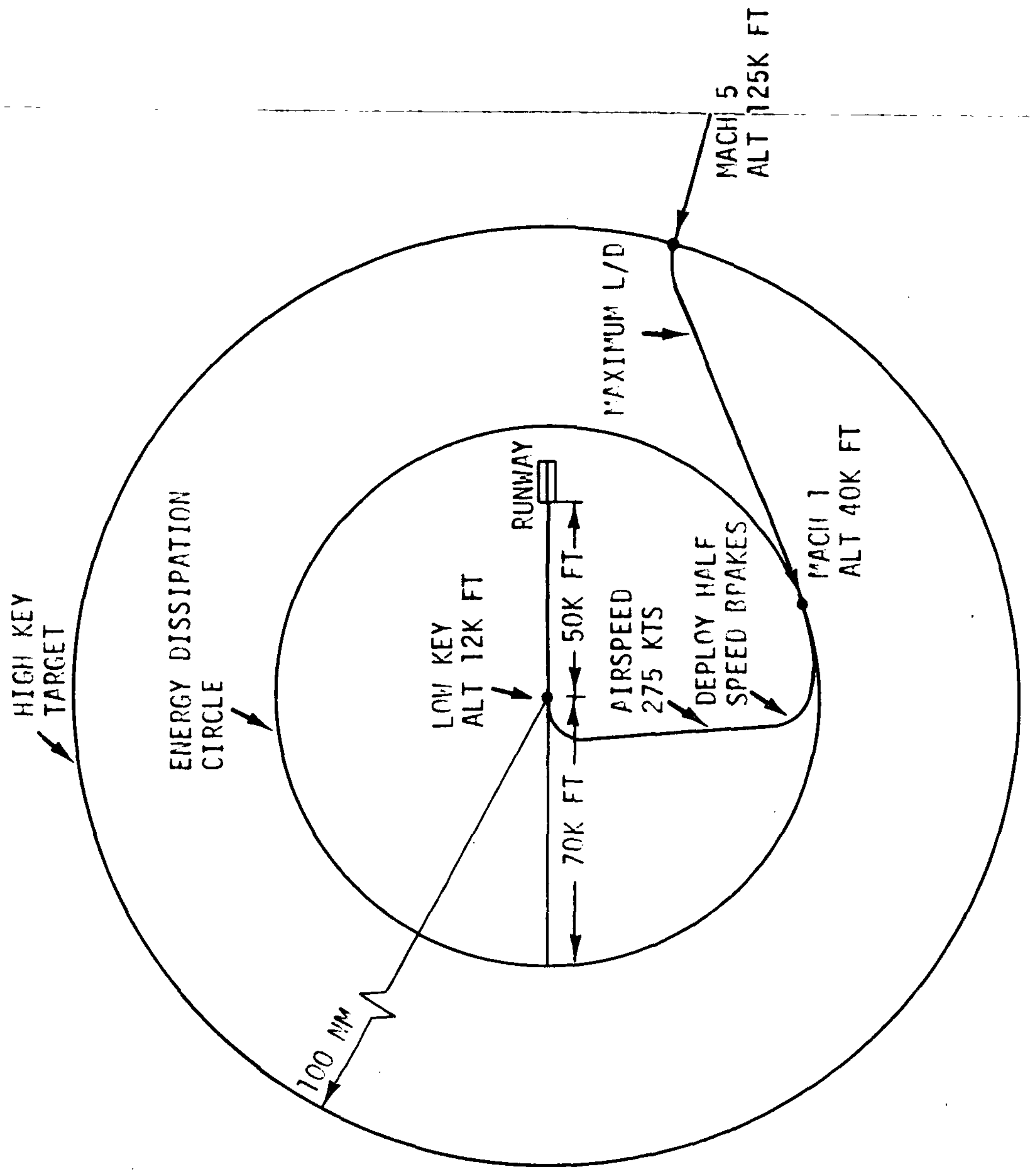


FIGURE 3.3-97

Key. The Low Key position is 50,000 ft distance from the touchdown area on the runway centerline extended. The heading to the Low Key position allows sufficient offset for a 30 degree banked turn to intercept the final approach heading.

3.3.2.4.2.2 Orbiter Final Approach - At KSC and all contingency airports, special use airspace as described in FAR Part 73, or its equivalent at foreign airfields, must be established. It will encompass a circle of approximately 25 nm radius about the airport. This positive control sterilized area will be activated from the start of deorbit to landing. Contact will be established and maintained with the tower.

A high energy approach will be executed to the destination field. Figure 3.3-98 shows a typical approach profile.

A conventional localizer will be used. The onboard computer will generate a glide slope of approximately 12 degrees using DME, barometric and radar altimeter inputs.

Before intercept of the localizer, all checklist items with the exception of landing gear and speed brakes will be completed (main propulsion purge done prior to deorbit, RCS safing, autoland system tested, landing winds inserted in the guidance computer and tower contact established, etc.).

Upon intercept of the localizer, at approximately 10,000 ft pressure altitude, with the speed brakes partially deployed, airspeed will be stabilized at approximately 275 knots. The speed brakes will then be automatically or manually modulated to maintain the vehicle's reference approach velocity.

3.3.2.4.2.3 Orbiter Landing - Initial landings will require CAVU weather (i.e., unlimited ceilings and visibility greater than 15 nm). However, as confidence is gained in the system, weather minimums will progressively be lowered to

ORBITER FINAL APPROACH AND LANDING

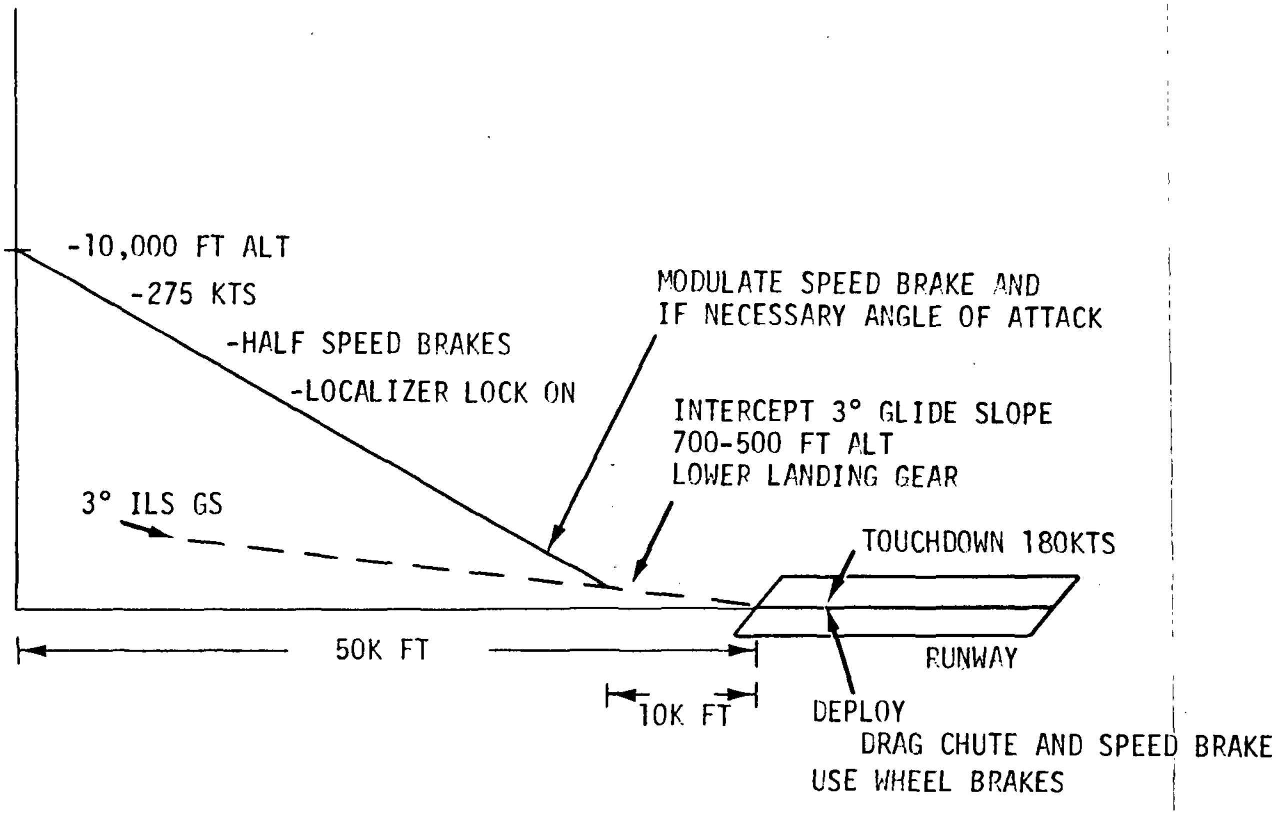


FIGURE 3.3-98

approximately 800 ft AGL and 1 mile visibility with Cat II operations feasible for emergencies. This will provide the pilot with the necessary see-to-land information during the flare.

At approximately 700 ft AGL the landing flare will begin. Intercept of the conventional ILS glide slope will occur at 500 ft. The landing gear is lowered and vehicle will then decelerate on the glide slope to the final landing flare. Touchdown will occur at 180 knots.

After touchdown the pilot will maintain directional control, apply wheel brakes, fully deploy the speed brakes and actuate the drag chute. After clearing the runway and releasing the drag chute, the vehicle will be taxied or towed to the maintenance safing and cooling area.

3.3.2.4.2.4 Orbiter Go-Around - If, on those missions where the ABES are installed, a go-around is required, two methods are available to the pilots.

An automatic mode of the autopilot, when initiated by the flight crew, will set takeoff thrust and adjust the vehicle attitude to maintain a 1.2 stall velocity (V_s) climb until the pilots either select a further mode of automatic operation or elect to fly the vehicle manually.

The flight crew has the option at any time to disconnect the autopilot and fly the vehicle manually. If a manual go-around is executed, thrust will be set to takeoff power, speed brake retracted, gear raised and attitude adjusted to maintain 1.2 V_s. The Orbiter will climb straight ahead to 400 ft AGL. At this altitude, airspeed is increased to 1.3 V_s and a 25 degree banked turn is initiated as soon as possible.

Altitude is then increased to 1000 ft AGL. On the down wind leg, power is reduced to maintain 1.3 V_s. Approximately four nm from the end of the runway a turn is commenced and gear lowered. The conventional localizer and glide slope is intercepted at approximately 3.5 nm.

3.3.2.4.3 Booster Flyback and Landing Operations

3.3.2.4.3.1 Booster Descent - Upon conclusion of the transition maneuver, the Booster will be in a subsonic, near maximum L/D glide and on a pre-programmed heading for return to the landing site. During the glide phase, vehicle systems status checks will be made and the airbreathing engines primed and the start sequence initiated at approximately 45,000 ft. After the computer has verified satisfactory engine performance exists, normal rated power will be established. A drift-down technique at maximum range airspeed (280 knots) will be utilized until the vehicle descends to its optimum cruise altitude.

An escort aircraft will be station keeping in the area of transition waiting to rendezvous with the Booster. UHF communications will be established with the escort aircraft as soon as possible. The escort aircraft will perform a flyaround inspection of the Booster to insure there is no structural damage which will jeopardize the flight to the launch site landing field. Since the Booster has no radar, the escort aircraft will also vector the Booster around any bad weather areas.

Upon reaching cruise altitude, the power will be set by the computer to maintain the maximum range airspeed.

3.3.2.4.3.2 Booster Cruise to Landing Site - During the cruise back, navigation updates will be made automatically from conventional ground based VOR/DME stations as they come into range. Updated navigation inputs can also be made based upon information supplied by the escort aircraft. The Booster flight path will be according to the pre-filed ATC flight plan. Deviations from the flight plan will be made, if necessary, in accordance with standard FAA or other controlling authorities procedures.

Position reports and other voice communications with appropriate air traffic control facilities will be conducted by either the Booster or the escort aircraft.

Escort Aircraft - The escort aircraft will have UHF and either or both of VHF and HF communications capabilities. The escort aircraft will provide the Booster with communications relay service, navigation information, visual air traffic avoidance assistance, and weather avoidance information. The communications relay service provided by the escort aircraft will be used for communications with the landing site during the entire flyback phase. Some of the reasons for Booster communications with the landing site are early notification of Booster emergencies and/or early notification of landing site anomalies. The escort aircraft will normally maintain visual contact with the Booster. Weather avoidance will be provided by directing the Booster through weather. The weather radar of the escort aircraft will be used to pick the best route through adverse weather. A safe vertical and horizontal separation distance will be used to provide spacing between the escort aircraft and the Booster, should instrument flight conditions be encountered.

3.3.2.4.3.3 Booster Terminal Area and Approach Procedures - All necessary vehicle preparations for landing will be made prior to the Booster's arrival in the terminal area. These preparations include vehicle peculiar operations such as main propulsion purge, RCS safing, etc., as well as the standard landing preparation of weather verification, systems checked, etc. In the terminal area the escort aircraft will provide the Booster with assistance as needed, i.e., communications relay, verification of navigation signals, etc.

From launch until after landing, the KSC or downrange landing airport special use airspace (FAR Part 73) will be activated. Positive control of the airport must be maintained to minimize the possibility of interference with the Booster landing. Radio contact will be established and maintained with appropriate air control facilities.

In the terminal area, the Booster will maneuver to either intercept the normal ILS glide slope or perform a straight-in approach. The Booster crew will complete the required checklists in preparation for approach and landing. The landing system will fly the vehicle to touchdown, with the flight crew closely monitoring system performance. The flight crew shall have the option of reverting to manual control.

3.3.2.4.3.4 Booster Landing - Upon touchdown, directional control of the vehicle will be maintained by the flight crew using rudder and nose wheel steering during vehicle roll-out. Immediately after touchdown, engine power will be brought to idle and the wheel brakes applied to stop the vehicle. The Booster will then taxi under its own power or be towed to the maintenance servicing and safing area.

3.3.2.4.3.5 Booster Go-Around - If during the approach, the flight crew elects to go-around, two methods are available to the pilots.

An automatic mode of the autopilot, when initiated by the flight crew, will set takeoff thrust and rotate the vehicle to the proper climb attitude. The vehicle will accelerate to and then maintain an airspeed of 1.2 V_s while climbing, until the pilots either select a further mode of automatic operation or elect to fly the vehicle manually.

If, during the approach, the flight crew elects to execute a manual go-around, the landing system will be disengaged, and the vehicle flown manually by the flight crew. The flight crew will set takeoff thrust, and rotate to the proper climb attitude. The landing gear will be retracted when a positive rate of climb is established. Climb out will be made straight ahead at 1.2 V_s to a minimum of 400 feet AGL. At the flight crew's discretion, but not below 400 ft AGL, a turn will be made to the down wind leg. Airspeed will be allowed to accelerate to 1.3 V_s. Upon reaching pattern altitude (approximately 2,000 ft AGL), power will be reduced to maintain level flight. At the appropriate distance from the approach end of the runway (depending on wind, weather, vehicle status, cause of the go-around, etc.), a turn will be made to intercept the ILS localizer and the landing gear lowered. The normal approach and landing procedures will be followed using either the automatic landing system or manual control.

3.3.2.4.4 Ferry Flight

3.3.2.4.4.1 General – Vehicle ferry flights will be required from the manufacturing facility (KSC) to the flight test and/or launch sites. Normal as well as contingency landing operations may also require ferry of both Booster and Orbiter.

3.3.2.4.4.2 Preparations – When ferry becomes necessary a maintenance team will fly in with applicable kits and GSE equipment. This will include an ATC transponder and a strap-on engine for the Orbiter. They will perform the necessary postflight and preflight servicing to ready the vehicle for flight.

The ferry flight crew may also be flown in depending on the circumstances surrounding the flight. The flight crew will review flight data including weather information and NOTAMs. They will review the flight plan and dispatch release prepared by the GMOC. The necessary takeoff computations and crew briefing will be completed.

The flight will be a cruise climb from about 23K ft to 26K ft for the Orbiter (17K to 22K with one engine out) and 19K ft to 24K ft for the Booster (15K to 20K with one engine out). Flight will be restricted to daylight VFR non-icing conditions with an escort aircraft. The flight plan will be by the most direct route considering terrain clearance and will not necessarily be on established airways. Stage length will be a maximum of 450 nm for Booster and Orbiter. Consideration will be given to in-flight refueling to increase range. Typical routing to Edwards from the manufacturing facility at KSC is shown in Figure 3.3-99. The flight plan will be filed with the appropriate authorities. To assist the ATCC in following the flights, the Booster and the Orbiter will be equipped with Air Traffice Control (ATC) transponders for all ferry flights. Also, ATC transponders are required by the FAA at certain airfields and are "favored" at any controlled airport.

All preflight, with the exception of a gross scrutiny check, will be completed by the ground crew. The flight crew will complete a checklist similar to that used on a transport aircraft in preparation for departure. Engine start will not be commenced until all preparations for flight, including flight clearance and escort aircraft airborne, are completed. Taxi will be minimized (or eliminated by towing) to save fuel.

3.3.2.4.4.3 Takeoff and Climb - Takeoff will be similar to that of a conventional large transport aircraft at maximum gross takeoff weight. During takeoff the safe decision speed concept (V_1) will be used. If an engine should fail or other such contingencies should occur before this speed, the vehicle will be stopped on the available runway. If a contingency occurs after this speed, the vehicle must continue the takeoff.

After takeoff, landing gear will be raised as soon as possible and a climbing turn made to the desired heading. The vehicle will then take a moderate time to achieve cruise altitude. The escort aircraft will rendezvous and provide the same functions as during Booster cruiseback.

TYPICAL FERRY ROUTINGS AND LANDING SITES

FLIGHT LEG	DISTANCE ~N M	RUNWAY DIMENSIONS ~FEET	FIELD ELEVATION ~FEET	RUNWAY WT. BEARING CAPACITY – POUNDS (TWIN TANDEM GEAR)
CAPE KENNEDY		TO BE CONSTRUCTED	APPROX S.L.	TO BE CONSTRUCTED
TO EGLIN AFB	340	12,000 x 300	85	500,000
TO BLYTHEVILLE AFB	440	11,600 x 300	255	455,000
TO SHEPPARD AFB	440	13,100 x 300	1015	540,000
TO BIGGS AAF	420	13,572 x 300	3947	440,000
TO YUMA MCAS	420	13,300 x 200	213	410,000
TO EDWARDS AFB	210	15,000 x 300	2302	560,000

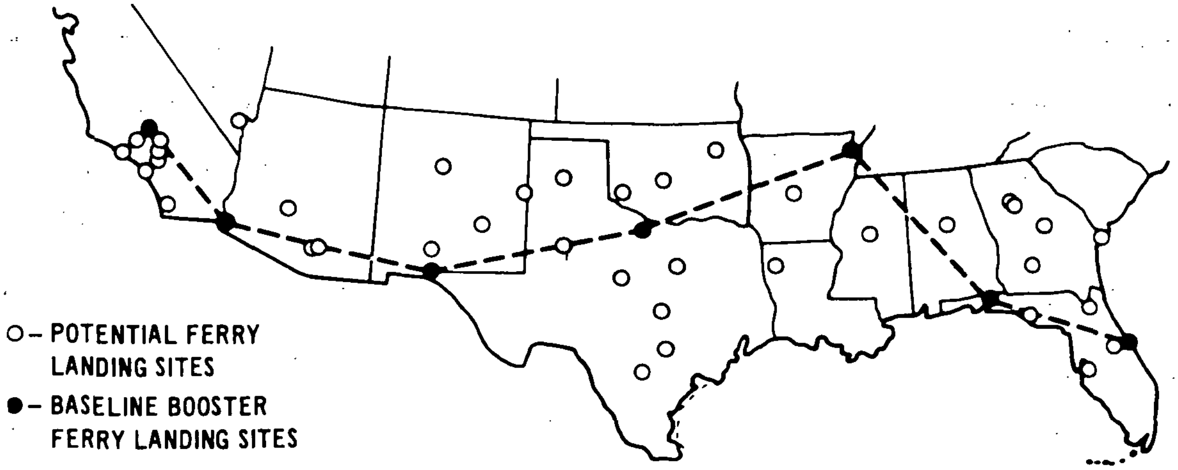


FIGURE 3.3-99

3.3.2.4.4.4 Cruise - The primary focus during cruise is accurate navigation and fine tuning of vehicle performance. The IMU systems with area navigation display will provide navigation for the stage length without updates. However, navigation updates may be made automatically from conventional ground based VOR/DME stations.

Position reports and deviations from the flight plan will be reported to the FAA or other controlling authorities. A continual check will also be maintained of the nearest suitable emergency landing field as the flight progresses.

3.3.2.4.4.5 Terminal Area and Approach Procedures - All necessary vehicle preparations for landing will be made prior to the vehicle's arrival in the terminal area. In the terminal area, the escort aircraft will provide assistance as needed to help minimize the possibility of a go-around.

In the terminal area, the vehicle will maneuver to intercept the normal ILS localizer and glide slope. The crew will complete the required checklists in preparation for approach and landing. Landing gear will be lowered sufficiently early in the approach to allow for alternate extension methods, if required. An automatic or manual landing will be made. Landing and go-around similar to that described in 3.3.2.4.2.3, 3.3.2.4.2.4, 3.3.2.4.3.4 and 3.3.2.4.3.5 will be performed.

3.3.2.4.4.6 Subsequent Flights - For landings at other than final destination, routine servicing and maintenance will be performed by maintenance personnel and GSE equipment carried in the escort aircraft. The preflight, preparation, etc., will then be repeated until arrival at the desired destination.

3.3.2.5 Abort

3.3.2.5.1 General - Abort operations for both the Booster and the Orbiter are described in the following paragraphs. A detailed description of the intact abort capability is provided in MDAC Memo Number SSPI-E450-584.

3.3.2.5.2 Booster

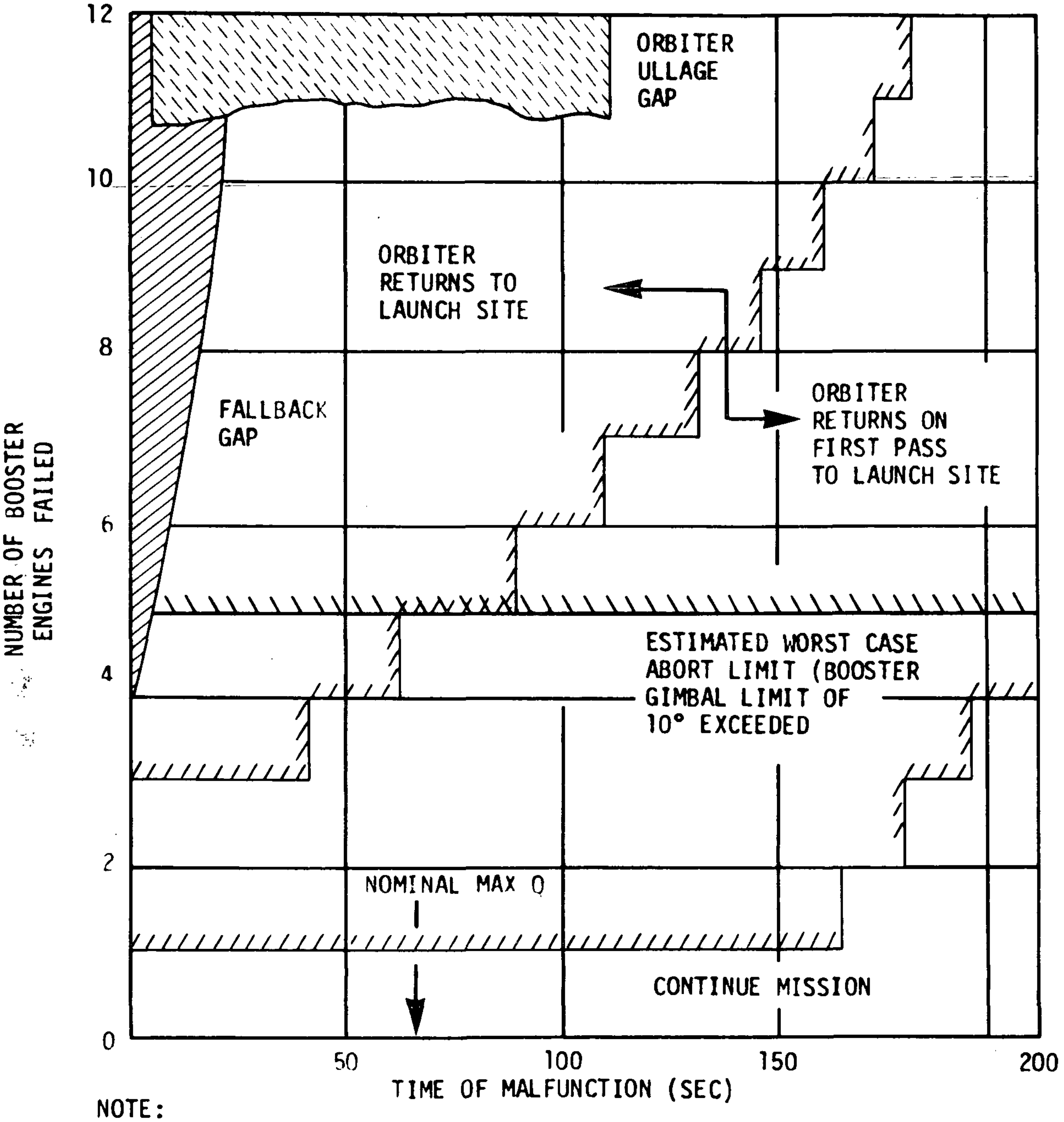
A. Capability - The baseline Canard Booster, which is used with the high crossrange Orbiter, has the basic performance capability to return to the launch site provided all engines do not fail. However, for certain combinations and numbers of main engines out, thrust-to-weight ratio and/or control requirements may preclude an intact abort as shown in Figure 3.3-100. Since the baseline Booster does not have propellant dump capability, the unused main propellant at the time of abort initiation must be burned out in an abort maneuver in such a manner that the Booster can enter and cruiseback to the launch site. Study results to date indicate that this is possible as long as the vehicle is controllable and a thrust-to-weight ratio of approximately one exists at the time of abort. If all engines fail, the Booster will be lost.

Failures of other systems may cause aborts although single or even double failures would not usually result in an abort because of the level of redundancy designed into the vehicle.

B. Operational Approach - Booster abort monitoring is envisioned as an onboard function. The onboard avionics will have the capability to perform the trajectory control function, the Guidance, Navigation and Control (G,N&C) system evaluation function and management and monitoring of other vehicle systems including propellant management. The trajectory control function will include (a) determining

ABORT CAPABILITY

(FOR BOOSTER ENGINE FAILURES)



NOTE:

- BOOSTER RETURNS TO THE LAUNCH SITE FOR ALL ABORTS
- SHOWN FOR EASTERLY MISSION

FIGURE 3.3-100

the trajectory from several independent sources (the redundant guidance and navigation systems), (b) evaluating the trajectory by comparing it with nominal values and limit lines and informing the flight crew when trends indicate a limit value is being approached, (c) planning and computing plans of action for aborts, and (upon approval by the flight crew), (d) execution and monitoring of the plan of action. The evaluation of the G, N&C system would include comparison of system outputs from several systems (possibly including Orbiter systems), switchover when the primary system performs unacceptably, and informing the flight crew when sufficient failures have occurred to warrant an abort. Management of other vehicle systems will include verifying proper system configuration, systems performance checks, malfunction detection and switchover, and informing the flight crew when sufficient failures have occurred to warrant an abort. When an abort is required, the appropriate action is displayed to the flight crew who in turn approves execution of the abort mode. Booster propulsion failures will result in continuing to burn in the mated configuration (unless all engines have failed), giving a greater-than-nominal downrange travel at staging but a lower staging velocity. This combination allows limiting the maximum downrange travel to be no greater than the nominal value (450 nm). Flyback to the launch site is then performed just as in the nominal mission.

3.3.2.5.3 Orbiter

A. Capability - The launch abort capabilities of the high crossrange Orbiter is shown in Ref.Fig.3.3-100 for the nominal mission. The initial 20 seconds of flight is an intact abort gap due to fallback limits for failure of 4 or more Booster engines. The high crossrange vehicle has the basic performance capability to abort and return to the launch site at any point from the fallback limits to approximately 185 seconds. From approximately 185 seconds to orbit insertion ($\approx$ 400 seconds), the Orbiter has the capability of returning via a once-around orbit to the launch site. The abort to a once-around orbit capability requires that approximately 1300 ft/s of on-orbit propellant be used. If both Orbiter engines fail at any time from staging to just before insertion, the vehicle is lost because the Orbiter does not have propellant dump capability. From approximately 30 to 120 seconds from liftoff, if all Booster engines fail, the abort capability of the Orbiter is constrained by propellant positioning required to start the engines.

The abort capability for missions other than the nominal mission is limited by the amount of OMS propellant available. Obviously, if enough propellant is available, the same abort-to-orbit capability employed for the nominal mission is used.

B. Operational Approach - Based on the capability described above, Orbiter abort modes have been defined as shown in Figure 3.3-101. Mode I covers the failure of a sufficient number of Booster engines to preclude continuing the mission but few enough to allow return on the first pass. Mode II covers failure of a sufficient number of Booster engines to preclude a return on the first pass and Mode III covers failure of one Orbiter engine.

As with the Booster, the Orbiter abort monitoring is envisioned as an onboard function. When an abort is caused by a Booster failure and a

ORBITER ASCENT ABORT MODES

MODE	FAILURE	TIME	ACTION REQUIRED
Mode I	$C_1 < N < C_2$	0-200 SEC	Burn booster propellant to depletion with remaining engines, stage, and target orbiter burn for a first revolution return using some OMS propellant.
Mode II	$N > C_2$	20-185 SEC	Burn booster propellant to depletion, if possible separate and burn main engines to achieve a trajectory from which entry and landing at the launch site is possible.
Mode III	One orbiter engine out - OMS propellant available	200-400 SEC	Burn remaining engine and OMS engines to achieve a once around return.

Definitions:

N - number of booster engines failed.

C_1 - number of booster engines which, when failed, preclude continuing the mission nominally but allow insertion into a first revolution return orbit.

C_2 - number of booster engines which, when failed, preclude insertion into a first revolution return orbit.

FIGURE 3.3-101

plan of action is displayed to the Booster crew, a corresponding display is provided to the Orbiter crew with an Orbiter plan of action. The Booster crew will make the abort decisions (prior to staging) and will inform the Orbiter crew of this decision. Each crew then proceeds to implement the abort plan. Following staging, the Orbiter will be responsible for decisions relative to Orbiter aborts. Again, the onboard avionics will monitor trajectory and systems data, compare outputs against nominal and limit values, determine when an abort is indicated, and present a plan of action for crew approval.

Aborts from orbit will be planned when any critical system is in its fail safe mode, since one additional failure could be catastrophic. The minimum acceptable time from abort decision to deorbit maneuver has not yet been determined, but it is felt that a four hour wait is acceptable. Of course, more frequent return capability is desirable for developmental flights. A study described in Reference NASA MSC-02666 has revealed that a set of four sites (KSC; Bergstrom AFB, Texas; Hickham AFB, Hawaii; Angerson AFB, Guam) around the world will provide at least a once-per-four hour return opportunity for all Shuttle orbits. This frequency is probably desirable for early flights but it is expected that it can be relaxed as the program progresses. Return opportunities are most valuable early in the mission and return to the launch site or at least to the Continental U.S. is always preferred over return to world-wide fields. Figure 3.3-102 summarizes first and second revolution return opportunities to the Continental U.S. launch site for launches from KSC, White Sands, and WTR.

LAUNCH AZIMUTHS LIMITATIONS FOR CONUS RETURN CAPABILITY

LAUNCH FROM	1ST REV RETURN HIGH CROSSRANGE	2ND REV RETURN HIGH CROSSRANGE
KSC	ALL AZIMUTH	ALL AZIMUTH
WHITE SANDS	ALL AZIMUTH	ALL AZIMUTH
WTR	ALL AZIMUTH	15° - 110° 195° - 300°

FIGURE 3.3-102

3.3.2.5.4 Water Ditching or Unprepared Surface Landing

3.3.2.5.4.1 General - Although the probability of a water ditching or unprepared surface landing is low, the possibility exists and appropriate contingency plans must be developed. The generation of pertinent emergency checklists is dependent upon final vehicle design, but general ditching technique guidelines are applicable.

3.3.2.5.4.2 Preparation - The time available for preparation prior to a ditching or unprepared surface landing varies with the circumstances surrounding the emergency. If time is of the essence, only the most critical items will be accomplished. Time permitting, the preparation phase will include:

- Send distress message
- Head for the best ditching area, if possible
- Determine optimum ditching heading
- Alert passengers
- Jettison all possible weight
- Determine minimum touchdown airspeed
- Secure all loose items
- Position survival equipment for emergency egress
- Maximize water tight integrity, if applicable
- Don personnel floatation gear - if water ditching
- Accomplish normal procedural steps for landing

3.3.2.5.4.3 Final Phase - Normal landing techniques will be utilized on the approach and landing. The final phase will include:

- Landing gear UP
- Warn passengers to brace for impact
- Minimum rate of descent and airspeed for touchdown.

3.3.2.5.4.4 Vehicle Egress - Evacuation of the vehicle should not commence until all forward motion of the vehicle has stopped. The vehicle evacuation phase will encompass:

- Open hatches
- Crew members and passengers egress with survival kit via inertia reel emergency descent device
- Swim clear of vehicle, if on water
- Inflate and board life rafts, if applicable
- Commence survival phase

3.3.2.5.4.5 Search and Rescue - The Space Shuttle System will utilize the international Search and Rescue (SAR) organization which presently exists for international commercial airline flights. This SAR system includes a network of Rescue Coordination Centers (RCC's). These RCC's have the responsibility, authority, and facilities to coordinate SAR efforts within their respective geographic areas. When an incident occurs, the RCC has a number of dedicated primary SAR aircraft and ships with which to initiate immediate action. The RCC's also have the capability of diverting commercial aircraft or ships in the vicinity of a distressed vehicle to assist in a coordinated effort.

For the areas in which an ICAO SAR capability does not exist, contingency plans will be developed, supported by DOD forces.

3.3.2.6 Training

3.3.2.6.1 Flight Support Personnel Training - The current ground support plan requires that only two consoles be manned continuously in support of the Shuttle missions. These two positions are manned by a Flight Director and a Communicator. The Communicator will probably be drawn from the flight crew ranks. The Flight Director will have, on call, four systems experts for consultation in the event of a problem. It is assumed that the ground network for the Shuttle Program already exists and only minimal Shuttle related training is necessary for those personnel. It is recommended that the approximately 12-16 ground support personnel to be trained be sent to flight crew basic and recurrent training as necessary and that no formal ground support training program be instituted.

For the flight test phase, a ground controller training program similar in scope to Apollo/Skylab training program will be required.

3.3.2.6.2 Flight Crew Training

3.3.2.6.2.1 General - The flight crew training program presented in this section pertains to training pilots for routine Shuttle operations. The Shuttle R&D phase will be flown by highly qualified astronaut/test pilots. As in the development of any new vehicle, the project astronaut/test pilots will be assigned early in the program. They will assist in design development, systems display requirements, cockpit layouts, procedures development, etc. At the completion of the R&D phase, the project astronaut/test pilots could provide a cadre of experienced pilots for Shuttle operations.

The operational Shuttle pilot training program is divided into 2 phases:

- basic training
- recurrent training

The basic training develops candidate Shuttle pilots for routine Shuttle operations. Upon completion of basic training the Shuttle pilots progress to an operational flight status where they undergo recurrent training prior to every flight. The recurrent training is interwoven with the operational requirements for backup crews, rescue crews, etc. so that the maximum training benefit is derived from the fulfillment of these operational requirements.

To provide operational consistency and to reduce time and unnecessary expenses, the Shuttle flight crew training is oriented to training pilots as vehicle operators only. Scientific experiments and nonpiloting tasks are to be performed by other appropriately trained personnel. The training program also trains Shuttle pilots to operate only one type vehicle at a time, Booster or Orbiter.

3.3.2.6.2.2 Basic Training - Only scheduled activities are delineated in the basic training syllabus presented below. However, the training pace is such that time exists for the many hours of unscheduled activities, i.e. study, physical conditioning, etc., that are an important complement to the training program. Once a cadre of Booster and Orbiter pilots is operational, new Shuttle pilot trainees would undergo General and Booster Specialized training. The future Orbiter pilot corps would be staffed by Booster pilots transitioning to Orbiter pilot status.

General	Basic Training (hours)
Indoctrination	20
Academic	90
Special Purpose	60
Flight Operations	10
Other	20

Specialized	Booster	Orbiter	Booster pilots upgrading to Orbiter pilots
Vehicle Systems	120	120	80
Special Purpose	10	40	30
Flight Operations	20	30	10
Vehicle Cross Training	12	12	--
Simulator	~150	~400	~200
	500+ ≈ 6 Mo.	800+ ≈ 10 Mo.	300+ ≈ 4 Mo.
	Into Booster Operating Cycle	Into Orbiter Operating Cycle	

Notes:

1. Booster operating cycle provides further training prior to each flight.
2. Orbiter operating cycle provides further training prior to each flight.
3. Specialized training is oriented towards specific vehicle types.
4. Indoctrination - introduction to program, review of space programs to date, etc.

   Academic - Space sciences, astronomy, physiology, meteorology, mathematics review, rocket theory, etc.

   Special Purpose - 'O'g, centrifuge, fire training, etc.

   Flight Operations - satellite systems, network relay, GMOC, mission profiles, etc.

   Vehicle Cross Training - Booster/Orbiter pilots introduced to Orbiter/Booster vehicle, operations, etc.
5. All simulators and Shuttle configured aircraft used for training will have cockpits that are replicas of the operational vehicle, including operational hardware in a mission simulator. The ground simulators are to be used for emergency and malfunction training as well as nominal operation and the Shuttle configured airplane used for nominal atmospheric flight training.

3.3.2.6.2.3 Recurrent Training - After completion of the basic training program, Booster and Orbiter pilots are assigned to the respective operating flight line. Prior to every launch, each Booster and Orbiter pilot undergoes a recurrent training program to ensure his preparation for the flight. The majority of recurrent training should be concentrated upon simulation of critical flight phases. So that maximum training benefit is derived from the various operational requirements for backup crews, rescue crews, etc., these requirements should be interwoven within the recurrent training program. The amount of annual training received by any crewmember is a function of how frequently he flies.

The recurrent training prior to each flight should consist of:

- Proficiency Training - Vehicle systems, flight rules, operating procedures, abort and emergency training are reviewed.
- Backup Training - Concentrated on simulator and Shuttle configured airplane training of critical flight maneuvers and emergencies.
- Prime Training - Same as backup training, but conclude with the mission launch.

A typical crew recurrent training cycle could encompass several weeks of training and operational duties, prior to a 1 week fly period. The training starts with a week of proficiency training. This is followed by several days of backup training. The backup training is identical and concurrent with prime training. This assures a backup crew available to assume the launch or replace individual prime crew members. The next function performed by a crew could be that of a rescue duty crew. The assigned rescue crew would also be available for other missions support duties. Following the rescue duty a crew becomes the prime crew for the next mission, and undergoes prime training for this mission. The prime training culminates with the mission launch. After the 1 - 7 day flight the returning crew is unscheduled for a several week period. This period allows R & R, annual vacations, time for military duties, etc. This period also allows for scheduling flexibility, restructuring of crews and a realistic launch frequency per crew.

Interspersed throughout the schedule should be off periods to provide further schedule flexibility, outside activities, and a realistic training pace.

Once a crew starts the training cycle, it should continue through the entire program to culminate in a launch. It is considered essential to properly train each crew prior to every launch.

A nominal Booster flight has fewer critical flight phases than a nominal Orbiter flight, and consequently the Booster pilot recurrent training program could be shorter than the Orbiter pilot recurrent training program.

3.3.2.7 Mission Simulator Requirements - The mission simulator would consist of an Orbiter simulator and a Booster simulator at the same location that can operate either independently or in an integrated mode for combined missions. High fidelity simulation of all horizontal and space flight phases and of all onboard systems is required for effective flight crew training. Accurate out-the-window visual scenes would be provided for earth reference, star scene, orbital maneuvers relative to other vehicles and ILS approaches. Motion simulation is desirable for training on specific emergency and critical maneuvers such as thrust loss, but trade studies will be performed to determine whether motion is cost effective. The size of the cockpit and nature of the mission permits instructors to be located in the cockpit with all the advantages of direct trainee observation and guidance and good visual presentation. This technique is heavily utilized by commercial airlines such as PAA. Trade studies would include evaluation of various part-task simulation approaches, and would be directed toward development of the most cost effective mission simulator.

Mission simulation requirements are discussed for each of the following elements:

A. Flight Displays and Controls

B. Out-the-Window Displays

C. Kinesthetic Effects

D. Audio Communications

E. Sound Environment

F. Instructor Consoles

G. Telemetry and Tracking Interface

H. Booster/Orbiter Interface

I. Cockpit Interface Subsystem (On Board Computer)

J. Simulation Computer Complex

Signal flow between the elements of the Orbiter simulator and the trainee and instructional staff is illustrated in Figure 3.3-103. The Booster simulator signal flow would be similar.

A. Flight Displays and Controls - The forward crew positions in the Orbiter and the Booster and the docking position in the Orbiter would follow the exact arrangement of the flight vehicles. The desirability of duplicating cargo handler positions would also be studied. Flight hardware would be used wherever practical, but care would be taken to examine the life of each instrument to ensure that it is long enough for the additional cycling always incurred in the simulator. Feel system mechanisms from the flight vehicles would be used wherever this is consistent with high fidelity feel simulation. Simulation of the G effects on the flight controls could (depending on their final design) require artificial hydraulic or electric loading systems to be used on the simulator even when none is required in the aircraft.

It appears very probable that the CRT display systems, especially those with back projected slide information would have to be flight hardware due to the unique nature of their design. The cockpits would not be pressurized, but the life-support system control panel would be simulated.

ORBITER SIMULATOR BLOCK DIAGRAM

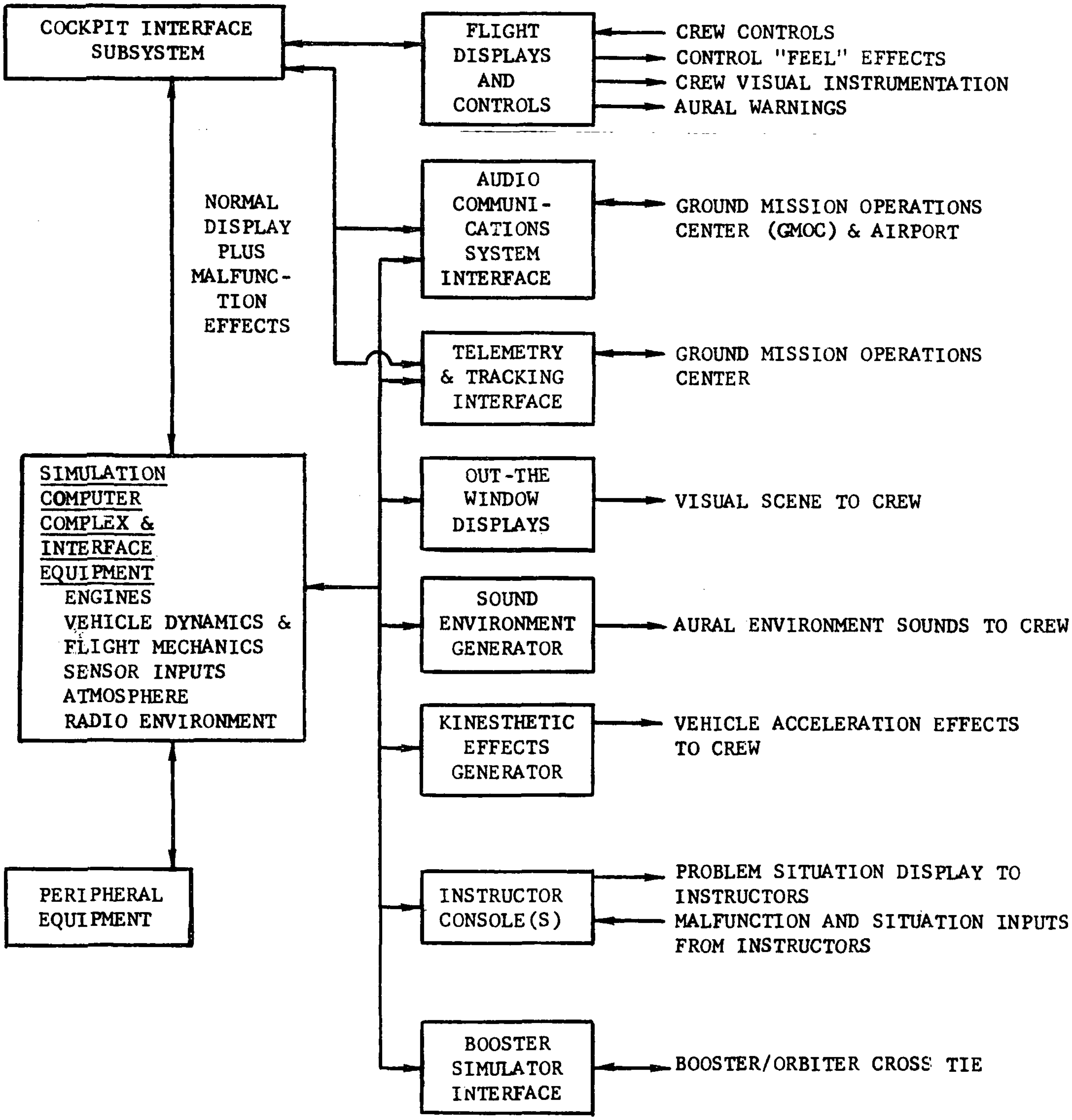


FIGURE 3.3-103

The autonomous capability of Shuttle vehicle systems makes it necessary to thoroughly train the flight crew in on board systems management. This requires a degree of system malfunction and corrective action simulation that is far more thorough than on previous aircraft and spacecraft simulators. The capability for malfunction simulation would be sufficient for evaluating crew ability to recognize and isolate malfunctions to the same degree that this is achievable in the Shuttle vehicle. Proper and improper crew corrective action, such as redundancy selection, would result in realistic system performance indications to the crew and on telemetry. Previous simulation techniques applicable to on board systems management include those used on the C5A simulator Malfunction Detection and Recording (MADAR) system, and simulators for Gemini and Apollo.

B. Out-the-Window Displays - The mission simulator requires wide-angle infinity optics displays for a great variety of flight conditions, e.g.

Booster: take off and taxi (ferry)
separation from orbiter
earth/sky reference for re-entry
ILS approach Category I, II, III, day and night

Orbiter: take off and taxi (ferry)
earth/sky reference
star scene
second orbital vehicle of various types from front and docking windows
docking and retrieval apparatus, extended payloads
ILS approach Category I, II, III, day and night.

The image sources for visual simulations of this variety have usually come from diverse devices such as mechanical models of runways and target vehicles, point light planetarium type displays, films, etc. These image sources were then combined optically in a device for display to the training crew. This resulted in a bulky, delicate and usually heavy device. Severe problems often existed in obtaining adequate servo response to reduce the overall system lag to acceptable levels. Fortunately, the state of the art in computer image generation and light weight infinity optics packages has evolved to the point that it is a strong candidate for application to the Shuttle visual system. Scene content of the order of 3000 shaded surfaces should be possible in color with exact computed perspective and lags of under 1/10 second. Recent work in the area of large rugged and low cost plastic mirrors makes a light weight and compact infinity window of high optical efficiency practical for presentation of the scene to the crew. Computed image generation thus allows all the flight phase images required to be provided in a single flexible device. Studies to define a cost effective visual system in Phase C should include assessment of the amount of scene content required for each task, the degree of color simulation that is necessary, and the relative merits of computer image generation and servo driven models for this application.

C. Kinesthetic Effects - The use of a compact, rugged, and light weight infinity optics package for the out-the-window scene makes it possible to design simple motion bases for the Orbiter and Booster sections of the simulator. Motion is important for training in three areas:

1. When the crew's first indication of an important effect is an acceleration:

Boost engine abort during ascent	O & B
Separation	O & B
Wind sheer effects during vertical ascent	B

Body bending	O & B
Stall and cross flow buffet	O & B
Thrust loss on jet engines	O & B

2. Feedback for handling characteristics:

Docking	O
Landing	O & B

3. Minor cue re-inforcement. The motion base provides additional reinforcement of a crew action; the primary information comes from instruments or visual scene:

Braking on landing	O & B
Parachute deployment	O & B
Docking bump	O

A trade study emphasizing cost effectiveness would compare a fixed base versus a motion base system for a Space Shuttle training simulator and would consider the possibility of utilizing one of each type in the event that two mission simulators are utilized. It is necessary to study the final Orbiter and Booster aerodynamic configurations and all the mission phases and contingencies in detail to determine if the acceleration cues arising from the mission operation and contingencies are sufficient to justify a motion base and which degrees of freedom each motion base should provide. At this point, it is important to note that for emergency procedures training such as engine out the variable stability aircraft could not be used due to the hazards presented to the aircraft and Shuttle crew. As an example of a motion base requirement, Boeing 747 pilots regard the cockpit lateral translational acceleration as the primary cue of an engine loss while yaw acceleration, roll acceleration, pitch acceleration, and longitudinal translation accelerations are of lesser importance. Also vertical translational acceleration (heave) is very important for takeoff rotation and landing flare training cues.

Present Booster and Orbiter configurations were checked for engine out lateral acceleration cues against the DC-10 transport aircraft for critical engine out cases on ferry takeoff and a landing approach. The lateral cockpit translational accelerations are tabulated below.

SPACECRAFT ENGINE LOSS COCKPIT LATERAL ACCELERATION	
Orbiter Ferry Takeoff	1.1 ft/sec^2
Orbiter Entry Landing Approach	0.7 ft/sec^2
Booster Ferry Takeoff	0.4 ft/sec^2
Booster Flyback Landing Approach	0.2 ft/sec^2

AIRCRAFT ENGINE LOSS COCKPIT LATERAL ACCELERATION	
DC-10 Max Gross Weight Takeoff	4.1 ft/sec^2
DC-10 Max Landing Weight Approach	2.0 ft/sec^2

It should also be noted that the present Booster canard jet flap configuration, loss of an engine results in simultaneous pitch down (due to a loss of canard supercirculation trim lift) and roll due to asymmetric thrust. Analysis of the magnitudes of cockpit acclerations on the final configuration will be required to determine the number of degrees of freedom, travel limits and acceleration and velocity limits of a suitable motion base.

D. Audio Communications - The audio communications mission simulation requires the simulated vehicles to be tied into the Ground Mission Operations Center (GMOC) in a realistic fashion. Circuit simulation would include artificial introduction of noise and loss of communications inserted by the instructor. The instructor audio channels would have override capability at all times and would be noise-free.

E. Sound Environment - A flexible electronic sound generation system responsive to the detailed simulations of the various systems is required. In addition, care must be taken to ensure low enough noise levels in the orbiter simulator to duplicate in-orbit powered down conditions. The following is a typical list of sounds to be simulated:

Engine - Main	O & B
Engine - Jet	O & B
Aerodynamics hiss	O & B
Canard Air Flow	B
Touch Down	O & B
Undercarriage Extension	O & B
Docking Hydraulics	O

F. Instructor Consoles - One practical way to apply commercial airline operations techniques to the Shuttle is in the simulator training philosophy. The instructors would ride in the cockpit as they do on PAA-747 simulators and make use of small portable consoles to control the simulation exercise and insert malfunctions. These small consoles permit the instructor to ride anywhere in the cockpit, such as behind the front seats or beside the docking position in the Orbiter. Operators consoles for ground communication and telemetry would be located outside the cockpit. Selection of the malfunctions to be simulated must be based on realistic fault analysis data. The exact malfunctioned component is to be identified and all the correct inter-system results of the malfunction computed by the simulation. No permanent damage would be caused by repetitive insertion of any malfunction.

G. Telemetry and Tracking Interface - It is required that the simulated vehicle tie into the Ground Mission Operations Center telemetry link so that combined training exercises with GMOC can be executed. Trajectory data would be transmitted to the GMOC during these combined exercises.

H. Booster/Orbiter Interface - The Booster and Orbiter simulators would have completely independent modes of operation so that training time can be more effectively allocated to Orbiter and Booster crews. It is a requirement, however, to conduct combined exercises analogous to actual launch situations. This combined mode of operation would be achieved by digital data exchange through block transfer channels between the two simulation computers. Audio channel interconnection would also be provided.

I. Cockpit Interface Subsystem - One of the earliest decisions which must be made for the Mission Simulator is the extent of actual flight Digital Interface Units and computers. The most cost effective approach should be determined by further trade-off studies to be contracted by NASA. These trade studies must include consideration of such advantages and disadvantages as:

Advantages in use of Flight Computers and DIU's

1. Flight software development can be done on the mission simulator.
2. Confidence in flight software can be built up by day to day use.
3. Changes in the flight software are certain to be quickly available in the mission simulator.
4. The use of flight software decreases the scope of simulation software development.
5. Confidence in avionics hardware can be built up by day to day use.

Disadvantages of Use of Flight Computers and DIU's

1. The flight computers will be considerably more expensive than non-redundant non-flight-hardened commercial interface equipment.
2. Realistic malfunction insertion becomes a much more difficult problem, especially if no modification of flight hardware or software is a ground rule.
3. The mission simulator is being used for flight software and hardware verification and is less available for training.

J. Simulation Computer Complex – The simulation computer complexes for the Orbiter and the Booster must fulfill both direct functional and indirect supporting requirements.

Direct Functional Requirements

1. Engine simulation
2. Sensor simulation
3. Radio equipment simulation
4. Vehicle dynamics and mechanics
5. Atmospheric model
6. Computed Visual Environment Storage
7. System simulation
8. On-board computer and flight software simulation
9. Ground and airborne navigation aid simulation (tracking, enroute navigation, ILS, satellite)
10. Instructor's Consoles and malfunction insertion
11. Storage of flight data for later review/demonstration.

Supporting Requirements

1. Sufficient peripheral equipment for software development, modification and debugging.
2. Higher level language for programming (such as Space Simulator Language).
3. Floating point arithmetic with a minimum 8 bit exponent, 24 bit mantissa.
4. Self diagnostic and simulator interface diagnostic capability.
5. Compiler for on-board computer source language (if on-board computers not used).

Commonality Between Booster and Orbiter Simulation

In order to obtain low costs, the following areas of commonality must be exploited fully.

1. Common Orbiter and Booster subsystems simulated identically.
2. Same computers and interface type used in Orbiter and Booster simulator.
3. Same programming language used in Orbiter and Booster simulator.
4. Same higher level programming language used in simulator and vehicle software (such as SPL).
5. Same visual system hardware in Orbiter and Booster simulator.
6. Same motion system type used in Orbiter and Booster simulator.

3.3.2.8 Other Operational Interfaces

3.3.2.8.1 Tracking and Data Relay Satellites - As the Shuttle Program progresses and the tracking and data relay satellite becomes operational, transition from the utilization of the MSFN to these Satellites will take place. Operational frequency bands, data rates, number of channels and antenna gains must be established based on analysis of user requirements. The Orbiter, as a user, will require duplex voice, payload data, and vehicle up and down data. Vehicle data, which is currently controversial, should be planned for contingency and backup operation support. Continuing analysis is proceeding to definitize specific utilization requirements for this data. The transition from MSFN to the TDRS will take place over a number of Shuttle flights to insure overall performance and interface verification.

3.3.2.8.2 Experiments - The experiment packages to be carried by the Space Shuttle will be designed to interface with the vehicle and ground based mission support activities. Experiments which are carried in the Orbiter payload bay will conform to ICD for Shuttle interfaces and the MSFN User Guide (MSFN 101.1). On-orbit experiments not contained in the payload shall be stowable on the vehicle stowage area and operated manually from the flight deck. (Photographic, Zero G, Radiation, etc.) Data shall be routed to the experimentor through the Ground Based Mission Support activity. Experiments shall be the responsibility of the Scientific Experiment Program Office.

The Ground Based Mission Support Activity shall:

A. Monitor experiment systems performance

B. Validate scientific data received

C. Maintain experiment log

D. Coordinate experiment inputs to the Flight Plan

E. Provide the Experimentor and/or Principal Investigator facilities to review the data

F. Develop in-flight operating procedures

G. Deliver flight returned data to the designated activity.

The Orbiter shall provide the features as specified in the Payload ICD.

3.3.2.8.3 Scientific Community - The results of experiments carried on in space are of interest to the general scientific community in addition to the experiment principal investigator. To this end, NASA has established a National Space Science Data Center (NSSDC) which could be used as the central reservoir for experiment data obtained by Shuttle experiments.

The scientific community can contact the NSSDC to request assistance in obtaining the data.

APPENDIX A

DOCUMENTATION CROSS-TIE

APPENDIX A

DOCUMENTATION CROSS-TIE - This section covers the documentation cross-tie between this document and other documentation. In case of conflict between the requirements of the Operations Plan and this document or any of the referenced documents, the requirements of the Operations Plan shall govern. The following documents, of the issue and dates indicated, shall form a part of this document to the extent specified herein:

DOCUMENT NO.	TITLE AND RELATIONSHIP
MDC-E0308, Part III-3	Space Shuttle, Operations Plan - This plan defines the requirements for ground and flight operations.
MDC-E0308, Part III-4	Space Shuttle, Facility Utilization and Manufacturing Plan - This plan defines the facilities requirements for ground and flight operations.
MDC-E0308, Part III-5	Space Shuttle, Test Plan - This plan defines the test requirements for development and operational phase activities at the operations site.
MDC-E0308, Part III-6	Space Shuttle, Logistics and Maintenance Plan - This plan defines the logistics and maintenance requirements and activities at the operations site.
GS 255D400	Space Shuttle, Ground Support Equipment General Specification - This document defines the performance design and physical descriptions for factory, development, flight test, launch site and post landing equipment.

DOCUMENT NO.	TITLE AND RELATIONSHIP
AFETR 127-1, Section A-2	Range Safety Manual, Policy and Procedure - The document identifies the flight range safety requirements for the Eastern Test Range.
MDAC Memo Number -- SSPI-E450-590	Space Shuttle Data Avionics Book. This document provides detail descriptions of the Shuttle onboard avionics subsystems.
I-EAST-TI-25	Space Shuttle Abort Analysis - This document identifies the preliminary study results of intact abort using the current baseline vehicles identified therein.
NASA-MSC-02542, Vol. I	Typical Shuttle Mission Profiles and Attitude Timelines. This volume provides descriptions and requirements for Space Station Resupply Missions.
NASA-MSC-02542, Vol. II	Typical Shuttle Mission Profiles and Attitude Timelines. This volume provides descriptions and requirements for four (4) Scientific Support Missions.
NASA-MSC-02542, Vol. III	Typical Shuttle Mission Profiles and Attitude Timelines, First 10 Shuttle Missions. This volume describes the first 10 payload carrying Shuttle missions.
FAR-Part 73	Federal Aviation Regulations - This document identifies special use airspace which will be required for Shuttle operations.

DOCUMENT NO.	TITLE AND RELATIONSHIP
NASA-MSFN 101.1	Manned Space Flight Network Users Guide - This document identifies requirements for experiments carried aboard the orbiter.
I-EAST-GLO-20	Space Shuttle New vs Existing Site - This trade study evaluates various candidate operations sites for the Shuttle program.
NASA-MSC-02666	Selection of Landing Airfields for Shuttle Orbiters with various Crossranges - This document identifies fifteen alternate landing sites which would provide at least a once-per-two-revolution return opportunity for all Shuttle orbits.
MDAC Memo Number -- SSPI-E450-584	Aborts - This document discusses a variety of abort situations and methods.
DN-I-EAST-TI-20	Downrange Landing and Alternate Return Modes vs Cruise Back
IM-I-EAST-MO-2	Space Shuttle Autonomy (GAFSO) - This trade study analyzes and recommends the optimum location, onboard or ground, of parameters and functions that are required for ground turnaround and flight operations.