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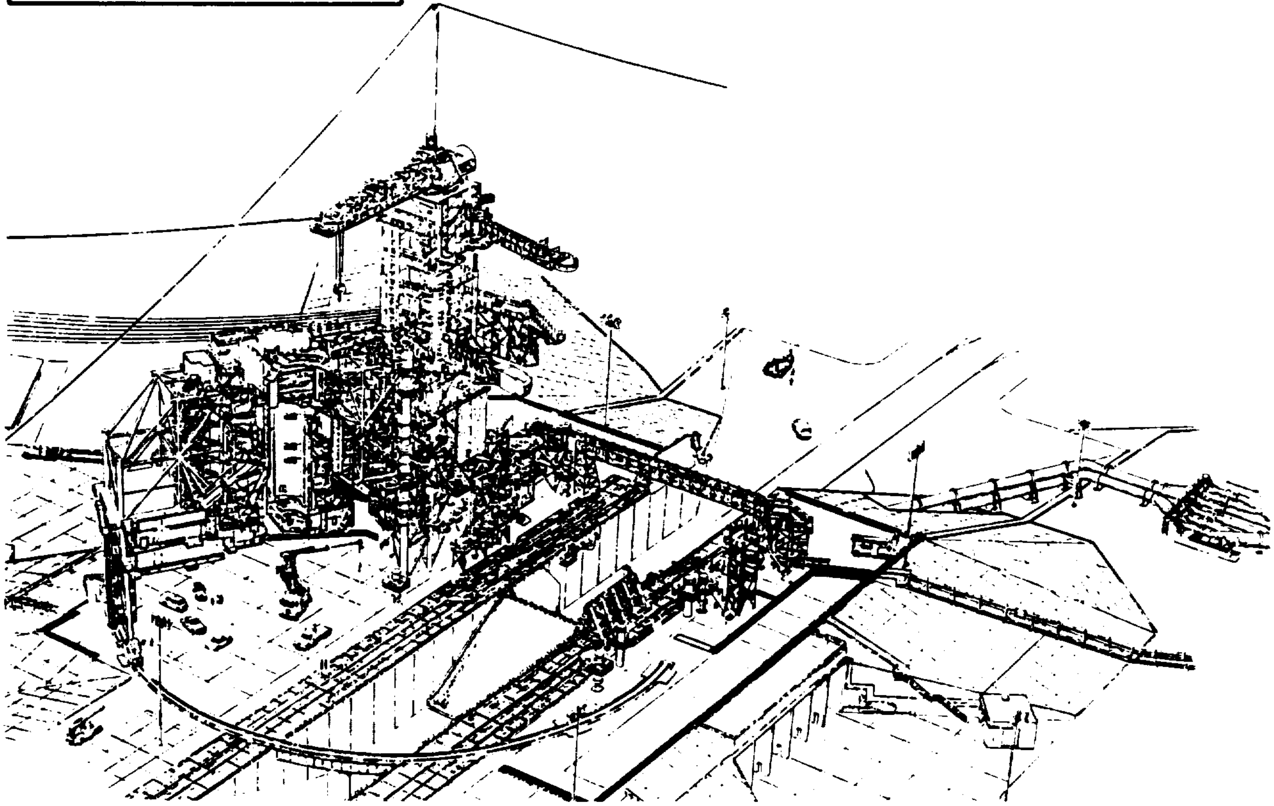
KSC ADVANCED PROJECTS & TECHNOLOGY OFFICE

# LIQUID ROCKET BOOSTER INTEGRATION STUDY



## STUDY PRODUCTS
## VOLUME III OF V
### PART 2
### SECTIONS 8-19

# FINAL REPORT
# PHASE I

NAS10-11475

NOVEMBER 1988

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# LIQUID ROCKET BOOSTER INTEGRATION STUDY

## VOLUME III OF V
## STUDY PRODUCTS
## PART 2
## SECTIONS 8-19

KENNEDY SPACE CENTER
NAS10-11475

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# LRBI FINAL REPORT
## CONTENTS GUIDE

VOLUME I - EXECUTIVE SUMMARY

VOLUME II - STUDY SUMMARY

SECTION 1: LRBI Study Synopsis - An assessment of the study objectives, approach, analysis, and rationale. The study findings and major conclusions are presented.

SECTION 2: Launch Site Plan - An implementation plan for the KSC launch site integration of LRB ground processing. The plan includes details in the areas of facility activations, operational schedules, costs, manpower, safety and environmental aspects.

SECTION 3: Ground Operations Cost Model (GOCM) - The updating and enhancement of this NASA provided computer-based costing model are described. Its application to LRB integration and instructions for modification and expanded use are presented.

SECTION 4: Cost - Summary and Analysis of KSC Costs.

VOLUME III - STUDY PRODUCTS

The study output has been developed in the form of nineteen derived study products. These are presented and described in the subsections of this volume.

VOLUME IV - REVIEWS AND PRESENTATIONS

The progress reviews and oral presentations prepared during the course of the study are presented here along with facing page text where available.

VOLUME V - APPENDICES

Study supporting data used or referenced during the study effort are presented and indexed to the corresponding study products.

# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ADP | Automatic Data Processing |
| A&E | Architectual and Engineering |
| AF | Air Force |
| AI | Artificial Intelligence |
| AL | Aluminum |
| AL-Li | Aluminum Lithium Alloy |
| ALS | Advanced Launch Systems |
| ALT | Alternate |
| AOA | Abort Once Around |
| AOPL | Advanced Order Parts List |
| AP | Auxiliary Platform |
| APU | Auxiliary Power Unit |
| ARF | Assembly and Refurbishment Facility |
| ARTEMIS | Accounting, Reporting, Tracking, & Evaluation Management - Information System |
| ASRM | Advanced Solid Rocket Motor |
| ASSY | Assembly |
| ATO | Abort to Orbit |
| ATP | Authority to Proceed |
| AUTO | Automatic |
| AWCS | Automated Work Control System |
| | |
| BITE | Built-in Test Equipment |
| BLOW | Booster Liftoff Weight |
| BOC | Base Operations Contractor |
| BSM | Booster Separation Motor |

| | |
|---|---|
| C | Celsius |
| CAD | Computer Aided Design |
| CALS | Computer Aided Logistics System |
| CCAFS | Cape Canaveral Air Force Station |
| CCB | Change Control Board |
| CCC | Complex Control Center |
| CCF | Compressor Converter Facility |
| CCMS | Checkout, Control and Monitor Subsystem |
| CDDT | Countdown Demonstration Test |
| CDR | Critical Design Review |
| CEC | Core Electronics Contractor |
| CER | Cost Estimating Relationships |
| CG | Center of Gravity |
| CH4 | Methane |
| CITE | Cargo Integration Test Equipment |
| CM | Construction Management<br>Configuration Management |
| C/O | Closeout<br>Checkout |
| CONC | Concrete |
| C of F | Cost of Facilities |
| COMM | Communications |
| CPF | Cost per Foot |
| CPF2 | Cost per Square Foot |
| CPF3 | Cost per Cubic Foot |
| CPM | Critical Path Management |
| CPU | Central Processing Unit |
| CR | Control Room |
| Cryo | Cryogenic |
| C/S | Contractor Support |
| CT | Crawler Transporter |
| CY | Calendar Year |

| | |
|---|---|
| dBase | Data Base - Software Program |
| dc | Direct Current |
| DDS | Data Processing System |
| DDT&E | Design, Development, Test & Engineering |
| DE | Design Engineering |
| DEQ | Direct Equivalent Head Count |
| DFRF | Dryden Flight Research Facility |
| DFI | Development Flight Instrumentation |
| DHC | Direct Head Count |
| DIST | Distributor |
| DOD | Department of Defense |
| DOS | Disk Operating System |
| DOT | Department of Transportation |
| | |
| ECLSS | Environmental Control & Life Support System |
| ECS | Environmental Control System |
| EL | Elevation |
| ELS | Eastern Launch Site |
| ELV | Expendable Launch Vehicle |
| EMA | Electrical Mechanical Actuator |
| EMERG | Emergency |
| EPA | Environmental Protection Agency |
| EPDC | Electrical Power and Distribution Control |
| EPL | Emergency Power Level |
| ET | External Tank |
| ET-HPF | External Tanks - Horizontal Processing Facility |
| ETR | Eastern Test Range |
| | |
| F | Fahrenheit |
| FAA | Federal Aviation Administration |
| F&D | Fill & Drain |
| FEP | Front End Processor |
| FLT | Flight |

| | |
|---|---|
| FMEA/CIL | Failures Modes & Effects Analysis/Critical Items List |
| FRF | Flight Readiness Firing |
| FRSC | Forward Reaction Control System |
| ft | Feet |
| FSS | Fixed Service Structure |
| FWD | Forward |
| FY | Fiscal Year |

| | |
|---|---|
| G&A | General and Administrative |
| G,g | Acceleration of Gravity |
| GAL | Gallons |
| GDSS(GD) | General Dynamics Space Systems |
| GEN | Generator |
| GFE | Government Furnished Equipment |
| GH2 | Gaseous Hydrogen |
| GHe | Gaseous Helium |
| GLOW | Gross Liftoff Weight |
| GLS | Ground Launch Sequencer |
| GN2 | Gaseous Nitrogen |
| GN&C | Guidance, Navigation & Control |
| GOAL | Ground Operations Aerospace Language |
| GOX | Gaseous Oxygen |
| GOCM | Ground Operations Cost Model |
| GPC | General Purpose Computer |
| GPM | Gallons Per Minute |
| GRD | Ground |
| GSE | Ground Support Equipment |
| GSFC | Goddard Space Flight Center |
| GTSI | Grumman Technical Services, Inc. |
| GUCP | Ground Umbilical Carrier Plate |

| | |
|---|---|
| H2 | Hydrogen |
| HAZGAS | Hazardous Gas |
| HB | High Bay |
| HDP | Holddown Post |
| He | Helium |
| HIM | Hardware Interface Module |
| HMF | Hypergolics Maintenance Facility |
| HPF | Horizontal Processing Facility |
| HQ | Headquarters |
| HVAC | Heating, Ventilation, and Air Conditioning |
| HW | Hardware |
| HYD | Hydraulic(s) |
| HYPER | Hypergolic |
| Hz | Hertz |
| | |
| IBM | International Business Machines |
| ICD | Interface Control Document |
| I/F | Interface |
| ILC | Initial Launch Capability |
| INST | Instrumentation |
| INTEG | Integration |
| IOC | Initial Operational Capability |
| IPR | Interum Problem Report |
| IRD | Interface Requirements Document |
| IUS | Interial Upper Stage |
| | |
| JSC | Johnson Space Center |

| | |
|---|---|
| K | Thousands |
| K | Kelvin |
| KLB | Thousands of Pounds |
| KSC | Kennedy Space Center |
| KW | Kilowatt |
| | |
| LAC | Launch Accessories Contractor |
| LC-39 | Launch Complex 39 |
| LCC | Life Cycle Cost |
| LCC | Launch Control Center |
| LCH4 | Liquid Methane |
| LESC | Lockheed Engineering and Science Company |
| LETF | Launch Equipment Test Facility |
| LEO | Low Earth Orbit |
| LH2 | Liquid Hydrogen |
| Li | Lithium |
| LN2 | Liquid Nitrogen |
| LNG | Liquid Natural Gas |
| LO2 | Liquid Oxygen |
| LOX | Liquid Oxygen |
| LPS | Launch Processing System |
| LRB | Liquid Rocket Booster |
| LRB-HPF | Liquid Rocket Booster Horizontal Processing Facility |
| LRBI | Liquid Rocket Booster Integration |
| LRU | Line Replaceable Unit |
| LSE | Launch Support Equipment |
| LSOC | Lockheed Space Operations Company |
| LUT | Launcher Umbilical Tower |
| | |
| MAX | Maximum |
| MECO | Main Engine Cutoff |
| MDAC | McDonnell Douglas Astronautics Company |
| MIL | Military |

| | |
|---|---|
| MIN | Minimum |
| MLP | Mobile Launch Platform |
| MMC | Martin-Marietta Corporation |
| MMH | Mono Methyl Hydrazine |
| MOD | Mission Operations Directorate |
| MOU | Memorandum of Understanding |
| MP | Manpower |
| MPS | Main Propulsion System |
| MSBLS | Microwave Scanning Beam Landing System |
| MSFC | Marshall Space Flight Center |
| MST | Mobile Service Tower |
| MTI | MortonThiokol, Inc. |
| | |
| N2 | Nitrogen |
| NASA | National Aeronautics and Space Administration |
| NDE | Non-Destructive Evaluation |
| NDT | Non-Destructive Test |
| NF | Nose Fairing |
| N2O2 | Nitrogen Tetroxide |
| NPL | Nominal Power Level |
| NPSH | Not positive Suction Head |
| NRC | National Research Council |
| NSTL | National Space Technology Laboratories (Stennis Space Center) |
| NSTS | National Space Transportation System |
| NWS | National Weather Service |
| | |
| OAA | Orbiter Access Arm |
| OIS | Operational Intercommunications System |
| OJT | On-the-job Training |
| O&M | Operations and Maintenance |
| OMD | Operating and Maintenance Documentation |

| | |
|---|---|
| OMI | Operations and Maintenance Instruction |
| OMRF | Orbiter Maintenance and Refurbishment Facility |
| OMRSD | Operational Maintenance Requirements and Specifications Document |
| OMS | Orbital Maneuvering System |
| OPF | Orbiter Processing Facility |
| OPS | Operations |
| OMBUU | Orbiter Mid Body Umbilical Unit |
| ORB | Orbiter |
| ORD | Operational Readiness Date |
| ORI | Operational Readiness Inspection |
| OSHA | Occupational Safety & Health Administration |
| OTV | Operational Television |

| | |
|---|---|
| PA | Public Affairs |
| PAWS | Pan Am World Services, Inc. |
| P/A | Propulsion/Avionics Module |
| Pc | Engine Combustion Chamber Pressure |
| PC | Personal Computer |
| PCM | Pulse Code Modulator |
| PCR | Payload Changeout Room |
| PDR | Preliminary Design Review |
| PER | Preliminary Engineering Report |
| PGHM | Payload Ground Handling Mechanism |
| PIC | Pyro Initiator Controller |
| PIF | Payload Integration Facility |
| P/L | Payload |
| PMM | Program Model Number |
| PMS | Permanent Measuring System |
| PO | Purchase Order |
| POP | Programs Operations Plan |
| PR | Problem Report |
| PRACA | Problem Reporting and Corrective Action |
| PRCBD | Program Review Control Board Directive |

| | |
|---|---|
| PRC | Planning Research Corporation |
| PRD | Program Requirements Document |
| PRESS | Pressure, pressurization |
| PROP | Propellant |
| PRR | Preliminary Requirements Review |
| PSI | Pounds Per Square Inch |
| psia | Pounds Per Square Inch Absolute |
| psig | Pounds Per Square Inch Gage |
| PSP | Process Support Plan |
| PT&I | Payroll Taxes and Insurance |
| P&W | Pratt & Whitney Company |

| | |
|---|---|
| Q | Dynamic Pressure |
| QA | Quality Assurance |
| Q-Alpha | Dynamic Pressure x Angle of Attack |
| QC | Quality Control |
| QD | Quick Disconnect |
| QTY | Quantity |

| | |
|---|---|
| R | Ranking |
| RAM | Random Access Memory |
| RCS | Reaction Control System |
| R&D | Research and Development |
| RF | Radio Frequency |
| RFP | Request for Proposal |
| RIC | Rockwell International Corporation |
| ROM | Rough Order of Magnitute |
| RP-1 | Propellant (Kerosene Related Petroleum Product) |
| RPL | Rated Power Level |
| RPS | Record and Playback System |
| RPSF | Rotation, Processing & Surge Facility |

| | |
|---|---|
| R/R | Remove/Replace |
| RSLS | Redundant Set Launch Sequencer |
| RSS | Rotating Service Structure |
| R&T | Research and Technology |
| RTLS | Return to Launch Site |

| | |
|---|---|
| SAIL | Shuttle Avionics Integration Laboratory |
| SAB | Shuttle Assembly Building |
| SCAPE | Self-Contained Atmospheric Protective Ensemble |
| SDI | Strategic Defense Initiative |
| SDV | Shuttle Derivative Vehicle |
| SEB | Source Evaluation Board |
| SEC | Second(s), Secondary |
| SGOS | Shuttle Ground Operations Simulator |
| SIES | Supervision, Inspection & Engineering Services |
| SIT | Shuttle Integrated Test |
| | System Integrated Test |
| SLC-6 | Shuttle Launch Complex No.6 |
| SLF | Shuttle Landing Facility |
| SOFI | Spray On Foam Insulation |
| SOW | Statement of Work |
| SPC | Shuttle Processing Contractor |
| SPF | Software Production Facility |
| SPDMS | Shuttle Processing Data Management System |
| SRB | Solid Rocket Booster |
| SRM | Solid Rocket Motor |
| SRSS | Shuttle Range Safety System |
| SR&QA | Safety, Reliability and Quality Assurance |
| SSC | Stennis Space Center (NSTL) |
| SSME | Space Shuttle Main Engine |
| SSV | Space Shuttle Vehicle |
| STD | Standard |
| STS | Space Transportation System |

| | |
|---|---|
| SUBSTA | Substation |
| SW | Switch |
| S/W | Software |
| | |
| TAL | Transatlantic Landing |
| TBD | To Be Determined |
| T&C/O | Test and Checkout |
| TFER | Transfer |
| T-0 | Liftoff Time |
| TOPS | Technical Operating Procedures |
| TPS | Thermal Protection System |
| TSM | Tail Service Mast |
| TTV | Termination/Test/Verification |
| TVA | Thrust Vector Activator |
| TVC | Thrust Vector Control |
| T/W | Thrust to Weight Ratio |
| TYP | Typical |
| | |
| ULCE | Unified Life Cycle Engineering |
| UMB | Umbilical |
| UPS | Unintegrated Power System |
| USAF | United States Air Force |
| USS | Utility Substation |
| | |
| V | Volt(s) |
| VAB | Vehicle Assembly Building |
| VAFB | Vandenberg Air Force Base |
| VIB | Vertical Integration Building |
| VLS | Vandenberg Launch Site |
| VPF | Vertical Processing Facility |

| | |
|---|---|
| WAD | Work Authorization Document |
| WBS | Work Breakdown Structure |
| WIP | Work in Progress |
| WSMR | White Sands Missile Range |
| WTR | Western Test Range |

# VOLUME III

## SECTION 8

## POTENTIAL IMPACTS TO ON-GOING LAUNCH SITE ACTIVITIES

# VOLUME III SECTION 8

# POTENTIAL IMPACTS TO ON-GOING LAUNCH SITE ACTIVITY

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# SECTION 8

# POTENTIAL IMPACTS TO ON-GOING LAUNCH SITE ACTIVITY

## 8.1 SUMMARY

The key potential impacts to on-going operations are identified and discussed in Section 1.7.2 of Volume II. Here in overview fashion the identified risks are grouped into the three phases of LRB implementation: Facility Activation, Transition and Operational Phases. Each of these periods was evaluated to establish impacts in the areas of manpower requirements, schedule risks and costs.

## 8.2 LRB SCENARIO PLANNING

The selection of a ground processing scenario for LRB was based on minimizing the impacts to scheduled on-going launch operations at KSC. The two new facilities (MLP and HPF) are planned to prevent interruption in the existing SRB MLP utilization and to decentralize both ET and LRB stand alone testing out of the VAB environment.

The existing facility mods are planned to be accomplished with minimum impacts to planned operations. The KSC multiflow processing baseline networked in ARTEMIS was used to evaluate open periods at facilities as windows of opportunity for these mods. Conversion of VAB/HB-4 to a full LRB/SSV integration cell must be planned in concert with on-going VAB work scheduling, especially with respect to SRB/SSV activities directly across the transfer aisle in HB-3.

## 8.3 MAJOR FACILITY ACTIVATION IMPACTS

Staffing of the activation management team required to plan and implement the activation of required facilities will begin early.

Pad modifications at Pad B will force some scheduled SRB missions to be moved over to Pad A during the last eight months prior to LRB certification for LRB. This planning is described in detail in Study Product 9, the Preliminary Transition Plan. During this Pad Mod period the greatest threat to mission loss or delay will exist. After the Pad Mod is complete schedule pressure will decrease since the modifications are planned to maintain SRB launch capability at the pads.

The required Pad Mods are dependent on LRB sizing. For example, as diameters grow out to 18 feet and engine positioning is selected in the "+" pattern, the outboard engine is forced outside the edge of the flame trench. Deflector modifications then become more severe while concrete mods to the trench become more likely. These will be significant "hits" to the Mod schedule and thus are potential high risk impacts.

Initial manpower buildup of the core LRB processing team will take place during the activation period, This team should be staffed with members of the Phase-B LRB study team and representative KSC and SPC talent. Working with the flight element contractor a series of LRB training programs will be developed.

## 8.4 MAJOR TRANSITION IMPACTS

The planned five year change from SRB to LRB will result in many potential impacts to on-going operations. The manpower build-up for LRB activation will have peaked during FY95 with the addition of approximately 800 people to the booster-related launch site work force of about 1200 (See Study Products 6 and 9 in Volume III on manpower and transition planning and the launch site plan described in Section 2, Volume II for more detailed descriptions).

Before transition begins; however, KSC and the Shuttle Processing Contractor will have implemented the LRB manpower plan hiring and training the required dedicated cadre of LRB personnel needed to meet the ILC of early FY96. During transition the major manpower challenge will be the integration of this cadre with the on-going STS operations and the parallel staffing required to support mixed SRB and LRB launch processing. The LRB/SPC processing team is anticipated to grow from the ILC level of approximately 220 to full staffing of 441 by the fourth LRB launch in early FY97. That staffing level will, by stationizing and other operational efficiencies, be able to support the launch rate build-up from 3 per year to 14 per year.

During the transition the expendable LRB will result in the deactivation of all retrieval, disassembly and refurbishment activities at the launch site. Manpower savings associated with these deactivations and the shut down of RPSF, ARF and the parachute facility are approximated by the manpower curves shown in the launch site plan. The related cost incentives (savings) have not been reflected in the cost summaries of this study.

All launch site costs for LRB implementation are presented in Section 4 of Volume II.

Schedule impacts during transition are more significant as related to integrated functions where simultaneous SRB and LRB processing is being supported. For example, the VAB will be supporting both SRB and LRB integrated operations in three high bays. Live propellant stacking of SRBs will require careful scheduling to avoid impacts with other operations. As SRB launches decrease however, only a single high bay will be required to support this activity. That will free up HB-3 for modifications to accommodate LRB.

For the second LRB Pad Mod we have the same challenge to avoid impacts that existed during initial activation. Pad A will now be momentarily out of use for an eight month period during which all missions will go off a single pad. Manifested missions with unique launch windows could cause an added challenge to avoid impacts during this period.

Joint operations (SRB & LRB) in the LCC during transition will be a potential impact due to firing room utilization and changing configurations. Implementation of the second generation LPS will be significant in easing this impact; however, new LRB console hardware and new ground software implementation are still challenging tasks.

A complete coverage of the planned LRB transition is presented in Study Product 9, Volume III.

## 8.5 OPERATIONAL PHASE IMPACTS

After full transition to LRB the beneficial aspects of LRB over existing SRB operations will be realized. The schedule pressure on integrated resources is significantly reduced. The increased flexibility of booster operations permits the integration of alternate vehicles such as Shuttle C, ALS and standalone ELVs with significantly lower launch site impacts. All SRB support operations and retrieval, disassembly and refurbishment operations have been phased out. Total manpower levels across the launch site have decreased from approximately 1200 for SRB to the LRB sustained level of 608. This means on-going LRB manpower levels are anticipated to be about one half the current SRB levels to support the same 14-15 per year launch rate manifest.

No significant launch site schedule impacts are envisioned in the operational phase. Manpower impacts have already peaked during the transition phase dual operations. On-going LRB processing activities are fully staffed for the planned 14-15 launch manifest. Costs impacts at the launch site during the operational phase are not considered to be significantly different from that planned to support the same SRB launch processing. A full discussion of launch site life cycle cost issues is presented in Sections 3 and 4 of Volume II.

# VOLUME III

## SECTION 9

## PRELIMINARY TRANSITION PLAN

# VOLUME III SECTION 9
# PRELIMINARY TRANSITION PLAN

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## VOLUME III SECTION 9
## PRELIMINARY TRANSITION PLAN

## LIST OF FIGURES

# VOLUME III SECTION 9
# PRELIMINARY TRANSITION PLAN

## LIST OF APPENDED SUPPORTING DATA AND FIGURES
## (SEE VOLUME V-APPENDICES, SECTION 9)

| | |
|---|---|
| 9.1 | KSC MULTIMISSION FLOW MODEL DESCRIPTION AND GROUNDRULES (WITH POTENTIAL LRB ENHANCEMENTS NOTED) |
| 9.2 | LAUNCH PROCESSING FLOW BREAKDOWNS AND BAR CHART DATA FOR LRB/STS MISSIONS #5 Through #18 |
| 9.3 | LRB STUDY OF ET PROCESSING OMIs |

# VOLUME III SECTION 9

# PRELIMINARY TRANSITION PLAN

## 9.1 OBJECTIVE AND GROUNDRULES OF THE TRANSITIONAL PERIOD

Within the basic 122 LRB mission life cycle, the greatest degree of change will be experienced within the first ten years after the authority to proceed. Planning, design and construction/modification of required facilities will be the primary concern in the first five year period at KSC. (These aspects of the LRB program have been covered in Section 1 of Volume III.) The second five year period is the subject of the preliminary transition plan.

The use of the new or modified facilities, for an incrementally increasing LRB launch manifest between the years 1996 and 2000 has to be planned in a logical progressive manner. The objective of this product is to specify the process and considerations at the KSC launch site required to move from the current all SRB powered STS, through those incremental steps, into a position to support a "full up" LRB capability of at least 14 missions per year. An overview of the launch site plan with this part highlighted is presented in Figure 9.1-1.

Once the transitional period has been completed, the fully operational phase begins. At the specified rate of 14 missions a year the minimal program life cycle of 122 missions will be reached in the year 2006. It is expected by that time, program extensions would be decided, improved liquid rocket boosters would become available, or an entirely new STS Shuttle will have been designed.

Elaboration of the connections between the three phases of the KSC launch site plan can be found in Volume II, Section 2.

The basic LRB groundrules which are assumed as transitional directives are as follows:

- LRB transition activities should result in minimum impacts to ongoing KSC launch operations.
- A dual SRB/LRB launch processing capability will be maintained throughout the entire transitional period.

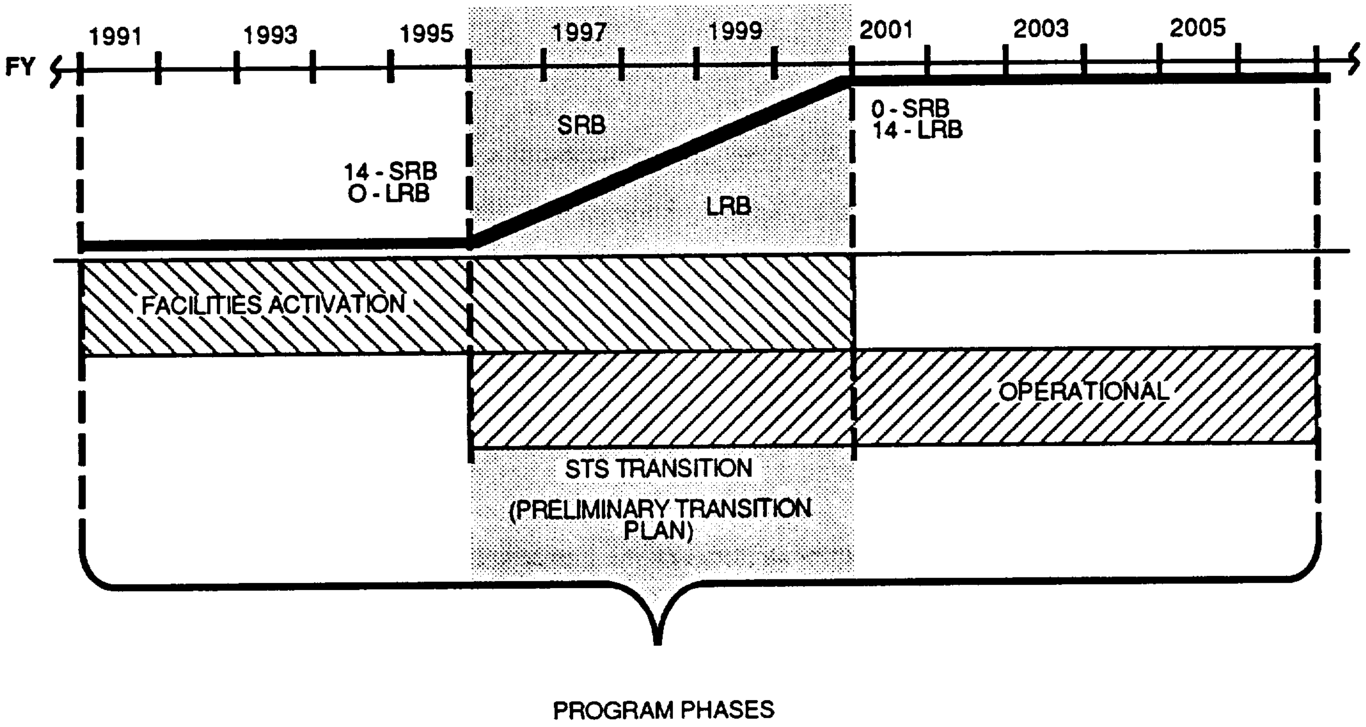


Figure 9.1-1. Launch Site Plan Overview.

- All launch projections are based on the March 1988 edition of the NASA manifest merged with an on-going 14-15 per year launch rate manifest.
- First-line facility activations will support an initial fiscal 1996 LRB boosted flight.
- Second line activations must result in a capability to perform a minimum of 122 LRB powered missions through the end of 2006.
- The baseline chosen for this analysis is the pump-fed LOX/RP-1 configuration; deltas for other configurations and differences between "Phase A" contractor design approaches will be described where appropriate.

The transition plan includes subsections covering: budgetary breakdowns; facility readiness; launch manifest integration; manpower considerations; documentation requirements; and a summary with recommendations for follow-on study.

## 9.2 BUDGETARY CONSIDERATIONS - FISCAL YEAR 1996 - 2000

The requirement to provide adequate manpower, equipment and facilities to support the first LRB powered mission in the 1996 time period, makes budgetary planning crucial. This section, like all others within the final report, is based on an authority to proceed (ATP) being granted by the beginning of fiscal year 1991. The distribution of costs starting at that time, through program completion is covered in the Launch Site Plan (Volume II, Section 2). A category-specific budgetary breakdown has been constructed for the transition time period (FY 1996 - 2000) in Figure 9.2-1.

The funds required are allocated primarily by source account as they were in the Launch Site Plan. During this particular period a mixture of facility activation and initial operations costs occurs. The funding for activation of the first line of facilities occurring within the FY 1991 through 1995 period is outside the parameters of this breakdown. It should also be noted that most training, documentation, and software development, etc... has taken place prior to the transition period.

|  |  | TRANSITION PHASE |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| FISCAL YEAR | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| LRB LAUNCH RATE | 0 | 3 | 6 | 9 | 12 | 14 | 14 |
| TRANSITION MILESTONES / BUDGET CATEGORIES | △ 1st LINE FAC. COMPL | △ ILC<br>△ IOC |  |  |  | △ 2nd LINE FAC. COMPL |  |
| NON RECURRING COSTS |  |  |  |  |  |  |  |
| 1st LINE C OF F | 78.56 |  |  |  |  |  |  |
| 2nd LINE C OF F | 27.46 | 31.11 | 36.32 | 49.26 | 25.63 | 19.22 |  |
| ACTIVATION MGMT TEAM | 16.02 | 4.65 | 5.38 | 7.45 | 3.86 | 2.91 |  |
| SUBTOTAL | 122.04 | 35.76 | 41.70 | 56.71 | 29.49 | 22.13 |  |
| RECURRING COSTS |  |  |  |  |  |  |  |
| PROPELLANTS (RP-1 & LOX) | .33 | .99 | 1.98 | 2.97 | 3.96 | 4.62 | 4.62 |
| PURGE GASES (N2 & He) | .16 | .48 | .96 | 1.44 | 1.92 | 2.24 | 2.24 |
| LSE/GSE SPARES | 21.33 | 21.33 | 22.73 | 27.81 | 27.81 | 33.47 | 33.47 |
| LRB PROCESSING PERSONNEL | 7.35 | 11.05 | 22.05 | 22.05 | 22.05 | 22.05 | 22.05 |
| NASA/NON-SPC SUPPORT | 11.15 | 10.85 | 13.10 | 11.35 | 9.50 | 8.35 | 8.35 |
| SUBTOTAL | 40.32 | 44.70 | 60.82 | 65.62 | 65.24 | 70.73 | 70.73 |
| ANNUAL TOTALS | 162.36 | 80.46 | 102.52 | 122.33 | 94.73 | 92.86 | 70.73 |

NOTES:
1. ALL COSTS ARE IN 1987 MILLIONS OF DOLLARS.
2. MMC LOX/RP-1 CONFIG USED FOR PROPELLANT CALCULATION.

Figure 9.2-1. LRB Transition Phase Budget.

## 9.3 FACILITY READINESS FOR TRANSITION

The facility planning of the LRB program must include a careful analysis of: The requirement for new, modified, or existing buildings; operational need dates; phased capability expansion, and trade studies of locations and design approaches.

A summary of the KSC facilities affected by LRB operations is presented in Figure 9.3-1. The detailed rationale and trade study analysis behind this facility summary is presented in Volume III, Sections 1 and 3. The need dates for each of the facility conversions or additions lead to a division of construction and readiness into a first and second line of facilities.

In Figure 9.3-2, the KSC facility transition overview shows the phased capability derived from the "two line" facilities approach. All facilities required for the currently specified 14 LRBs per year - launch rate or 122 mission program life cycle should be completed by FY 2001.

### 9.3.1 First Line Facilities

The Ground Operations Plan (Volume III, Section 1), and the Facility Requirements and Concepts (Volume III, Section 3), provide additional justification for the division of transition into two lines of facilities.

An initial LRB capability of eight launches per year can be supported by the first line of facilities shown in the top portion of Figure 9.3-2. Moving the ET processing out of VAB HB-4 enables the modification of that bay for LRB integration; at the same time it creates the need for a horizontal ET processing facility. The construction of the first new LRB MLP is the real "long pole" in preparing initial launch capability. The LRB Horizontal Processing Facility co-located with the new ET facility is a basic requirement for LRB program implementation. The LETF and LCC modifications are also support necessities. The first pad modification for dual launch vehicle configurations is the key action enabling the initial launch capability to be scheduled in 1996. Figures 9.3.1-1 through 9.3.1-3, present the schedule for the first line facility activations and significant milestones leading to initial operational capability (IOC).

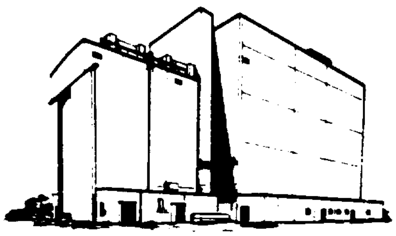
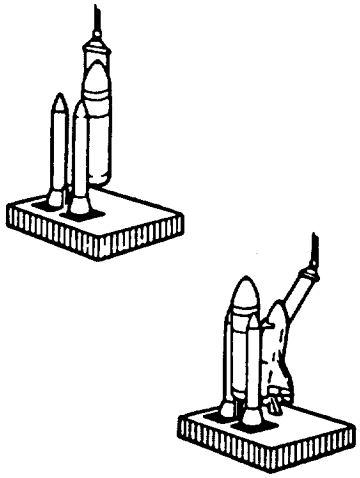
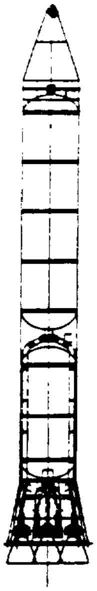
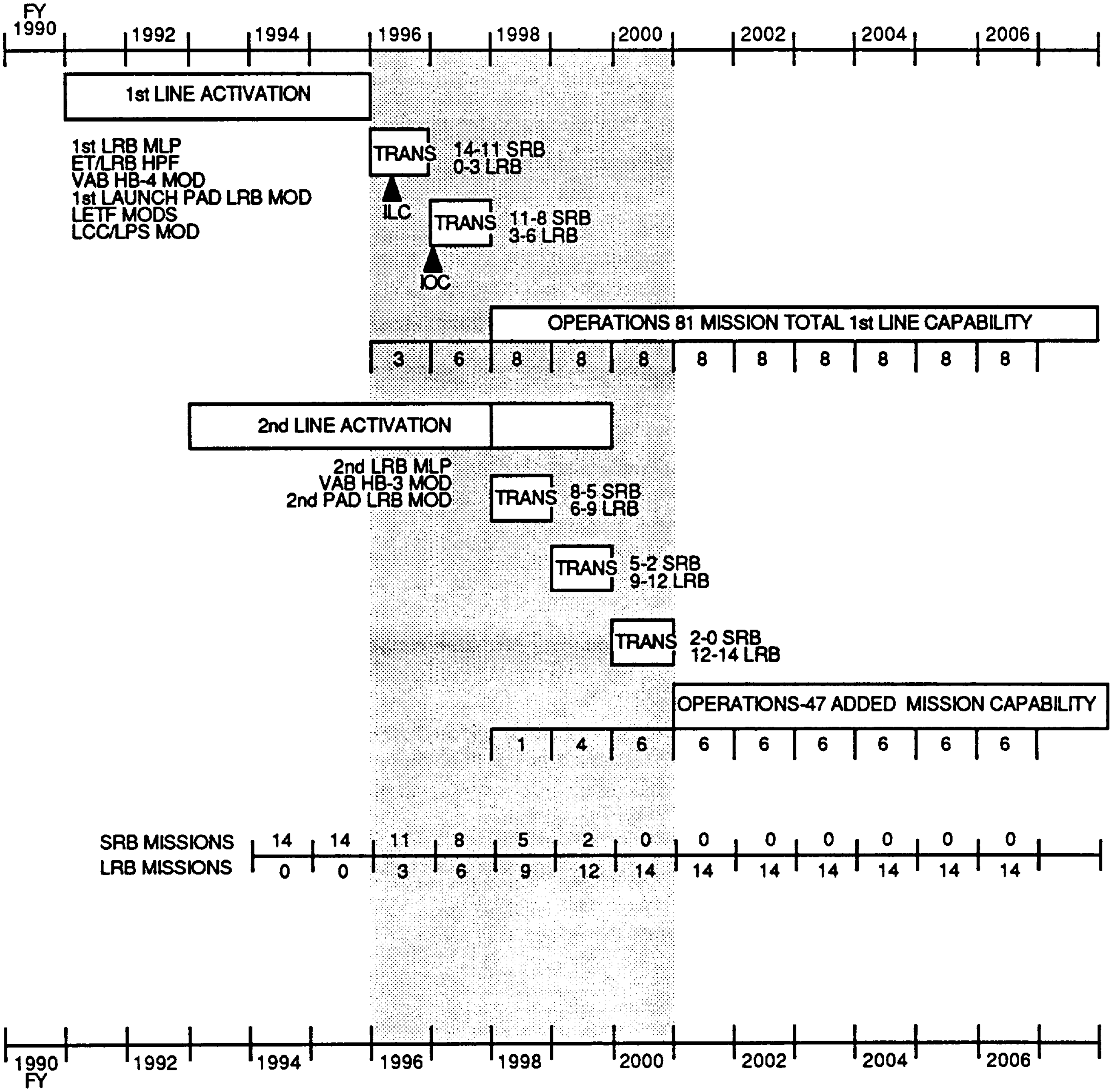
| | | |
|---|---|---|
|  |  |  |
| FACILITY | PROCESSING FUNCTION | LRB IMPACTS |
| ● BARGE DOCK | ● RECEIVING | ● NONE-USE AS IS |
| ● LRB & ET TOWWAY | ● ELEMENT TRANSFER | ● PARTIALLY NEW |
| ● LRB HORIZONTAL PROCESSING FACILITY (LRB-HPF) | ● ASSEMBLY/CHECKOUT & STORAGE | ● NEW |
| ● ET HORIZONTAL PROCESSING FACILITY (ET-HPF) | ● CHECKOUT/SURGE | ● NEW |
| ● ORBITER PROCESSING FACILITY (OPF) | ● CHECKOUT/SERVICING | ● NONE-USE AS IS |
| ● VERTICAL ASSEMBLY BLDG (VAB) | ● INTEGRATION | ● ACCESS PLATFORM MODIFICATION/ET RELOCATION |
| ● MOBILE LAUNCH PLATFORM (MLP) | ● INTEGRATION | ● NEW |
| ● CRAWLER WAYS | ● STS TRANSFER | ● VAB HB-ACCESS RE-ACTIVATION |
| ● LAUNCH EQUIPMENT TESTING FAC. (LETF) | ● VERIFICATION/CERTIFICATION SUPT | ● ADDITIONAL EQUIP. TESTING CAPABILITY |
| ● LAUNCH CONTROL CENTER (LCC) | ● COMMUNICATIONS AND CONTROL | ● CONSOLE/SOFTWARE MODIFICATIONS |
| ● PROPELLANT FACILITIES | ● FUEL & OXIDIZER STORAGE/DISTRIBUTION | ● PARTIALLY NEW & MODIFICATIONS |
| ● LAUNCH PAD | ● SERVICING/FINAL CHECKOUT & LAUNCH | ● FLAME DEFLECTOR AND UMBILICAL MODIFICATIONS |

Figure 9.3-1. Launch Site Facility Summary.



TOTAL LRB MISSIONS
THROUGH 2006=128

Figure 9.3-2. KSC Facility Transition Overview.

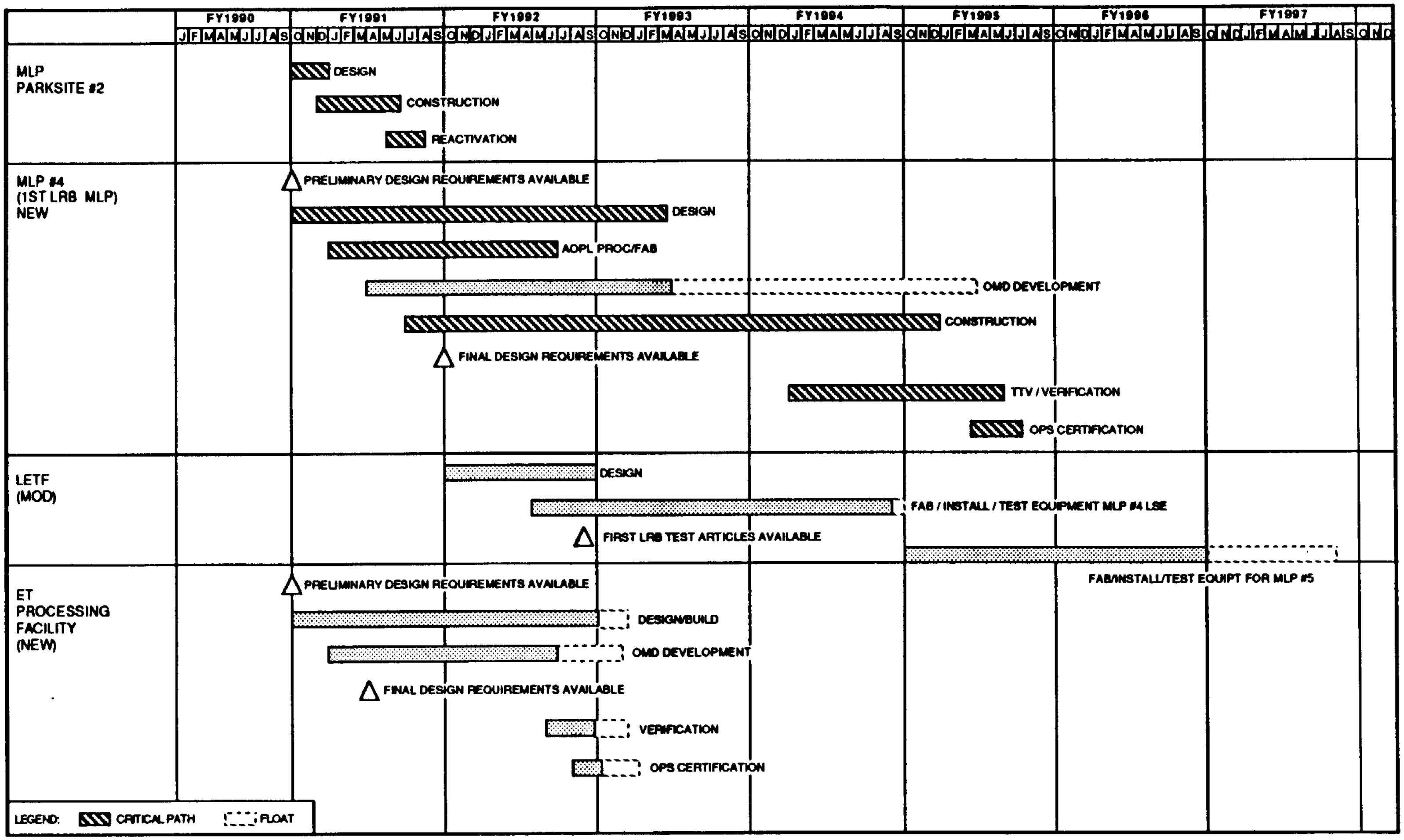


Figure 9.3.1-1. KSC Facility Activation 1st Line, Page 1.

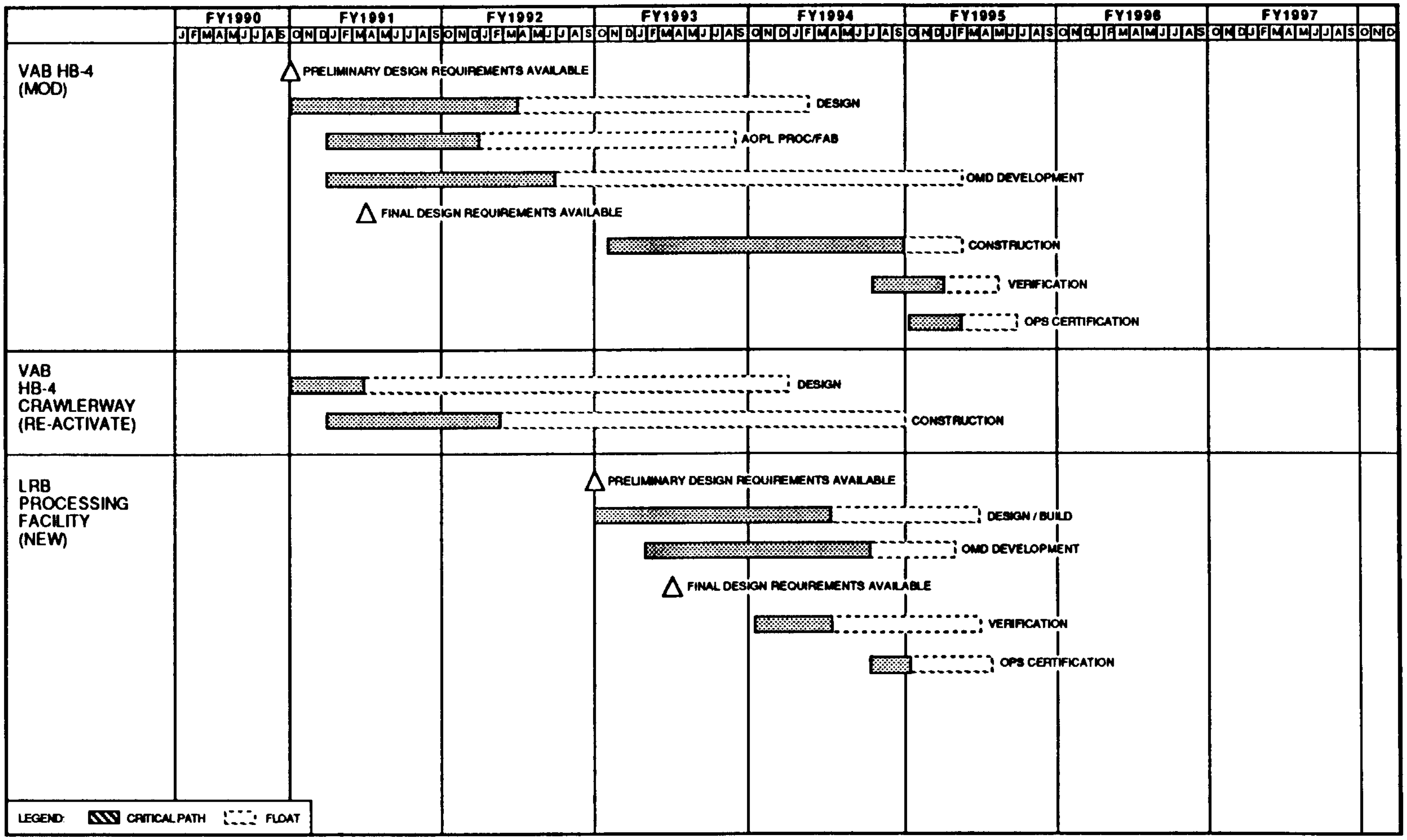


Figure 9.3.1-2. KSC Facility Activation 1st Line, Page 2.

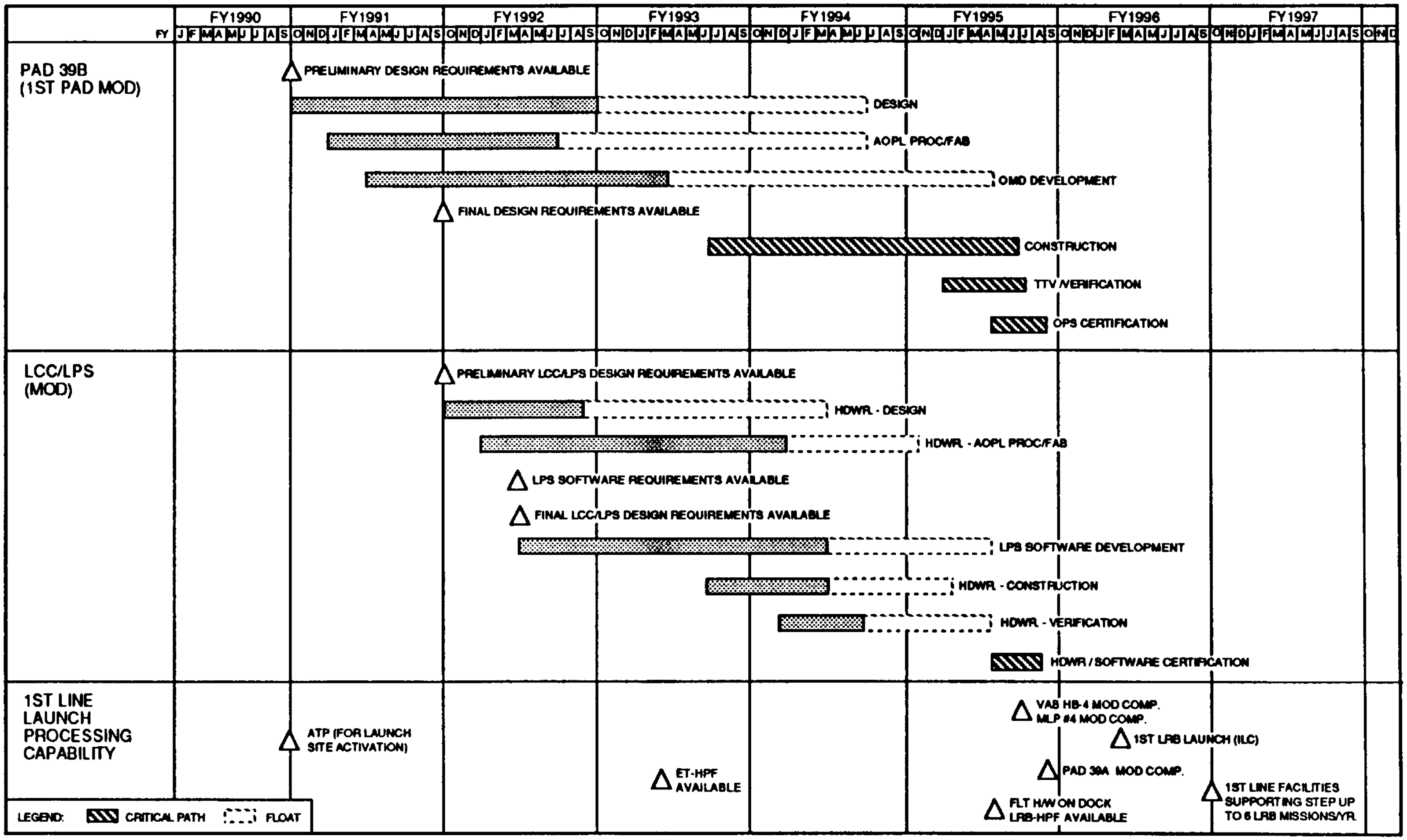


Figure 9.3.1-3. KSC Facility Activation 1st Line, Page 3.

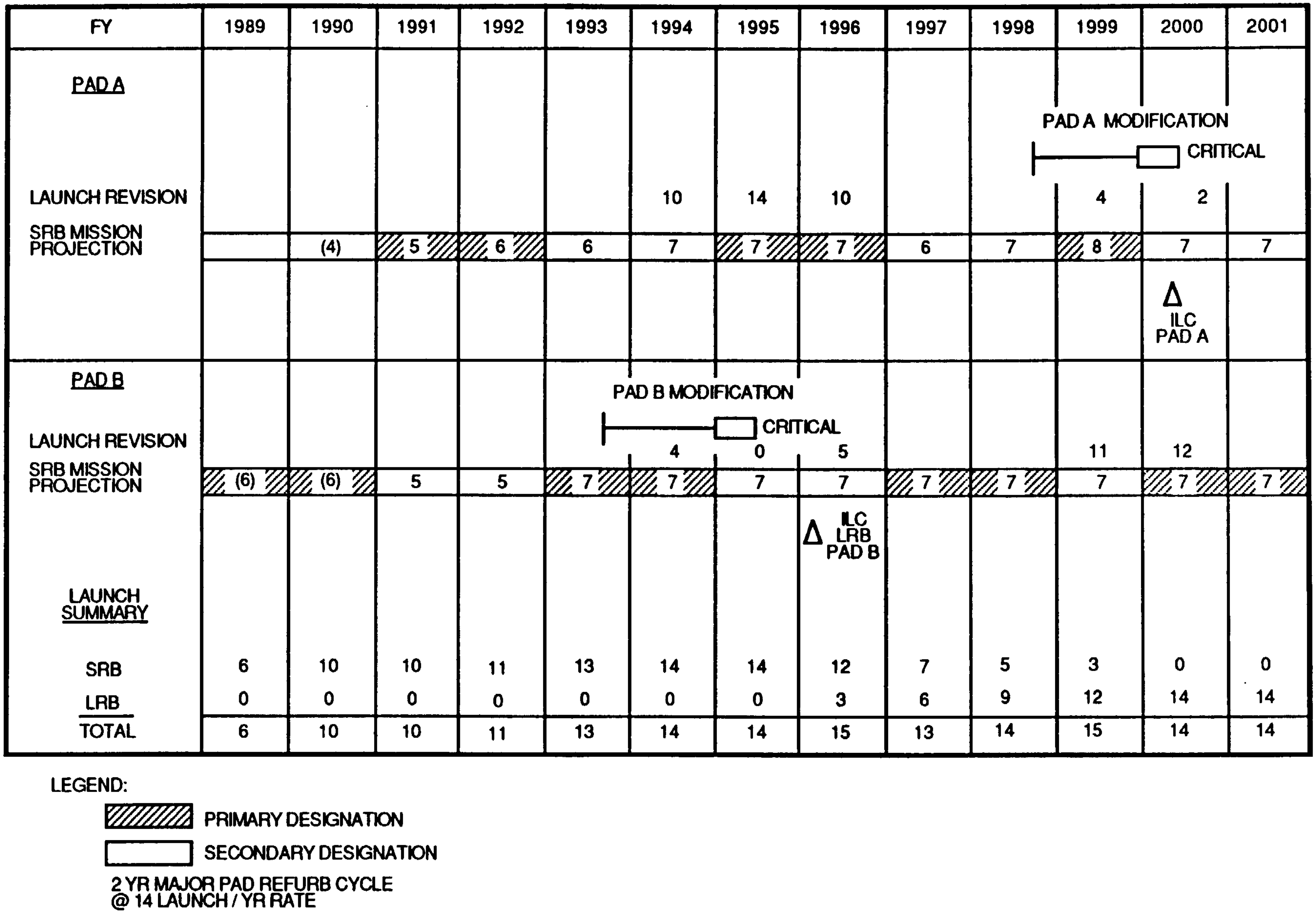
### 9.3.1.1 MLP Schedule Criticality

The most critical path in our preliminary transitional plan is the construction of new mobile launch platforms for the liquid rocket booster configuration. In this case the design work must begin immediately upon the program's Authorization To Proceed (ATP). In fact, some of the more preliminary design analysis may need advanced funding before the formal ATP. Other factors contributing to the length of this construction effort are: Site preparations, the support structure for the MLP which will be assembled at its pedestal height of 22 feet; and subsystem installation and checkout. This, approximately three and one half year process has been backed off of the flight hardware delivery dates and ground handling schedules to give us the recommended ATP. The availability of pressure-fed configurations is generally earlier than pump-fed; the activation schedule currently projected is optimized for the latter.

### 9.3.1.2 Launch Pad Modification Criteria

Second only to the MLP, the launch pad modification schedule is also very time critical, although the cause is quite different. On the pad, unlike the MLP, there will be the additional requirement to perform SRB operations. The initial construction activities could be conducted between launch processing activity at the pad, but final construction and certification will require an eight month dedicated down time.

The choice of which pad to modify first for a dual SRB/LRB launch capability is based on an extrapolation of current refurbishment cycles. Pad A is currently in cycle and based on a two year rotation, Pad B will be due starting in 1995. By scheduling the modification downtime during this normal refurbishment cycle on Pad B, the work should be accomplished in time to support both the pathfinder flow, and the first LRB launch. As illustrated in Figure 9.3.1.2-1, a shift of some currently scheduled SRB launches will have to be made to Pad A during this period. For example, in the year 1995, all 14 scheduled SRB missions will have to be performed off of Pad A. The average 18 day pad flow plus the four day refurbishment time projected for 1995 would theoretically permit as many as 16 launches from a single pad. Modification of Pad A to the same dual launch capability in the year 2000 does require some adjustment to the two year cycle. Again some launches must be off-loaded to the other pad during the final stages. The result is the second refurbishment of Pad B, after its modification, will have to be limited to a one year period (1999) so that Pad A conversion can occur during FY 2000.



| FY | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PAD A** | | | | | | | | | | | PAD A MODIFICATION | CRITICAL | |
| LAUNCH REVISION | | | | | | 10 | 14 | 10 | | | 4 | 2 | |
| SRB MISSION PROJECTION | | (4) | ▨ 5 | ▨ 6 | 6 | 7 | ▨ 7 | ▨ 7 | 6 | 7 | ▨ 8 | 7 | 7 |
| | | | | | | | | | | | | Δ ILC PAD A | |
| **PAD B** | | | | | PAD B MODIFICATION | | CRITICAL | | | | | | |
| LAUNCH REVISION | | | | | | 4 | 0 | 5 | | | 11 | 12 | |
| SRB MISSION PROJECTION | ▨ (6) | ▨ (6) | 5 | 5 | ▨ 7 | ▨ 7 | 7 | 7 | ▨ 7 | ▨ 7 | 7 | ▨ 7 | ▨ 7 |
| | | | | | | | | Δ ILC LRB PAD B | | | | | |
| **LAUNCH SUMMARY** | | | | | | | | | | | | | |
| SRB | 6 | 10 | 10 | 11 | 13 | 14 | 14 | 12 | 7 | 5 | 3 | 0 | 0 |
| LRB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 9 | 12 | 14 | 14 |
| TOTAL | 6 | 10 | 10 | 11 | 13 | 14 | 14 | 15 | 13 | 14 | 15 | 14 | 14 |

LEGEND:

- ▨ PRIMARY DESIGNATION
- ☐ SECONDARY DESIGNATION
- 2 YR MAJOR PAD REFURB CYCLE @ 14 LAUNCH / YR RATE

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Figure 9.3.1.2-1. Launch Pad LRB Activation Rationale.

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#### 9.3.1.3 LRB Pathfinder Hardware Flows

The KSC impact and timelines for pathfinder flows using the chosen vendor's hardware remain - TBD. The verification of new and modified facility interfaces to the flight hardware require that such arrangements be solidified in Phase-B LRB studies. The tentative nature of KSC facility completion and the anticipated arrival of the first mission hardware provides built-in contingency for our first flow projections, covered in Section 9.4.1. The timing and number of pre-mission fit checks as well as fueling, countdown and engine readiness tests will be decided once a more mature configuration and list of production milestones is developed.

### 9.3.2 Second Line Facilities

Once an initial launch capability has been established, the specified launch rate to program maturity mandates additional facility provisions. A second line of facilities has been identified to fully comply with this program specification.

Within the second line of facilities the second new MLP enables the processing of more than the earlier eight (8) missions per year. This was a limit reached because of the combination of VAB and pad processing time, along with post launch refurbishment and hold-down post tensioning, requiring the MLP in place. Also needed were the second VAB high bay and launch pad modifications to avoid single failure points as well as to compensate for full rate scheduling realities.

Figure 9.3.2-1 presents the schedule for the second line activation and the "on-line" milestones enabling launch rate increases.

### 9.3.3 Facility Construction/Modification Scheduling Impacts

The impact to on-going refurbishment operations of the first and second lines of LRB facilities is illustrated in Figures 9.3.3-1 through 9.3.3-11. These figures are presented in a one page per fiscal year format, for the years 1991 through 2000. Starting with the ATP, construction bars representing the same schedule of work depicted in Figure 9.3.1-1,-2,-3, and 9.3.2-1, are overlaid onto a SRB mission model showing specific facility utilization. The beginning of Pad B modification in FY 1993, causes existing launch activity displacements to Pad A beginning in FY 1995. In actuality, any mission that could be shifted over to a Pad A, even during the construction interruptible phase of modification, would likely be moved. The FY 1995 part of the figure also shows the first

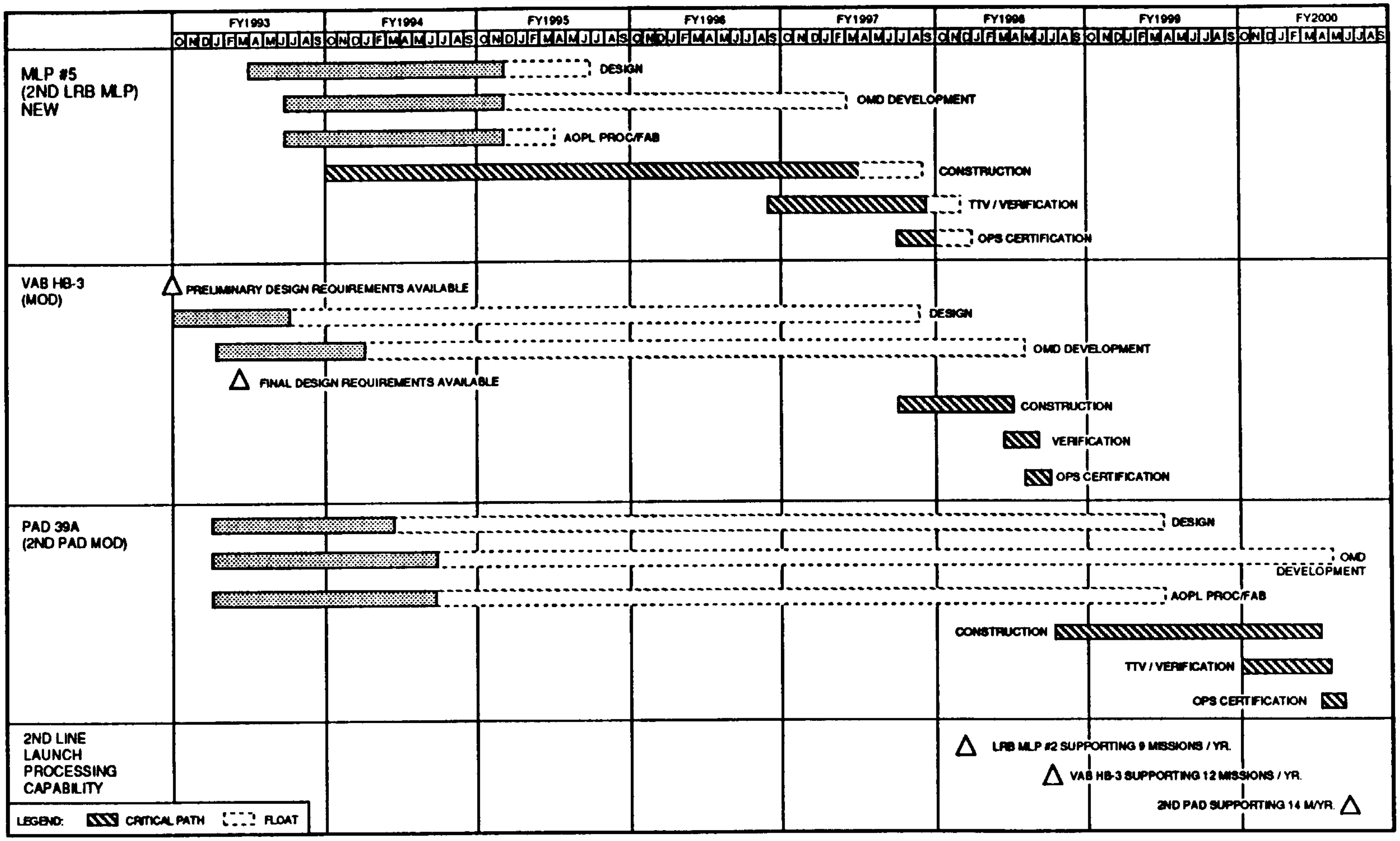
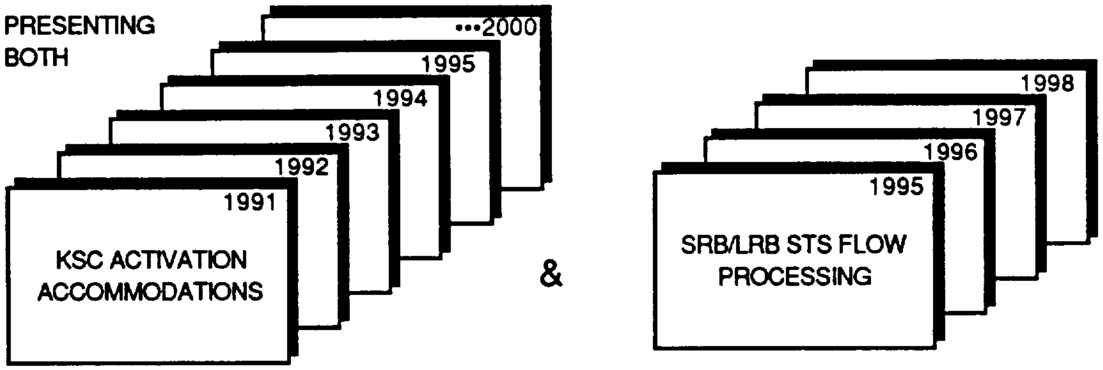


Figure 9.3.2-1. KSC Facility Activation 2nd Line Plan.

# FY1991-2000
# KSC SRB/LRB PROCESSING FACILITY UTILIZATION
# (FIGURES 9.3.3-2 THRU -11)



<u>INTERPRETIVE REMARKS</u>

- ACTIVATION/CONSTRUCTION BARS INCLUDE THE SCHEDULE FLEXIBILITY (ie. FLOAT TIME) ALLOWANCE FOR EACH ACTIVITY.
- ARROWS INDICATE FACILITY PROCESSING ACTIVITIES DISPLACED TO ALTERNATE FACILITIES.
- 'X's INDICATE FLOW PROCESSING REQUIREMENTS PERFORMED ELSEWHERE DUE TO THE CHANGE FROM SRB TO LRB.
- LRB FLIGHT PROCESSING FACILITY BARS FOR STS-111 THROUGH STS-147 WERE ADJUSTED FOR LRB (ie. SHORTER FLOW TIME, EXCEPT AT PAD)
- ALL MISSION PROCESSING FLOWS WERE BASED ON KEEPING THE LAUNCH DATE FIXED (LRB PROCESSING ACTIVITIES WERE "BACKED OFF" TO MAINTAIN THE PROJECTED LAUNCH DATE).
- PAD TIME BARS INCLUDE A 4 DAY REFURB AFTER LAUNCH.
- MLP TIME BARS INCLUDE 4 DAY REFURB AFTER LAUNCH AND 2 DAY HDP VERIFICATION PRIOR TO THE START OF VAB INTEGRATION.

Figure 9.3.3-1. Overview of Facility Utilization Projections.

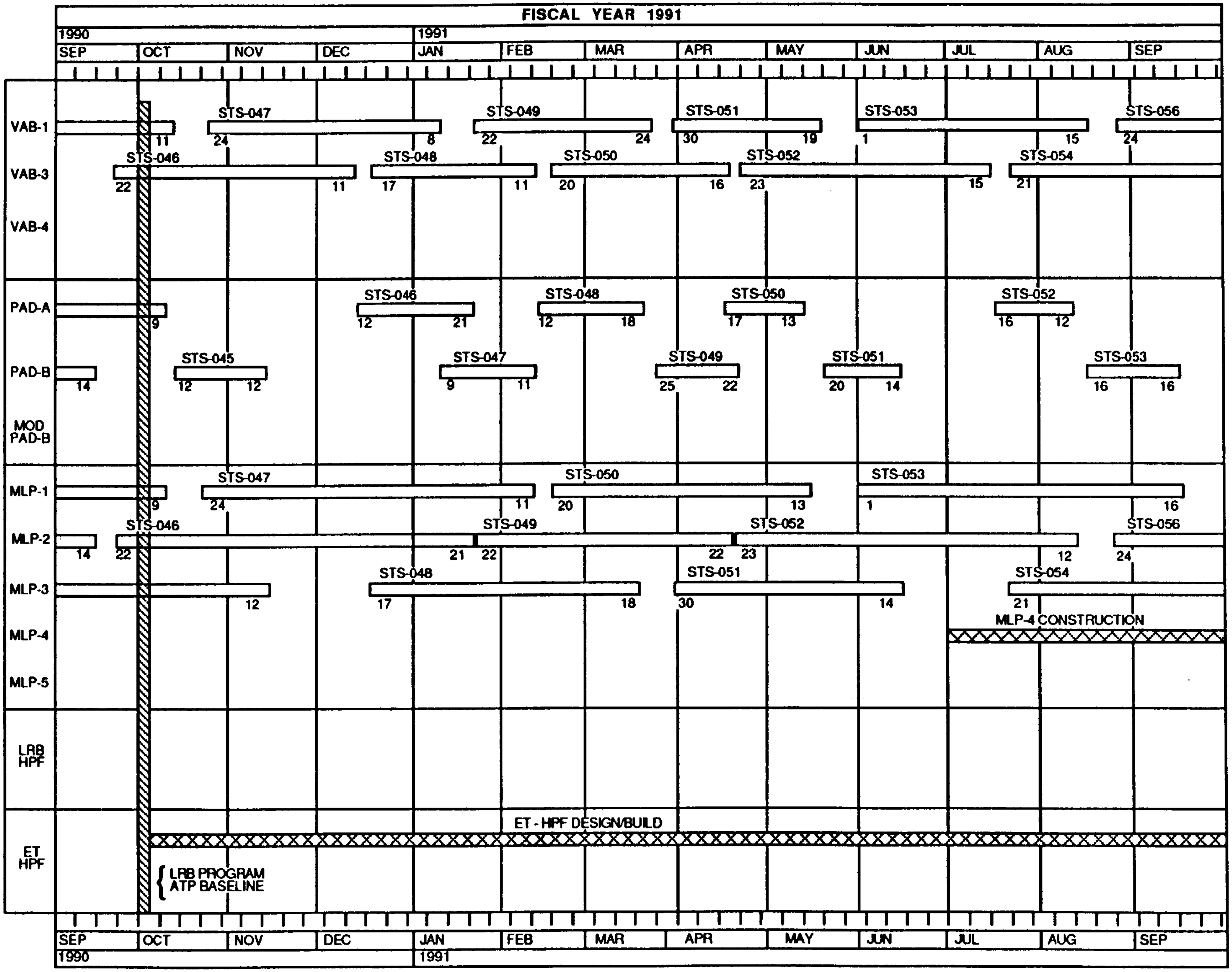


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Figure 9.3.3-2. FY1991 KSC SRB/LRB Processing Facility Utilization.

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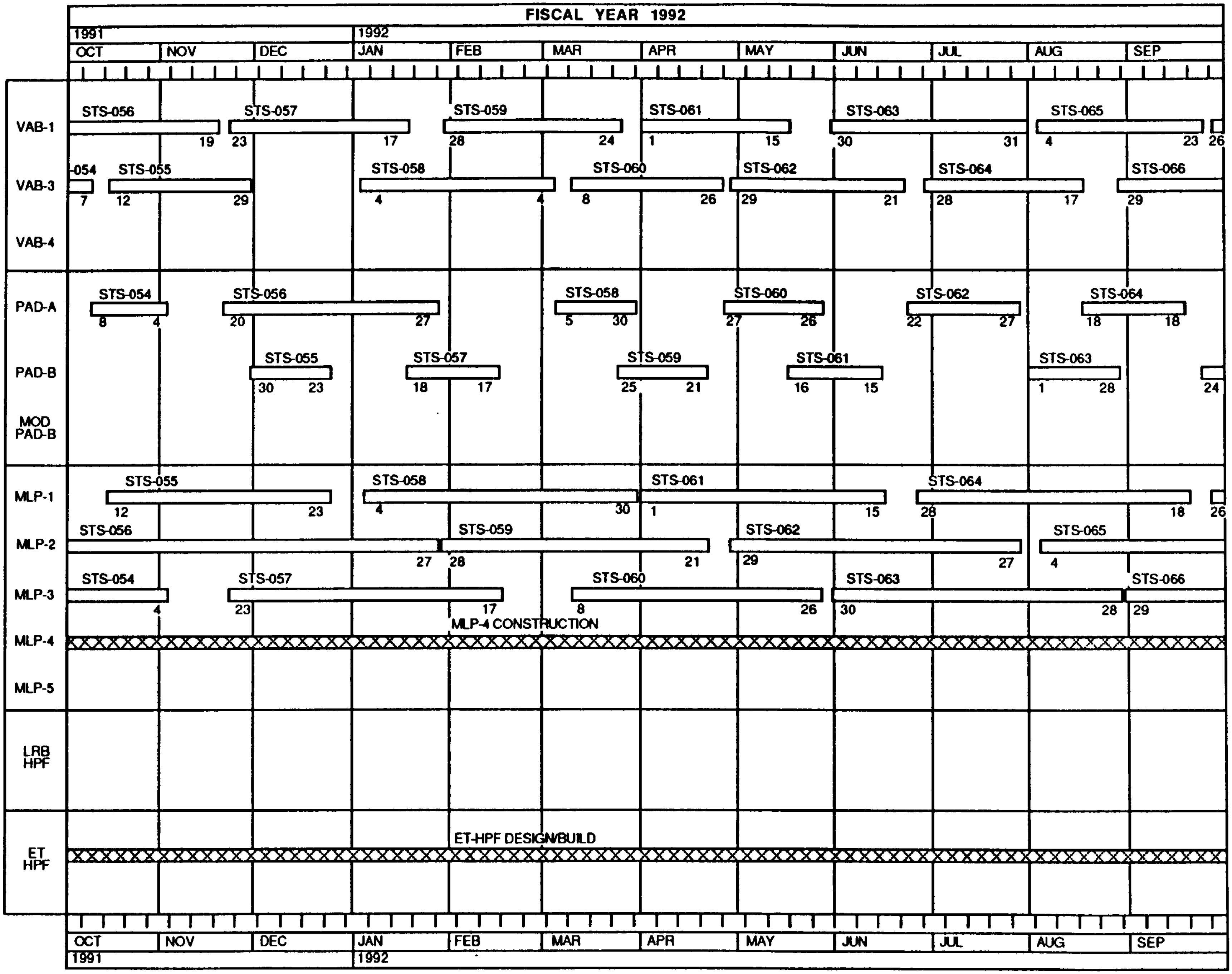

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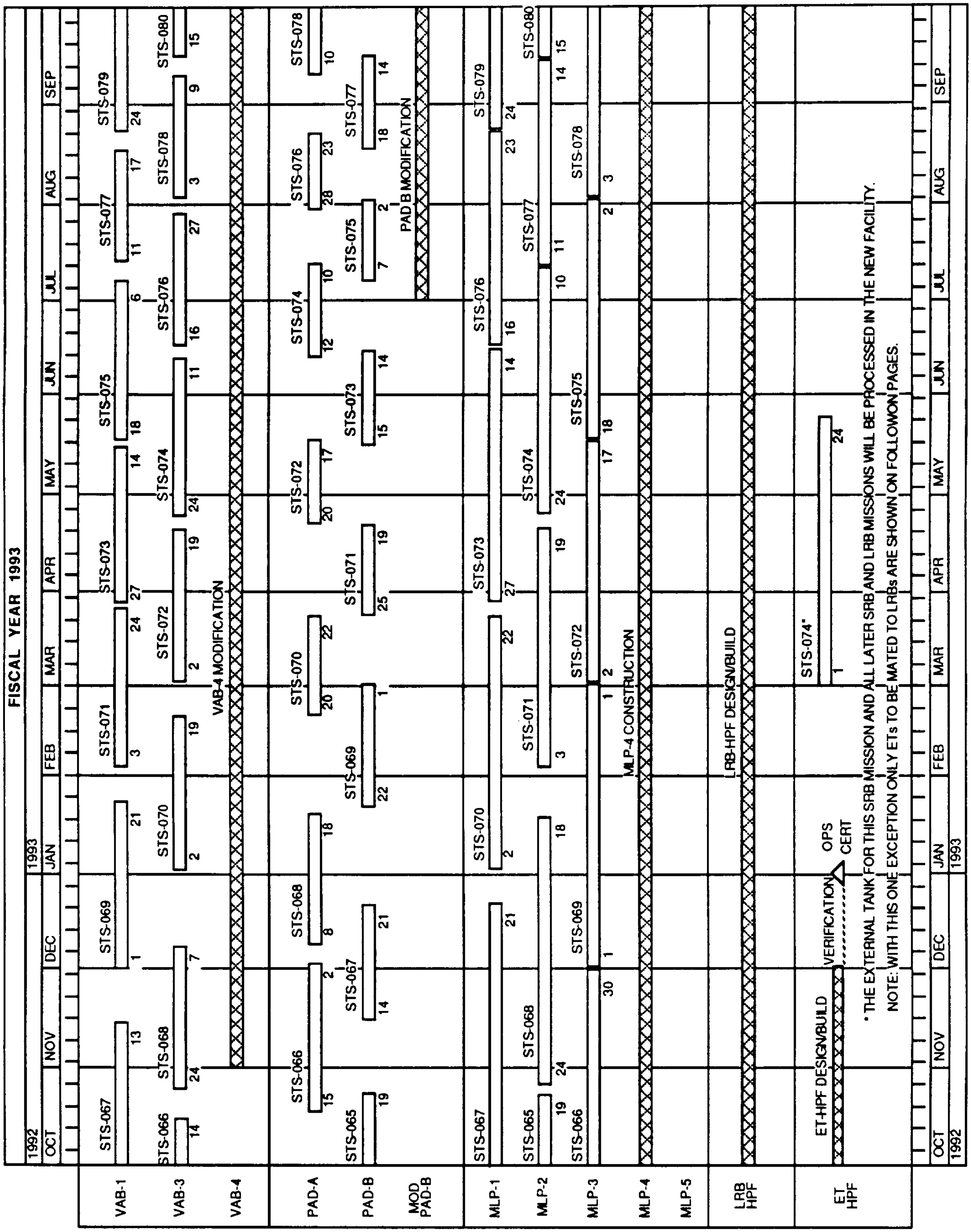
Figure 9.3.3-3. FY1992 KSC SRB/LRB Processing Facility Utilization.

3-9.4 11/12 9:00a



* THE EXTERNAL TANK FOR THIS SRB MISSION AND ALL LATER SRB AND LRB MISSIONS WILL BE PROCESSED IN THE NEW FACILITY.

NOTE: WITH THIS ONE EXCEPTION ONLY ETs TO BE MATED TO LRBs ARE SHOWN ON FOLLOWON PAGES.

Figure 9.3.3-4. FY1993 KSC SRB/LRB Processing Facility Utilization.

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/DS1

3-9.4 11/12 9:00a

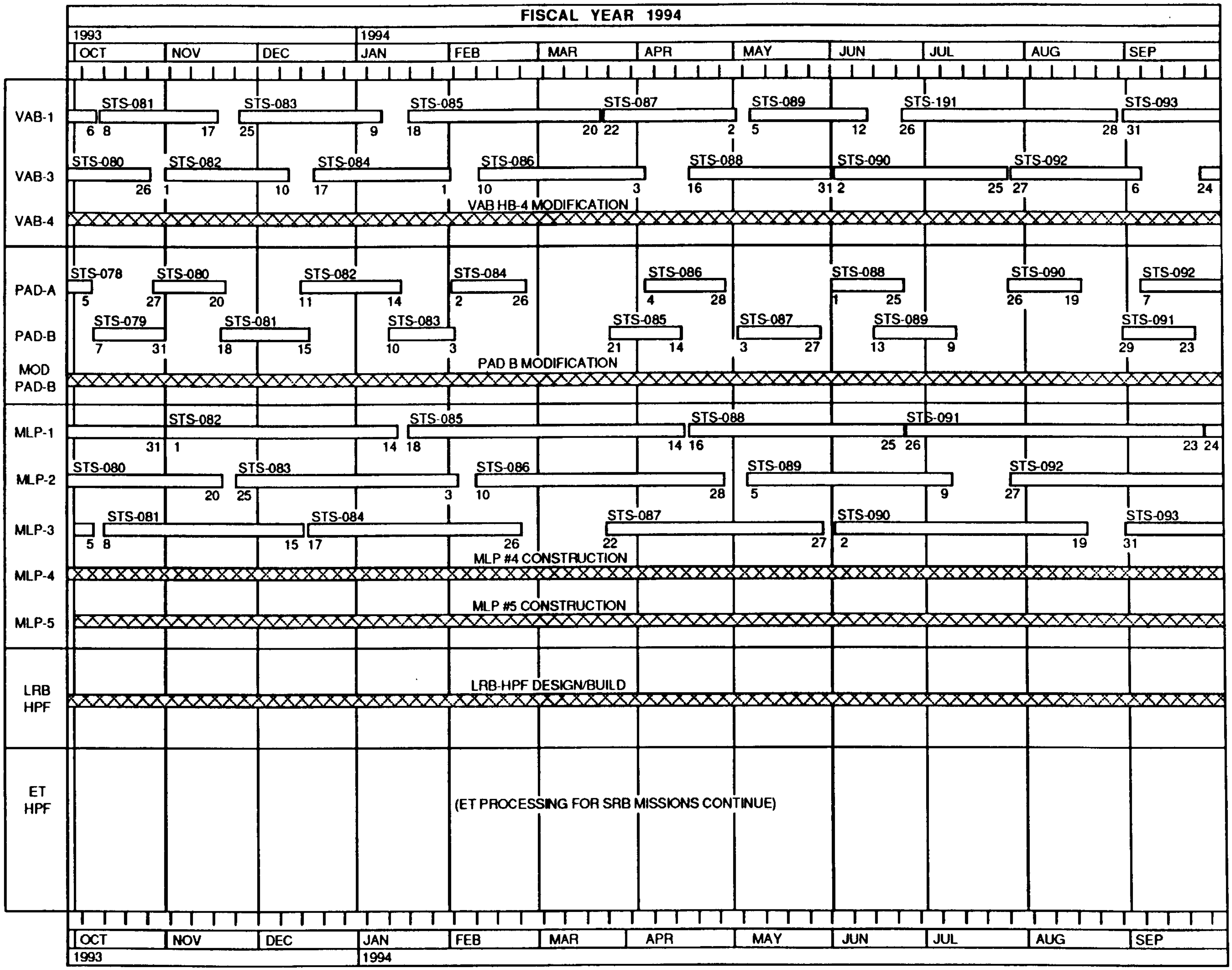

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Figure 9.3.3-5. FY1994 KSC SRB/LRB Processing Facility Utilization.

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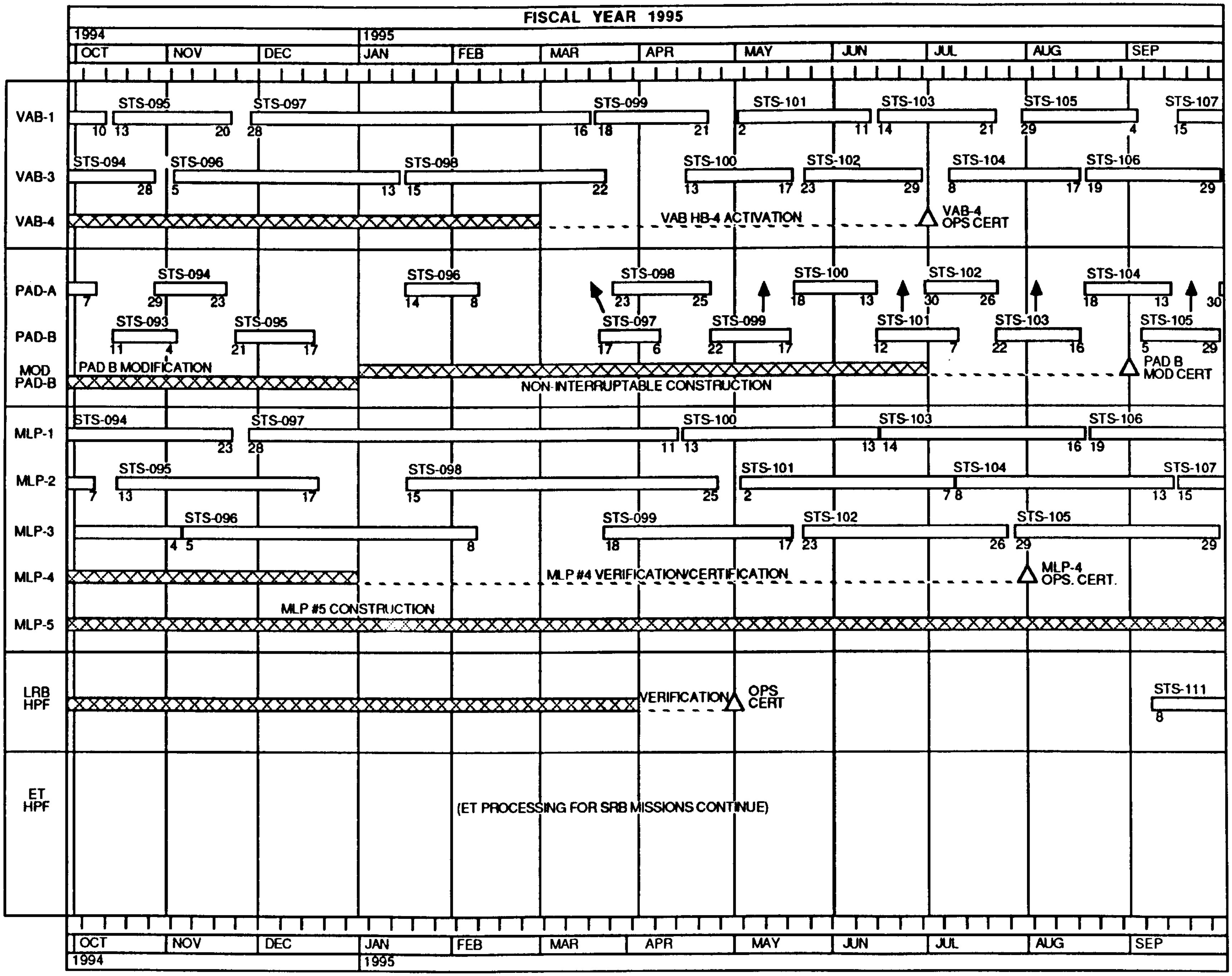

Figure 9.3.3-6. FY1995 KSC SRB/LRB Processing Facility Utilization.

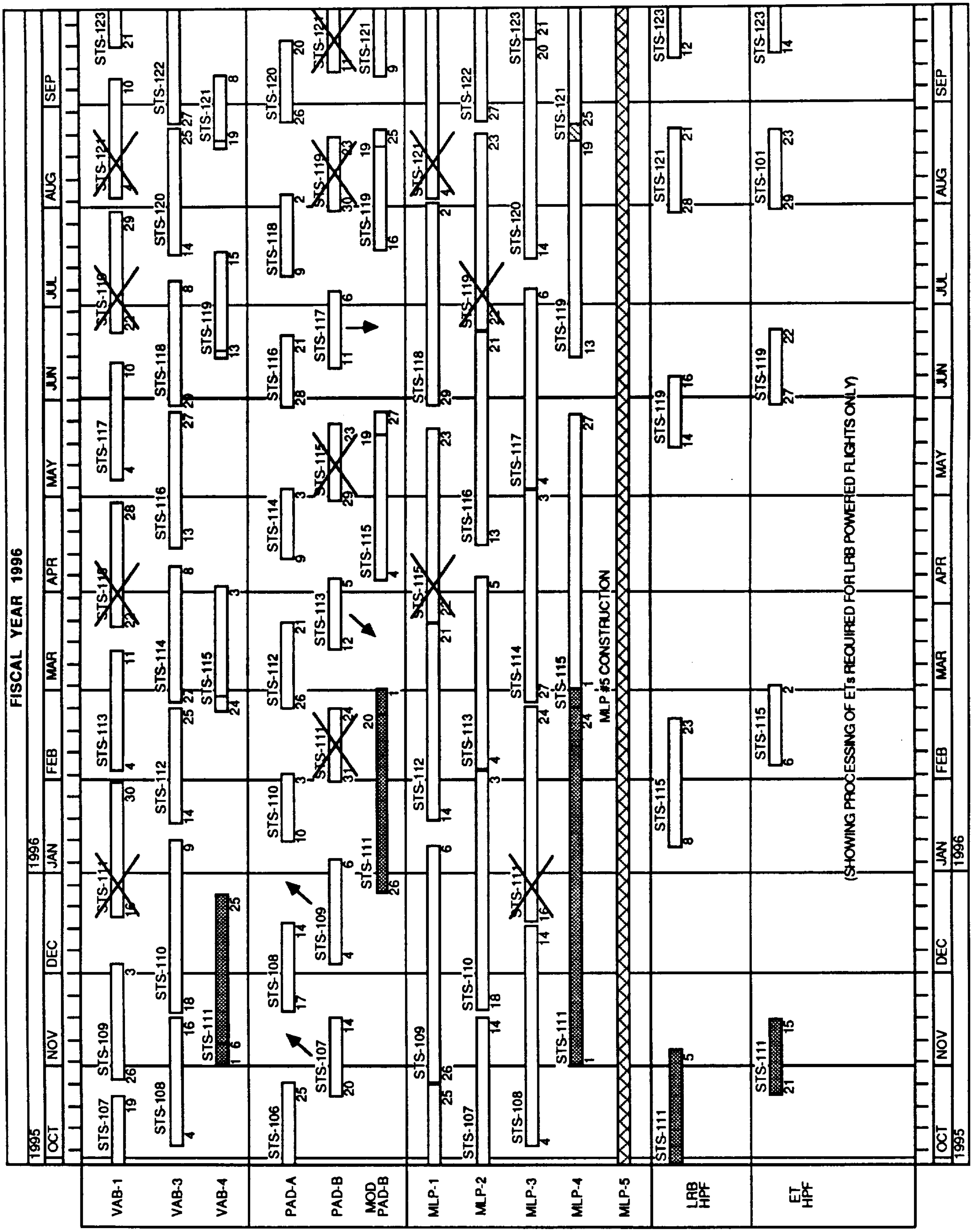

Figure 9.3.3-7. FY1996 KSC SRB/LRB Processing Facility Utilization.

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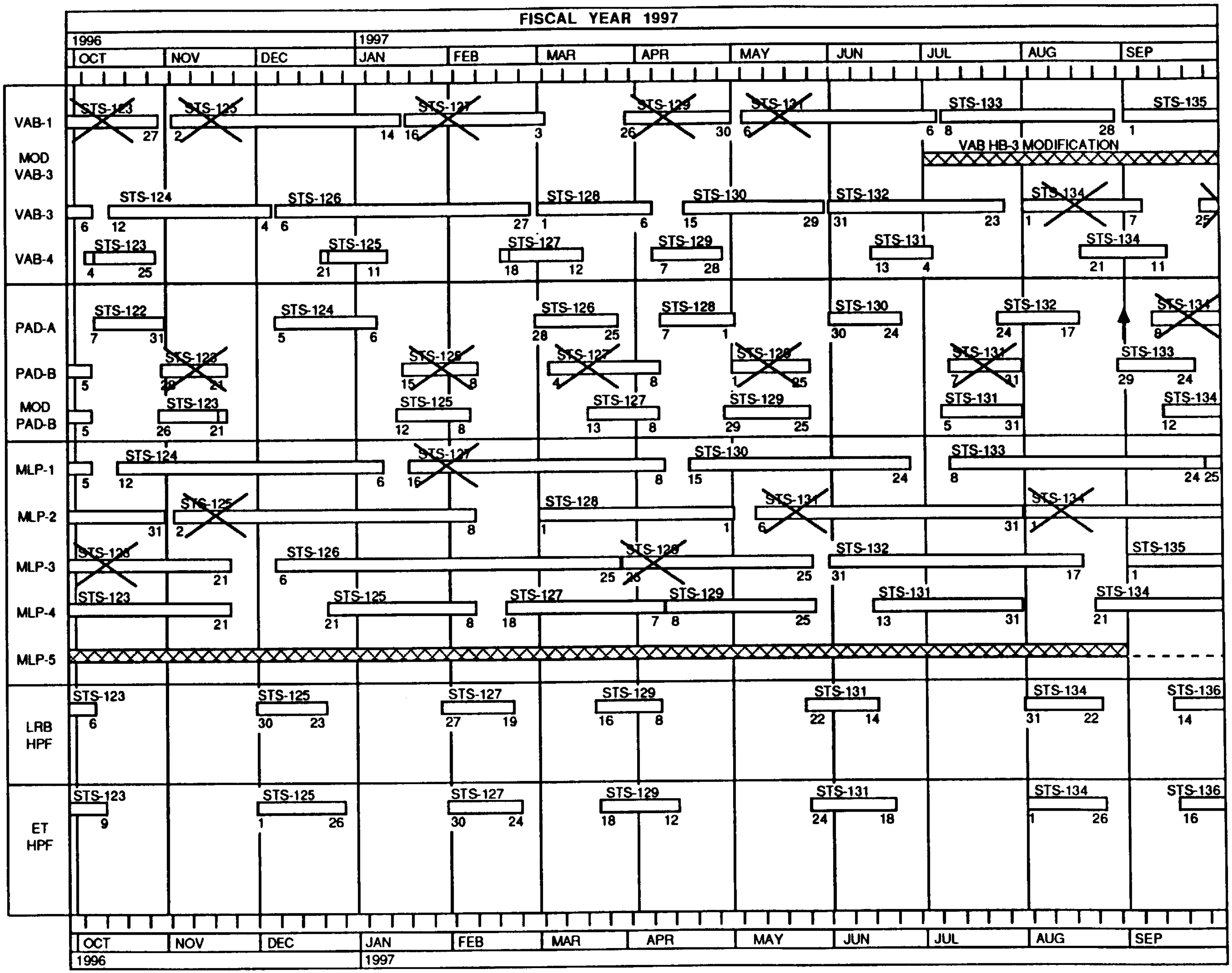

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Figure 9.3.3-8. FY1997 KSC SRB/LRB Processing Facility Utilization.

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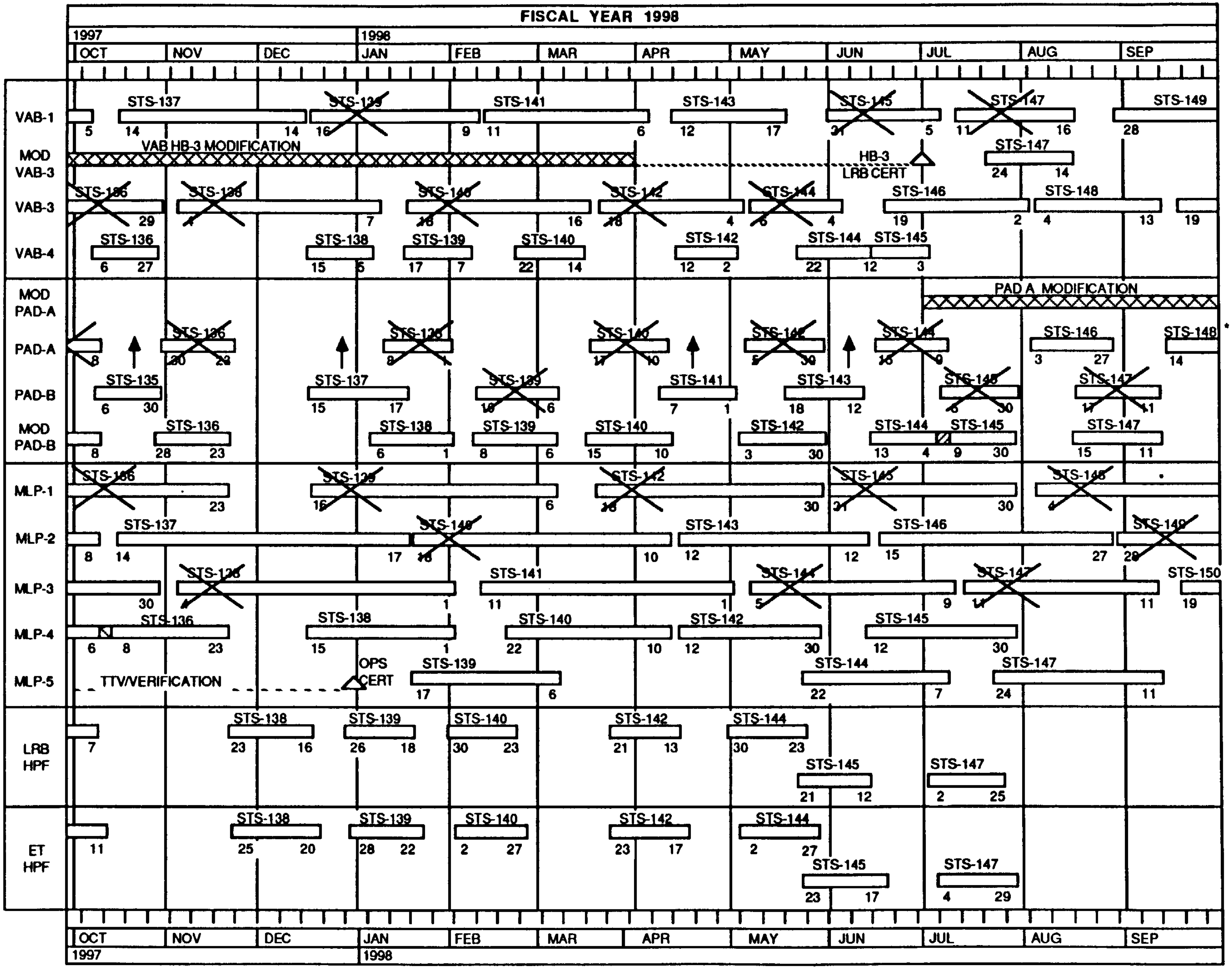

*LRB FLIGHT PROCESSING FOR STS-148 AND ON NOT RESCALE.

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Figure 9.3.3-9. FY1998 KSC SRB/LRB Processing Facility Utilization.

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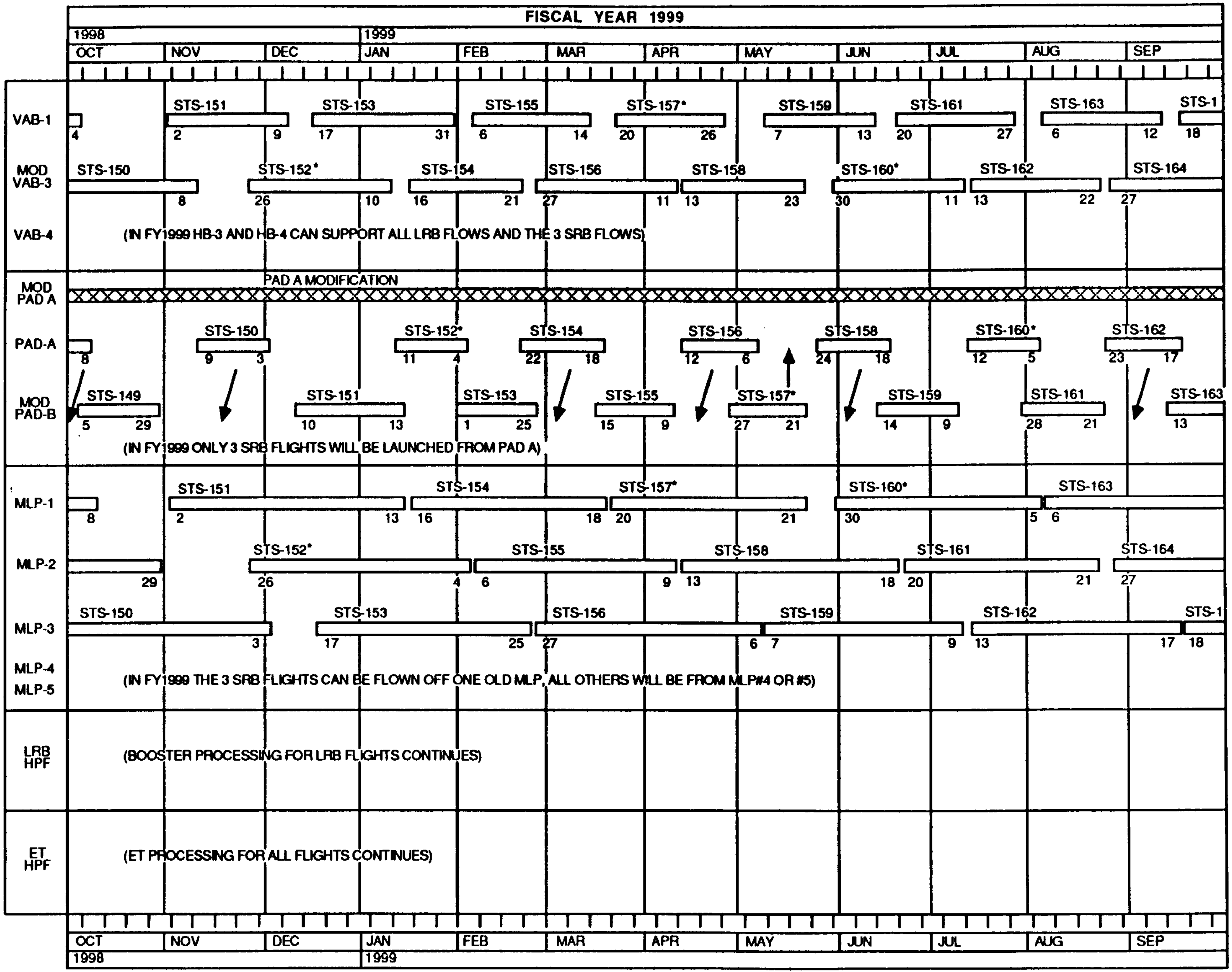

* INDICATES SRB MISSION

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Figure 9.3.3-10. FY1999 KSC SRB/LRB Processing Facility Utilization.

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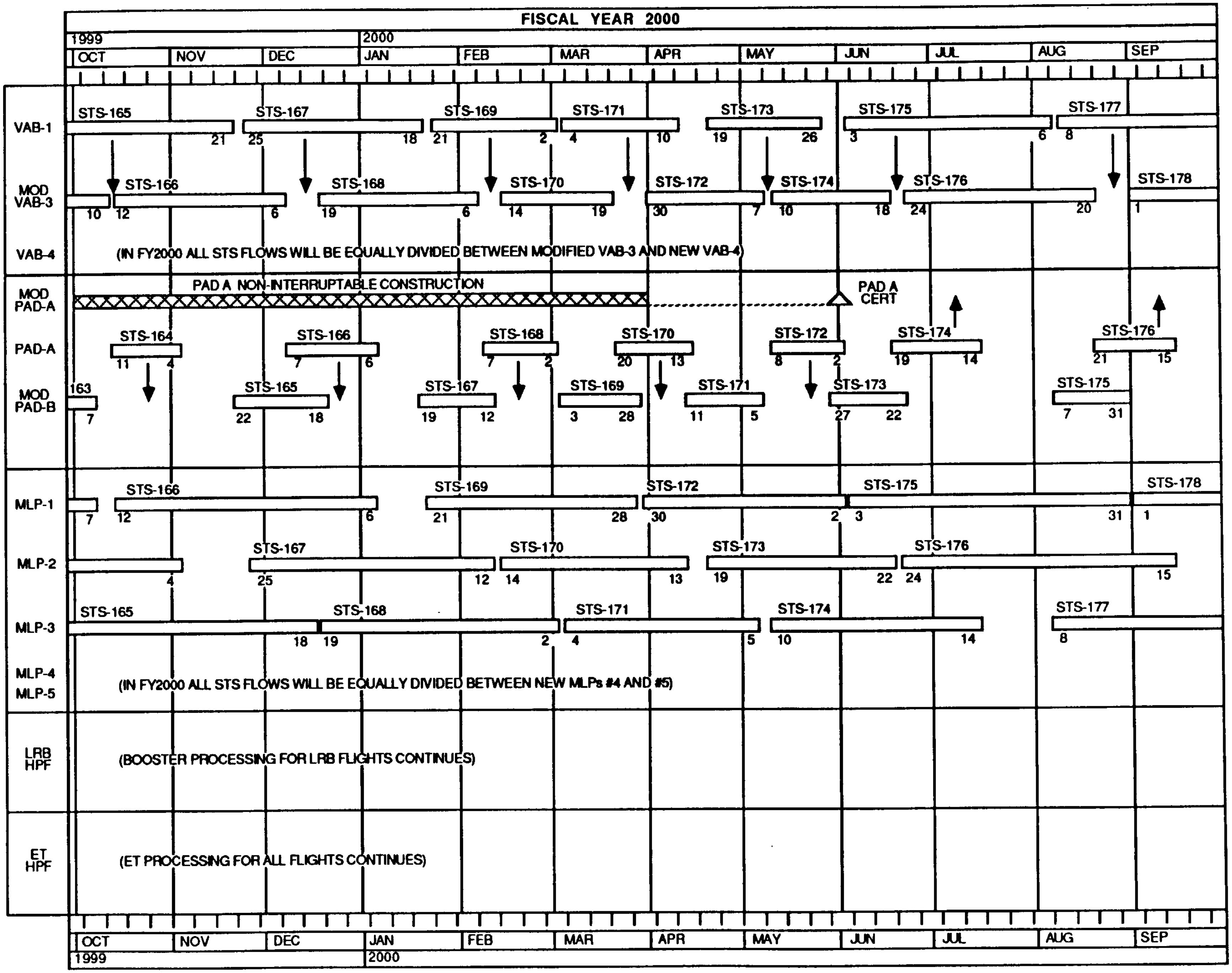

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/DS1/TT1/JN1

Figure 9.3.3-11. FY2000 KSC SRB/LRB Processing Facility Utilization.

3-9.4 12/8 9:00a

use of the ET-HPF and the LRB-HPF for LRB flight hardware. The projection of increased LRB facilities use, and reduced utilization of existing SRB-only facilities continues to be illustrated through to the end of the transition period.

## 9.4 MANIFEST INTEGRATION OF LRB WITH SRB

Before integrating LRB flows into the current SRB manifest, a clear understanding of the projected LRB "generic" flow has to be assured. Figure 9.4-1 provides an annotated breakdown of the operations and locations involved in such a "generic" flow.

Given the tasks and time involved in the ground preparation of each launch configuration, integration of the two (SRB & LRB) into a common mission manifest requires comparative analysis. Figure 9.4-2 shows typical flows for both the SRB and the LRB in the 1995/1996 time period. The use of different facilities and time allotments is clearly evident. The standalone processing of ETs and SRB/LRBs in each flow is considered off line. The processing time between missions for the Orbiter at 51 days remains the longest bar on the critical path. The LRB flow cuts down on VAB stacking time and the MLP support requirement while adding two days to the pad processing flow.

### 9.4.1 First Four LRB Flows

The beginning of LRB flight hardware operations at KSC is reflected in Figure 9.4.1-1. The first three flows incorporate an arbitrary learning curve in multiples of 2.5, 2.0 and 1.5 respectively, to the generic workdays projected for the fourth (IOC) mission. The unassigned period between LRB hardware "on dock" and MLP earliest and latest need dates provides flexibility in delivery dates and the time for the pathfinder exercises described in paragraph 9.3.1.3. It is important to note that SRB missions are launched from modified Pad B between the first and second, and the second and the third LRB missions. This relieves Pad A scheduling as well as verifying a dual configuration capability.

Figures 9.4.1-2 through 9.4.1-7, show how the learning curve affected the generic flow projection and gives the calendar basis for integrating the first three flows into the multimission manifest.

### 9.4.2 LRB Generic Flow

The generic flow first shown in Figure 9.4-1 was chosen as the baseline flow for the fourth LRB

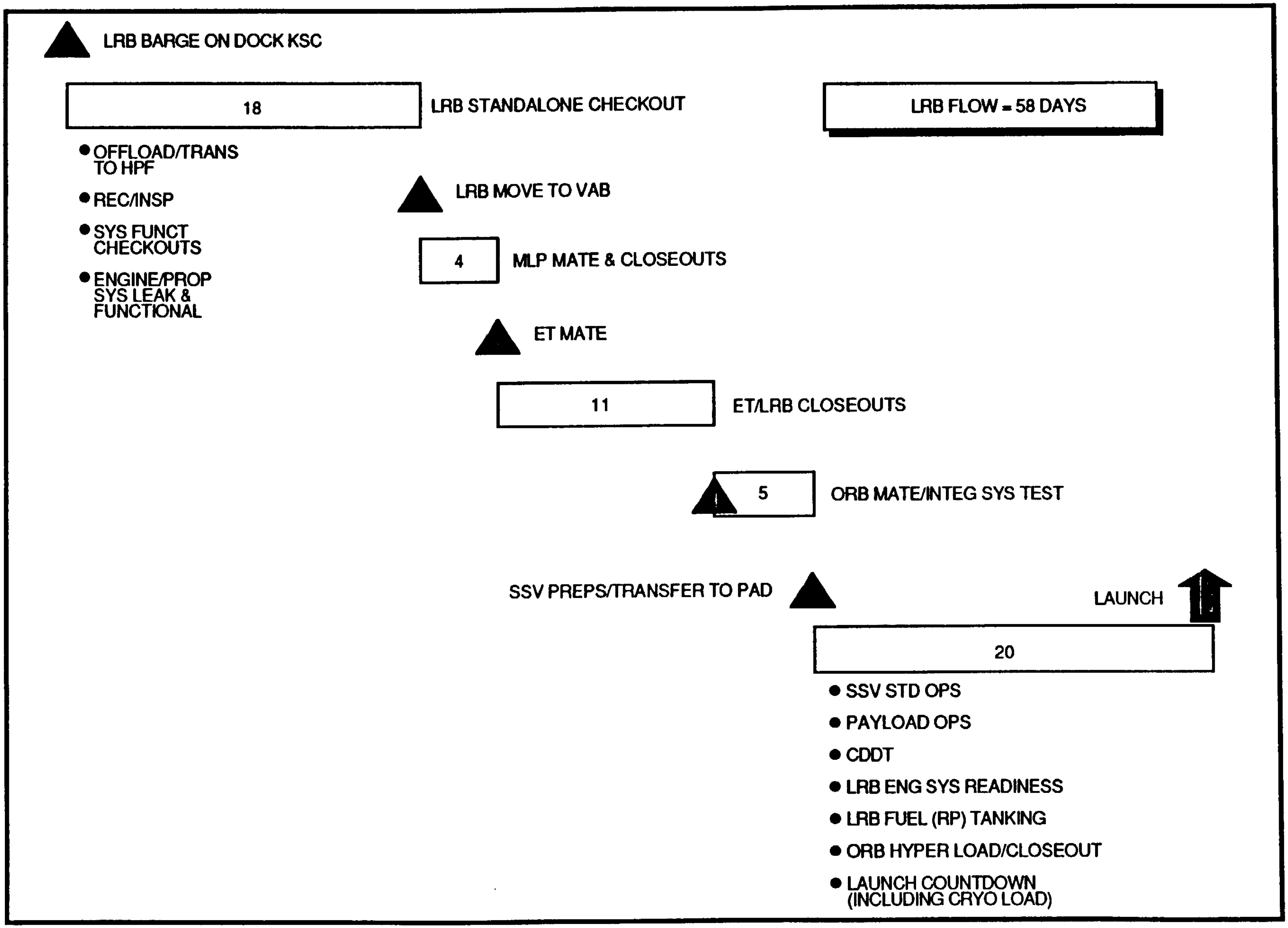

Figure 9.4-1. Generic LRB Ground Processing Flow

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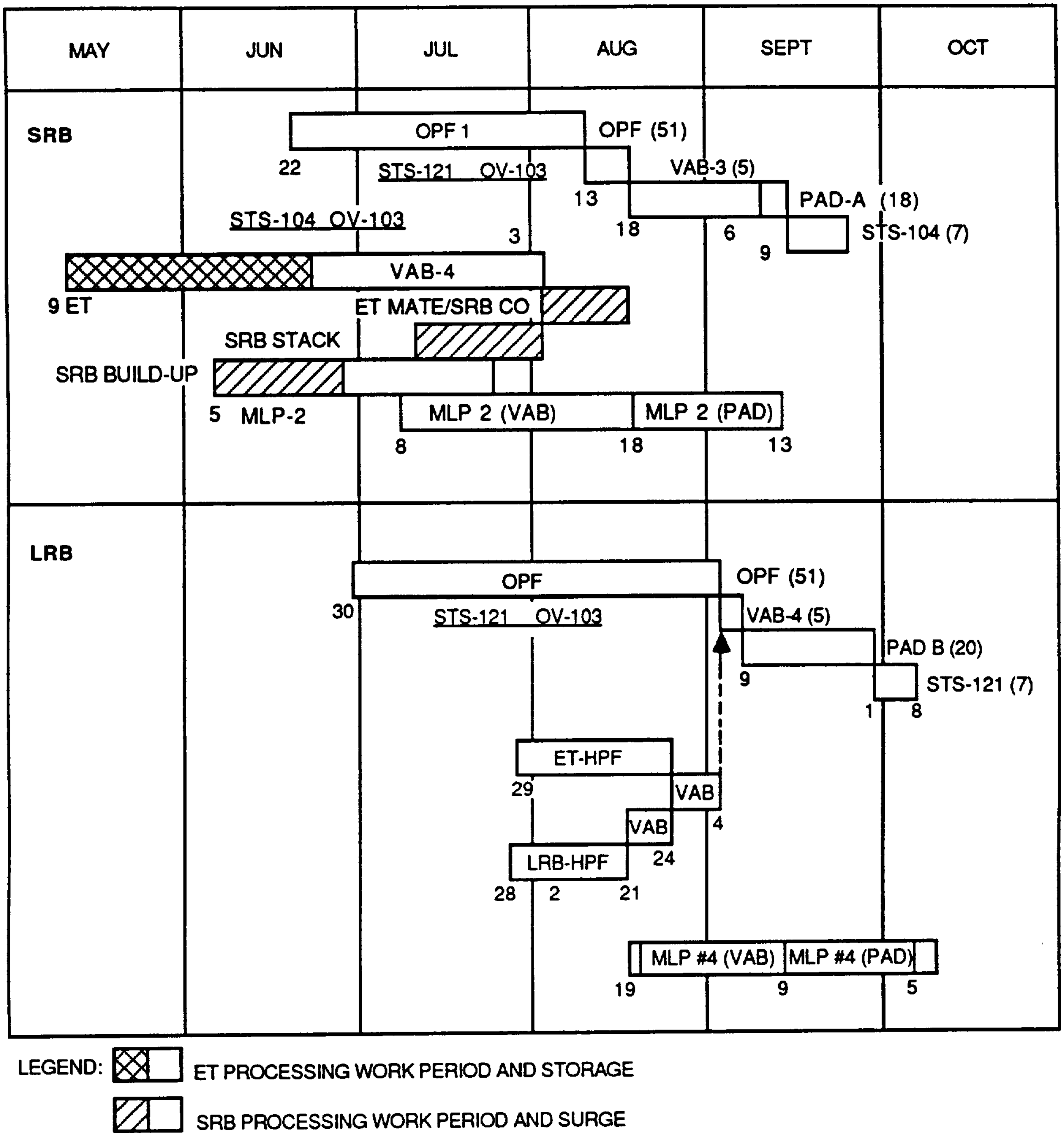
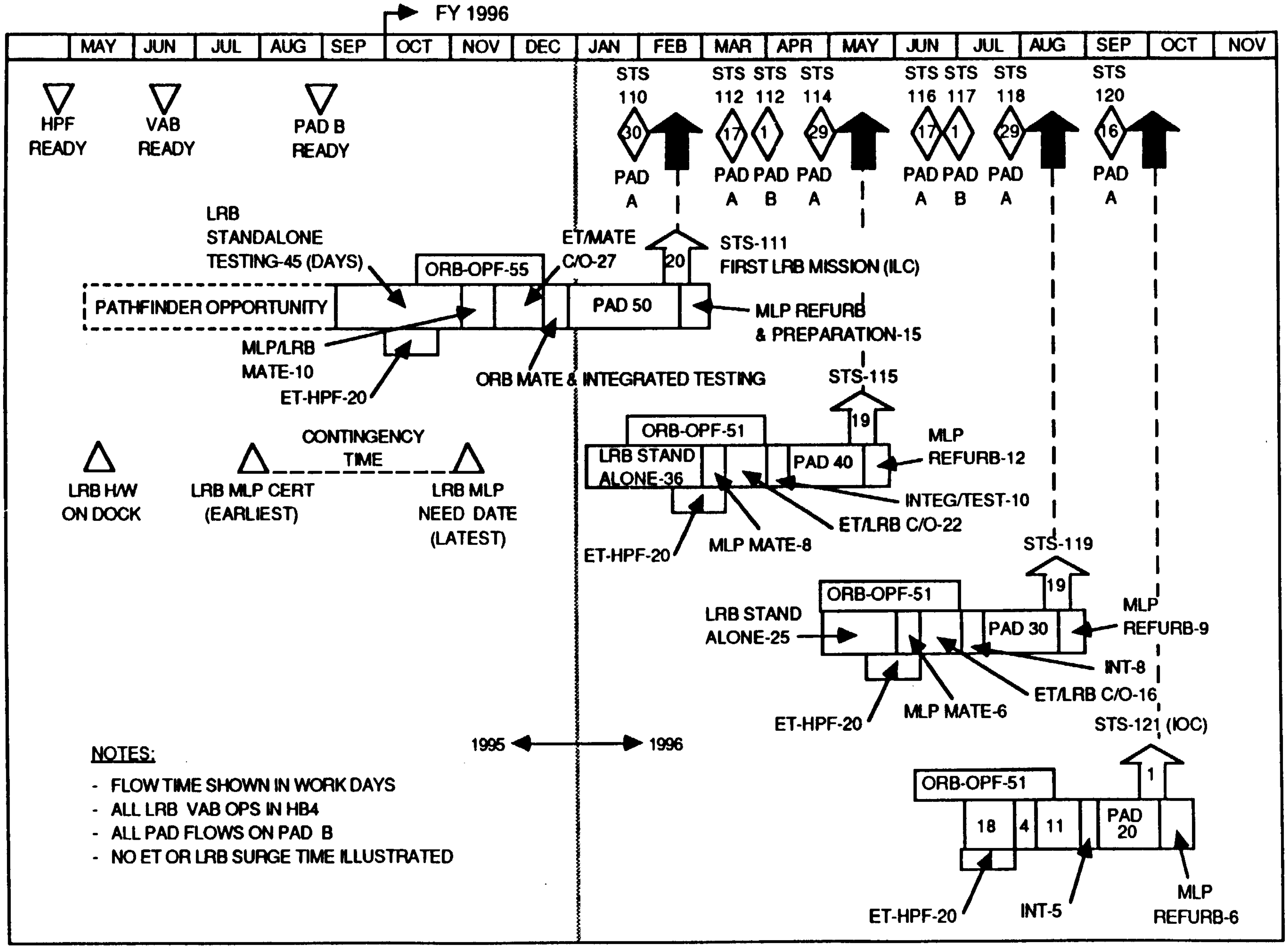


Figure 9.4-2. Comparative Facility Planning Chart For Typical STS Flows.



NOTES:

- FLOW TIME SHOWN IN WORK DAYS
- ALL LRB VAB OPS IN HB4
- ALL PAD FLOWS ON PAD B
- NO ET OR LRB SURGE TIME ILLUSTRATED

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Figure 9.4.1-1. LRB Processing/Launch Transition To I.O.C.

3-9 11/19 91100a

| FY 1996-I.L.C. FIRST LRB POWERED STS MISSION | | | | | | |
|---|---|---|---|---|---|---|
| KSC LOCATION | PROCESSING FUNCTION | GENERIC WORK DAYS | LOCATION SCHEDULE DAYS/SHIFTS (FACTOR) | CALENDAR START | CALENDAR COMPLETE | CALENDAR DAYS |
| — | STS-111 MISSION | 7 | 7/3 (1.00) | FEB 20 | FEB 27 | 7 |
| PAD | FINAL C/O & CD | 50 | 6/3 (1.14) | DEC 26 | FEB 20 | 57 |
| VAB | ORB MATE & INTEG TEST | 13 | 7/3 (1.00) | DEC 13 | DEC 25 | 13 |
| OPF | ORBITER PROCESSING | 55* | 5/3 (1.29) | OCT 03 | DEC 12 | 71 |
| VAB | LRB/ET MATE AND C/O | 27 | 7/3 (1.00) | NOV 16 | DEC 12 | 27 |
| ET-HPF | ET PROCESSING | 20* | 5/3 (1.29) | OCT 21 | NOV 15 | 26 |
| VAB | LRB MATE TO MLP | 10 | 7/3 (1.00) | NOV 06 | NOV 15 | 10 |
| LRB-HPF | LRB STAND-ALONE PROC. | 45 | 5/3 (1.29) | SEP 08 | NOV 05 | 58 |
| MLP | STS INTEGRATION SUPPORT (INCLUDING 5-DAY HOLDDOWN POST VALIDATION) | 55 | 7/3 (1.00) | NOV 01 | DEC 25 | 55 |
| | LAUNCH READINESS (INCLUDING 10 DAYS FOR POST LAUNCH REFURB) | 60 | 6/3 (1.14) | DEC 26 | MAR 01 | 69 |

* Function not subject to Learning Curve Factor (LCF). All others multiplied by a LCF of 2.5 for this flow only.

Figure 9.4.1-2. Launch Processing Flow Breakdown-LRB/STS 111.

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3-9.4 11/112 9:00a

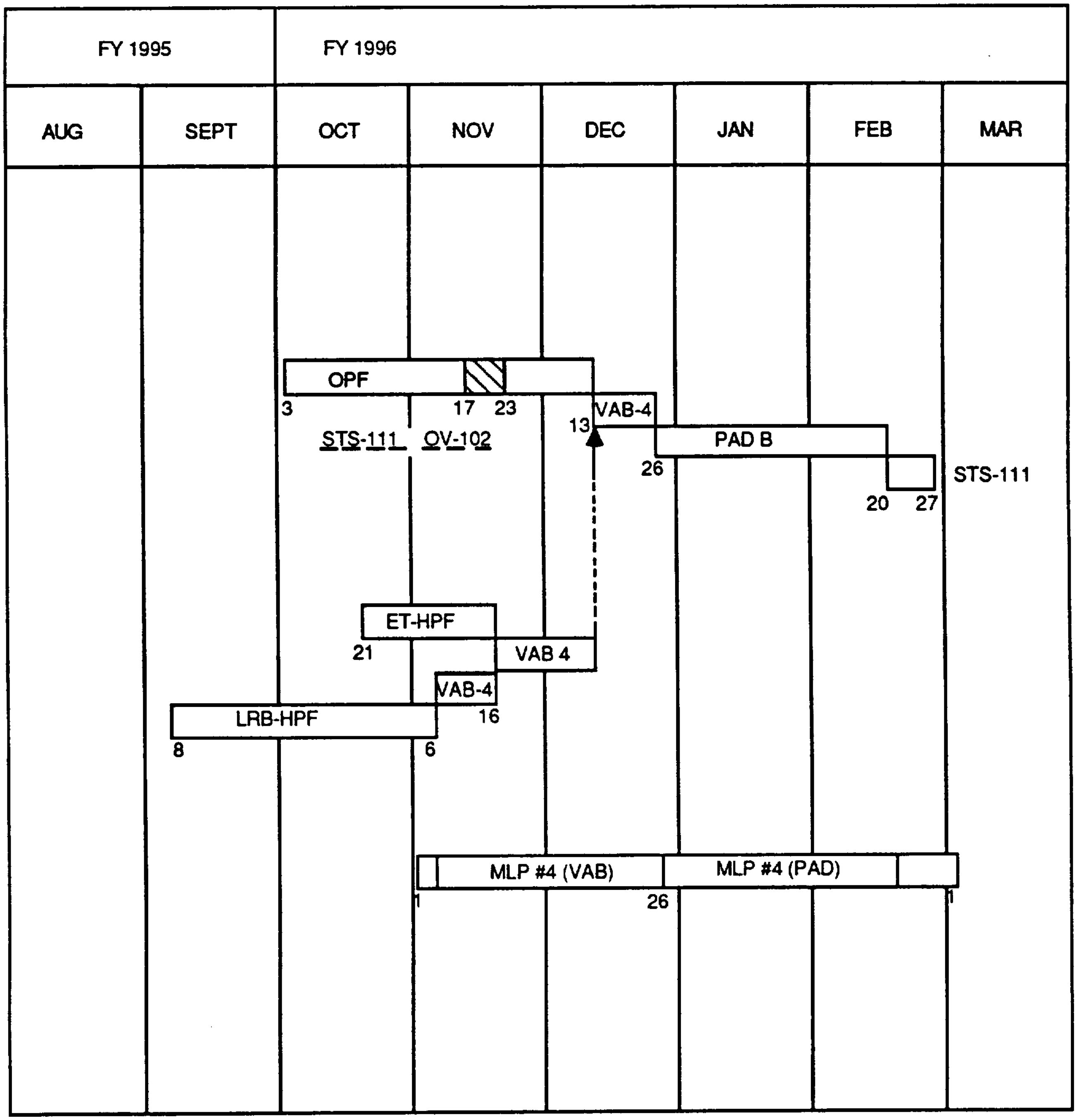

Figure 9.4.1-3. Launch Processing Bar Chart-LRB/STS 111.

| FY 1996-SECOND LRB POWERED STS MISSION | | | | | | |
|---|---|---|---|---|---|---|
| KSC LOCATION | PROCESSING FUNCTION | GENERIC WORK DAYS | LOCATION SCHEDULE DAYS/SHIFTS (FACTOR) | CALENDAR START | CALENDAR COMPLETE | CALENDAR DAYS |
| — | STS-115 MISSION | 7 | 7/3 (1.00) | MAY 19 | MAY 26 | 7 |
| PAD | FINAL C/O & CD | 40 | 6/3 (1.14) | APR 04 | MAY 19 | 46 |
| VAB | ORB MATE & INTEG TEST | 10 | 7/3 (1.00) | MAR 25 | APR 03 | 10 |
| OPF | ORBITER PROCESSING | 51* | 5/3 (1.29) | JAN 20 | MAR 25 | 66 |
| VAB | LRB/ET MATE AND C/O | 22 | 7/3 (1.00) | MAR 03 | MAR 24 | 22 |
| ET-HPF | ET PROCESSING | 20* | 5/3 (1.29) | FEB 06 | MAR 02 | 26 |
| VAB | LRB MATE TO MLP | 08 | 7/3 (1.00) | FEB 24 | MAR 02 | 08 |
| LRB-HPF | LRB STAND-ALONE PROC. | 36 | 5/3 (1.29) | JAN 08 | FEB 23 | 47 |
| MLP | STS INTEGRATION SUPPORT (INCLUDING 4-DAY HOLDDOWN POST VALIDATION) | 44 | 7/3 (1.00) | FEB 20 | APR 03 | 44 |
| | LAUNCH READINESS (INCLUDING 8 DAYS FOR POST LAUNCH REFURB) | 48 | 6/3 (1.14) | APR 04 | MAY 27 | 55 |

* Function not subject to Learning Curve Factor

Figure 9.4.1-4. Launch Processing Flow Breakdown - LRB/STS 115.

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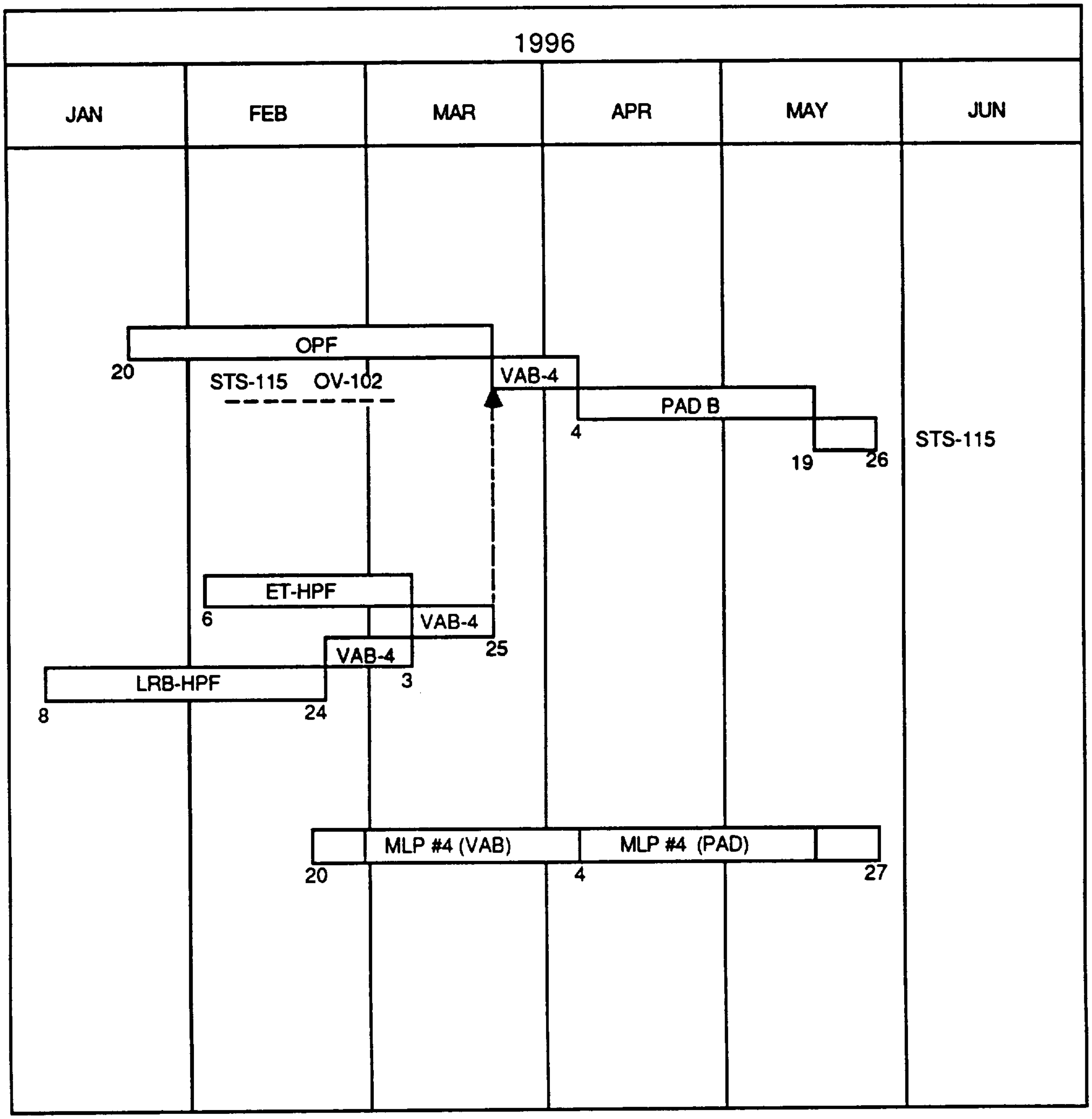

Figure 9.4.1-5. Launch Processing Bar Chart-LRB/STS 115.

| FY 1996 - THIRD LRB POWERED STS MISSION | | | | | | |
|---|---|---|---|---|---|---|
| KSC LOCATION | PROCESSING FUNCTION | GENERIC WORK DAYS | LOCATION SCHEDULE | CALENDAR | | CALENDAR DAYS |
| | | | DAYS/SHIFTS (FACTOR) | START | COMPLETE | |
| — | STS -119 MISSION | 7 | 7/3 (1.00) | AUG 19 | AUG 26 | 7 |
| PAD | FINAL C/O & CD | 30 | 6/3 (1.14) | JUL 16 | AUG 19 | 34 |
| VAB | ORB MATE & INTEG TEST | 08 | 7/3 (1.00) | JUL 08 | JUL 15 | 08 |
| OPF | ORBITER PROCESSING | 51* | 5/3 (1.29) | MAY 03 | JUL 07 | 66 |
| VAB | LRB/ET MATE AND C/O | 16 | 7/3 (1.00) | JUN 22 | JUL 07 | 16 |
| ET-HPF | ET PROCESSING | 20* | 5/3 (1.29) | MAY 27 | JUN 21 | 26 |
| VAB | LRB MATE TO MLP | 06 | 7/3 (1.00) | JUN 16 | JUN 21 | 06 |
| LRB-HPF | LRB STAND-ALONE PROC. | 25 | 5/3 (1.29) | MAY 14 | JUN 15 | 33 |
| MLP | STS INTEGRATION SUPPORT (INCLUDING 3-DAY HOLDDOWN POST VALIDATION) | 33 | 7/3 (1.00) | JUN 13 | JUL 15 | 33 |
| | LAUNCH READINESS (INCLUDING 6 DAYS FOR POST LAUNCH REFURB) | 36 | 6/3 (1.14) | JUL 16 | AUG 25 | 41 |

* Function not subject to Learning Curve Factor (LCF), all others multiplied by a LCF of 2.0 for this flow only.

Figure 9.4.1-6. Launch Processing Flow Breakdown - LRB/STS 119.

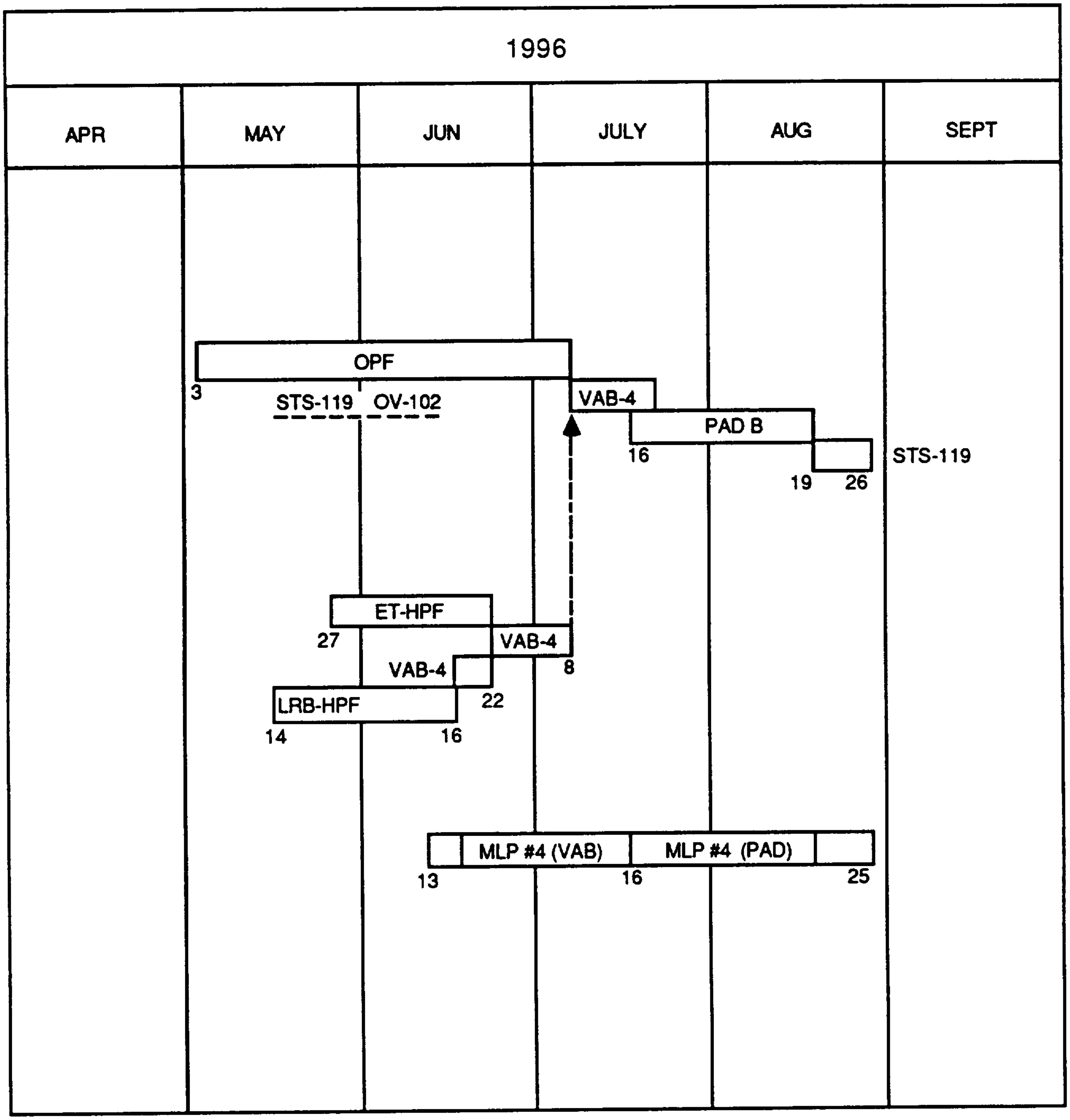

Figure 9.4.1-7. Launch Processing Bar Chart-LRB/STS 119.

mission. The calendar correlation backed off from the existing STS-121 launch date is shown in tabular and bar chart form in Figures 9.4.2-1 and 9.4.2-2. This flow and launch processing schedule establishes the IOC of the LRB program. All flows projected in this phase of the LRBI study for missions following STS-121 will use this same schedule of processing work days.

### 9.4.3 Launch Rate Phases

Figures 9.4.3-1 and 9.4.3-2 start with the four missions previously discussed and extrapolates the generic mission into launch rate increases of 6, 9, 12, and 14 LRB missions per year. The facilities shown being used for the LRB missions and all launches shown in this figure for the third year (1998) will be reassigned to optimize utilization.

Additional tabular and graphical depictions of LRB missions #5 through #18 are furnished in the appendix to this product (Volume V, Section 9).

## 9.5 TRANSITIONAL MANPOWER CONSIDERATIONS

During the period 1995 through the year 2000, there will be many manpower adjustments required. The activation management team will be redirecting their attention from the first line of facilities to the second. Additional new personnel will be needed to support the mixed fleet processing. The LRB processing tasks will be affected by standard learning curve principles. Finally, SRB specialists will have to be retrained and cycled back into the new mainstream of STS operations.

### 9.5.1 Balance/Affect Of The Booster Change

Taking the overall situation of different NASA contractors, contractor teams, and launch support service arrangements into account, an early assessment of the employment impact to KSC is illustrated in Figure 9.5.1-1. The small percentage increase due to probable incorporation of LRB processing into the SPC contract is more than offset by the reduction or elimination of separate recovery and refurbishment contracts.

### 9.5.2 Existing SRB Personnel Transition

The groundrule that an SRB processing and launch capability will be retained to the end of the

| FY 1997 - I.O.C. LRB MISSION #4 | | | | | | |
|---|---|---|---|---|---|---|
| KSC LOCATION | PROCESSING FUNCTION | GENERIC WORK DAYS | LOCATION SCHEDULE DAYS/SHIFTS (FACTOR) | CALENDAR START | CALENDAR COMPLETE | CALENDAR DAYS |
| — | STS -121 MISSION | 7 | 7/3 (1.00) | OCT 01 | OCT 08 | 7 |
| PAD | FINAL C/O & CD | 20 | 6/3 (1.14) | SEPT 09 | OCT 01 | 23 |
| VAB | ORB MATE & INTEG TEST | 05 | 7/3 (1.00) | SEPT 04 | SEPT 08 | 05 |
| OPF | ORBITER PROCESSING | 51 | 5/3 (1.29) | JUN 30 | SEPT 03 | 66 |
| VAB | LRB/ET MATE AND C/O | 11 | 7/3 (1.00) | AUG 24 | SEPT 03 | 11 |
| ET-HPF | ET PROCESSING | 20 | 5/3 (1.29) | JUL 29 | AUG 23 | 26 |
| VAB | LRB MATE TO MLP | 04 | 7/3 (1.00) | AUG 21 | AUG 24 | 04 |
| LRB-HPF | LRB STAND-ALONE PROC. | 18 | 5/3 (1.29) | JUL 28 | AUG 20 | 24 |
| MLP | STS INTEGRATION SUPPORT (INCLUDING 2-DAY HOLDDOWN POST VALIDATION) | 22 | 7/3 (1.00) | AUG 19 | SEPT 08 | 22 |
| | LAUNCH READINESS (INCLUDING 4 DAYS FOR POST LAUNCH REFURB) | 24 | 6/3 (1.14) | SEPT 09 | OCT 05 | 28 |

Figure 9.4.2-1. Launch Processing Flow Breakdown-LRB/STS 121.

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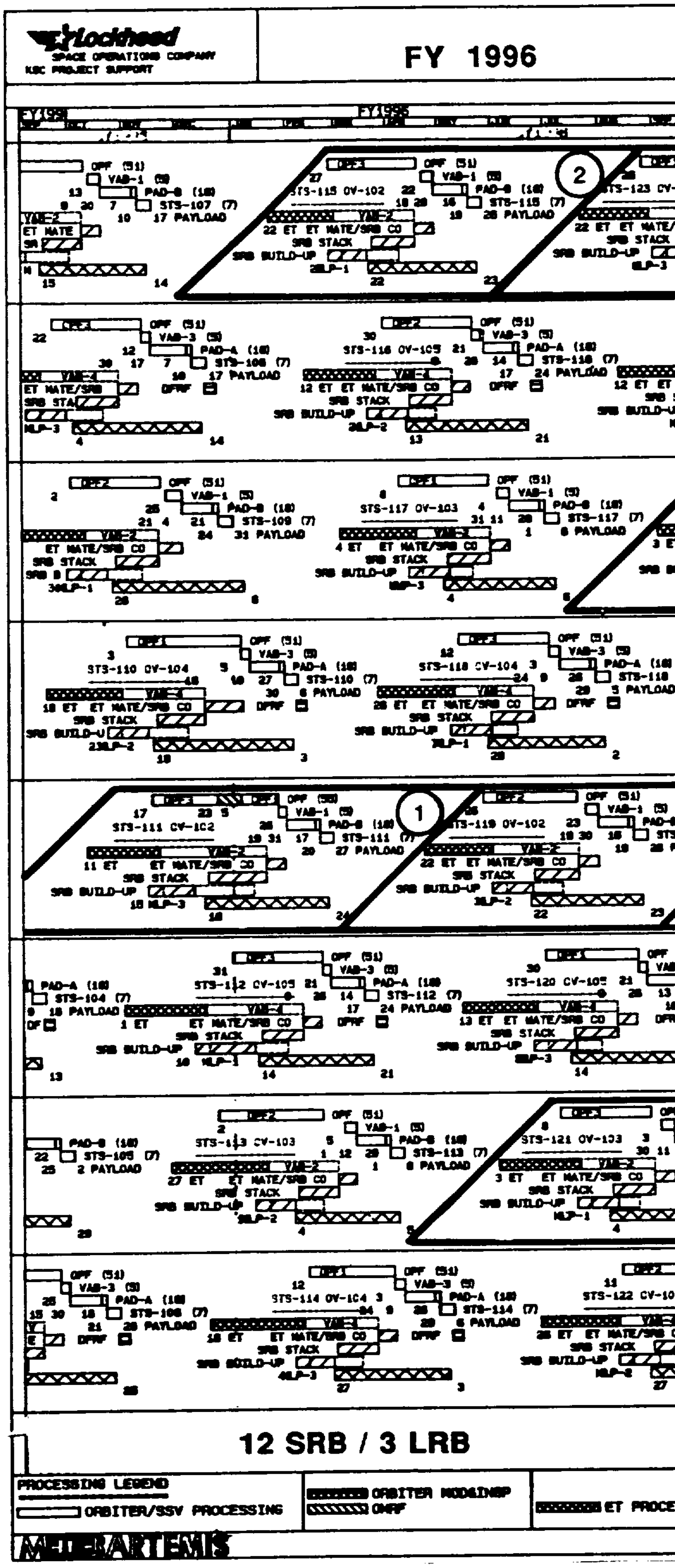

* LAST SRB FLIGHT

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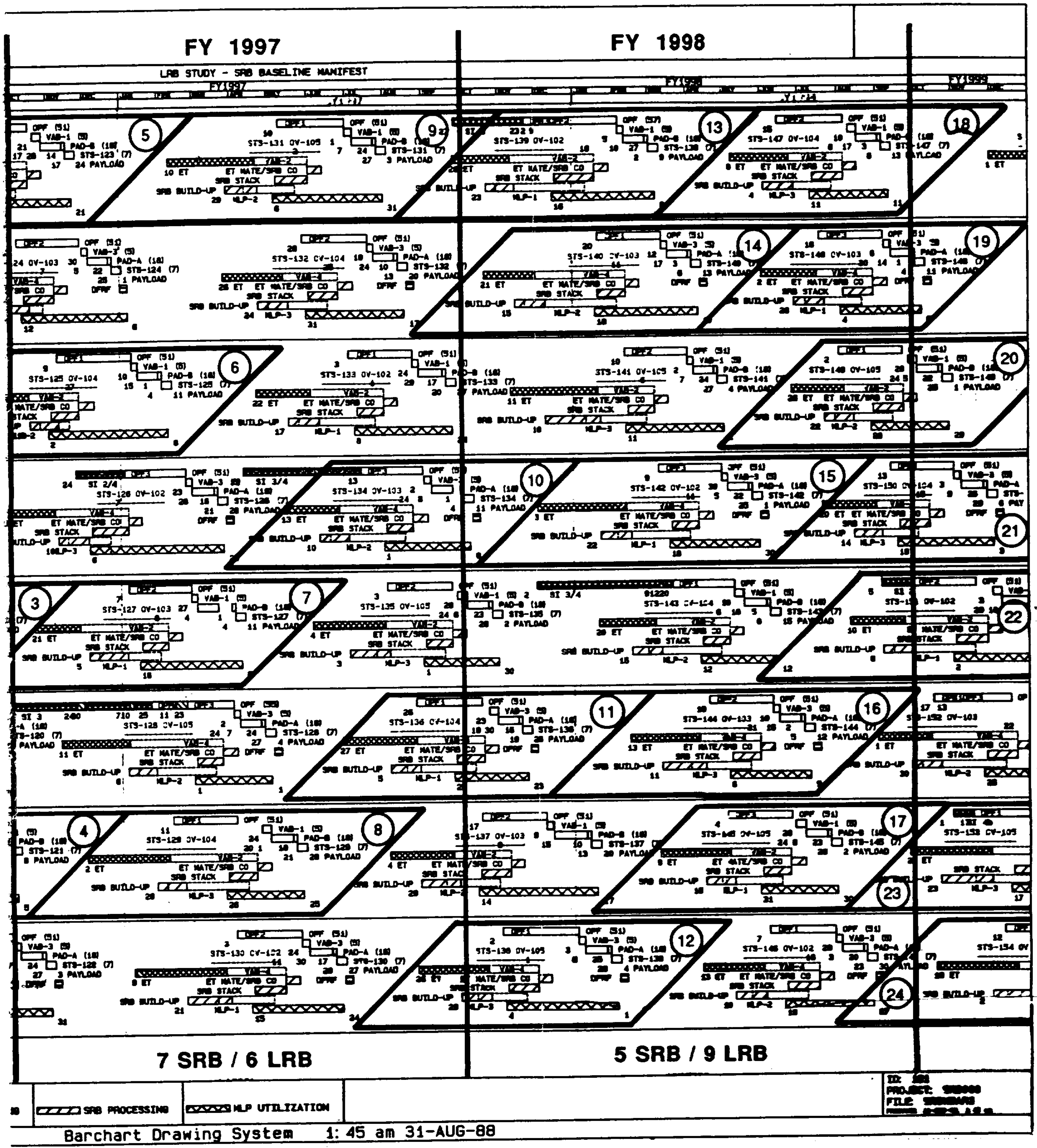

OJECTED (STS-160)

Figure 9.4.3-1 Facility Planning Chart, Page 1.

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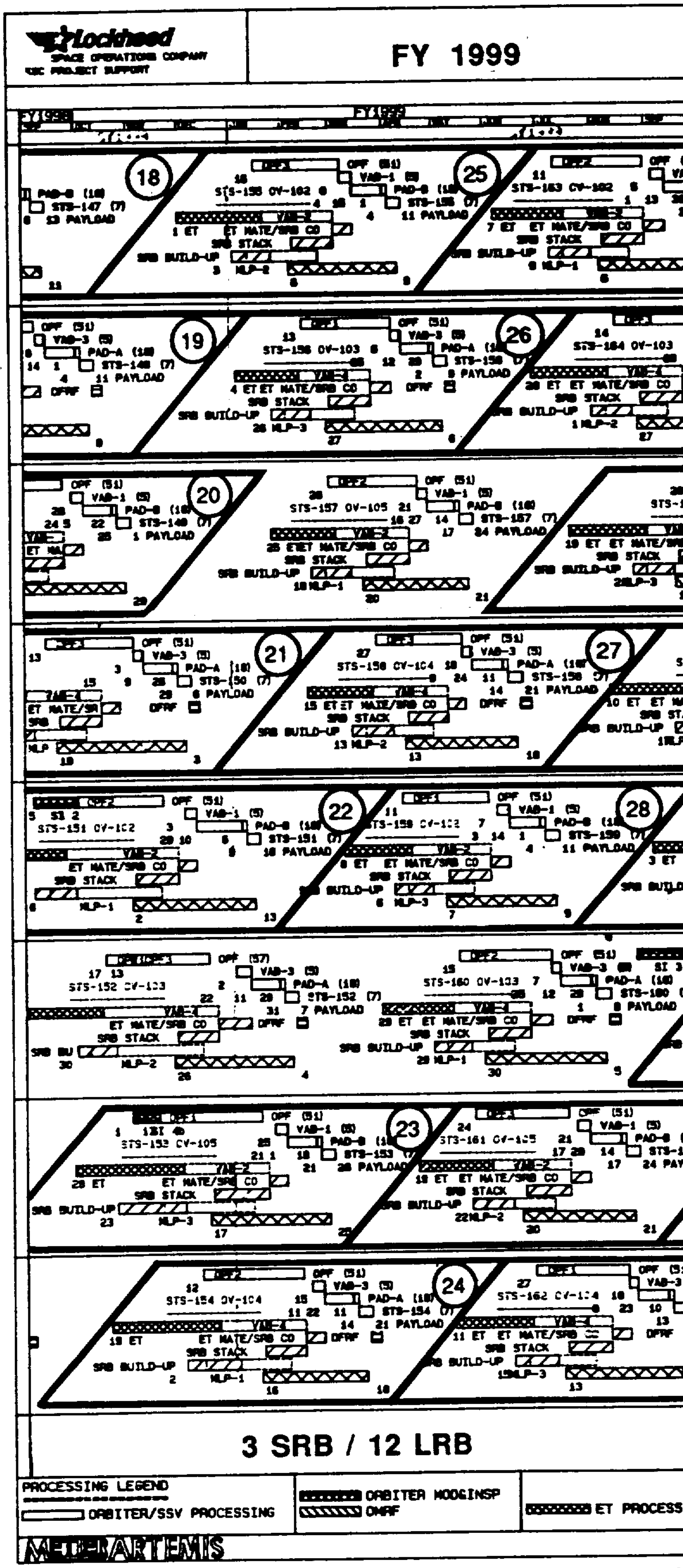

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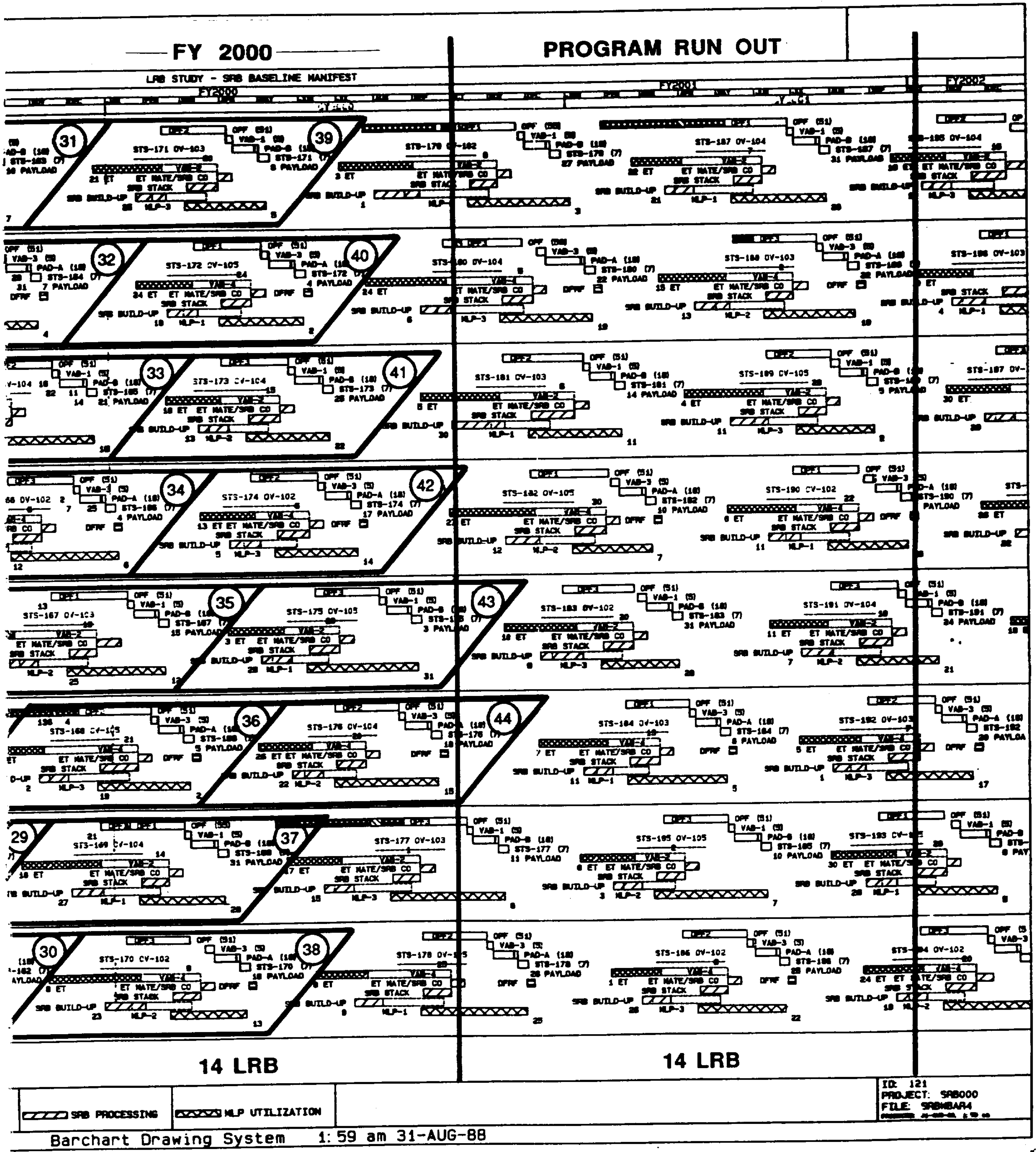

ST SRB FLIGHT PROJECTED (STS-160)

Figure 9.4.3-2 Facility Planning Chart, Page 2.

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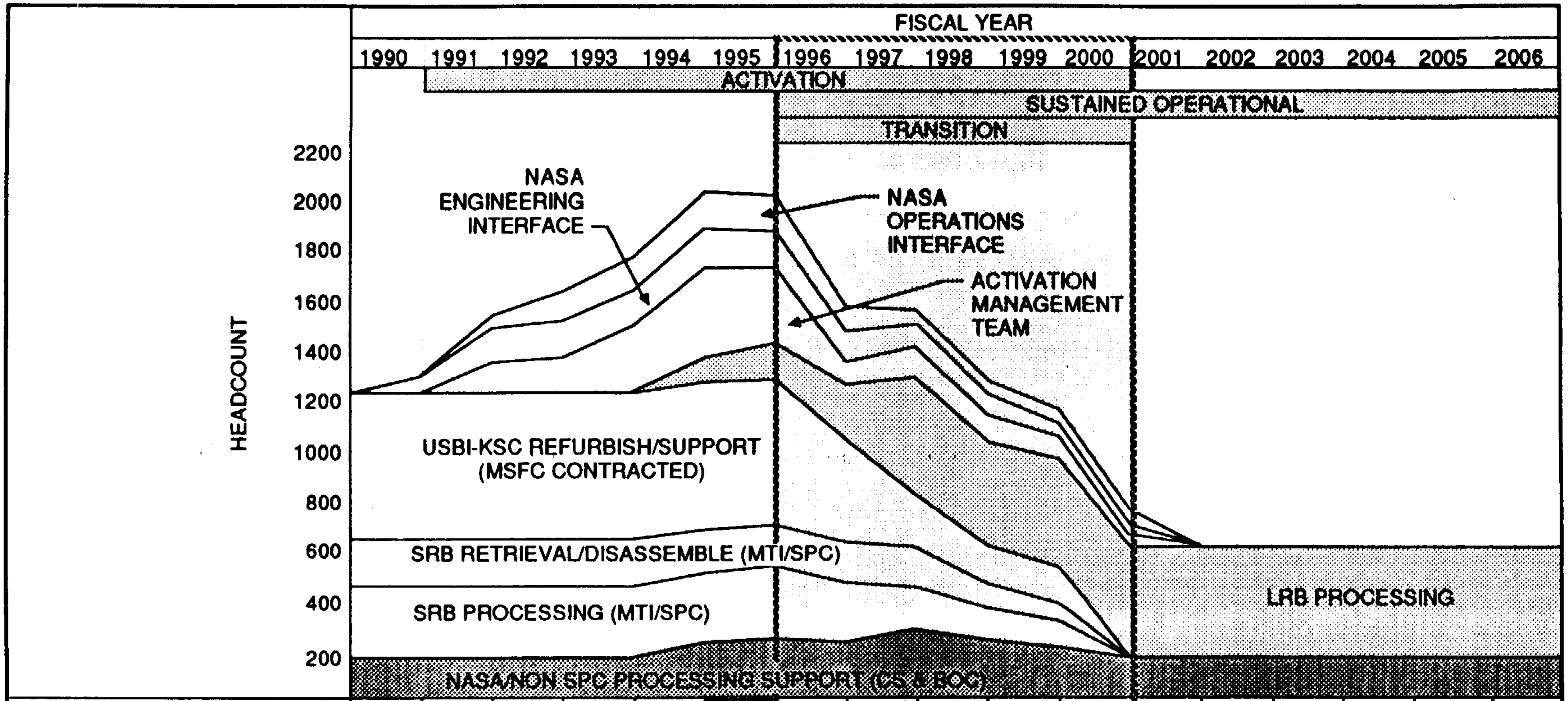

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | 1342 | 1597 | 1704 | 1789 | 2050 | 2024 | 1603 | 1546 | 1295 | 1145 | 719 | 608 | 608 | 608 | 608 | 608 | 608 |
| NASA OPERATIONS INTERFACE | | 36 | 123 | 145 | 145 | 145 | 116 | 58 | 44 | 44 | 15 | | | | | | |
| NASA ENGINEERING INTERFACE | 79 | 157 | 142 | 135 | 127 | 127 | 102 | 64 | 57 | 51 | 44 | | | | | | |
| ACTIVATION MGMT. TEAM | | 141 | 176 | 246 | 363 | 286 | 83 | 96 | 133 | 69 | 52 | | | | | | |
| LRB PROCESSING | | | | | 110 | 147 | 221 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 |
| USBI REFURB/SUPPORT | 600 | 600 | 600 | 600 | 600 | 600 | 474 | 342 | 216 | 200 | | | | | | | |
| SRB RETRIEVAL/DISASSEM. | 160 | 160 | 160 | 160 | 160 | 160 | 126 | 91 | 57 | 50 | | | | | | | |
| SRB PROCESSING | 336 | 336 | 336 | 336 | 336 | 336 | 264 | 192 | 120 | 100 | | | | | | | |
| NASA/NON-SPC PROC. SUPP. | 167 | 167 | 167 | 167 | 209 | 223 | 217 | 262 | 227 | 190 | 167 | 167 | 167 | 167 | 167 | 167 | 167 |

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Figure 9.5.1-1. LRB/STS Manpower Projection.

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transition period requires that another decision will have to be made. Three factors could speed the decision process: the last SRB flight shown in Figure 9.4.3-2 is STS-160 projected to be launched August 1, 1999; The annual recertification requirement for SRB technical skills; and the deteriorating ability to perform SRB work on the reduced launch schedule will promote the earliest possible decision on SRB phase-out. Also, the confidence gained in successfully performing the 44 LRB missions during the transition period should weigh against a decision to maintain an SRB launch processing capability.

Variables that could lead to retaining an SRB processing capability are; SRB applications on an unmanned "Shuttle C" derivative and the implementation of an advanced SRB sharing the STS launch manifest with the LRB. Both of these scenarios are outside the parameters of the current study.

A result of the expected SRB obsolescence is the gradual incorporation of SRB personnel into other KSC programs with the final core processing group lasting only partway into the year 2000. Many of the skills, and experience gained on the SRB electrical, TVC and thermal protection systems can be applied to great benefit on the LRB.

## 9.6 DOCUMENTATION REQUIREMENTS FOR TRANSITION

The documentation systems for a new flight element are varied and complex. Each should be developed and functional prior to IOC A list on which to build includes:

- Flight hardware drawings and LRU Specifications
- Station set documents and drawings
- GSE and LSE; drawings, FMEA/CIL analysis, and preventive maintenance OMIs
- Logistical spares and propellant acquisition plans
- PRACA - problem report storage, retrieval and analysis systems
- Processing OMRSD,OMIs and job cards
- Ground processing planning, scheduling and tracking systems
- Launch commit criteria and flight rules
- Standard practice instructions and manuals

### 9.6.1 OMD/OMIs

The transfer of LRB maintenance and operations inspection and verification requirements from outside contractors and NASA centers into the KSC network occurs via the OMD organization. Of all the requirements, those formalized into the OMRSD are preeminent. The KSC conversion of the OMRSD requirements into OMIs covering operational safety, sequential logic, and quality buy-offs, is a critical aspect of KSC LRB implementation.

#### 9.6.1.1 LRB Standalone Processing OMIs

Shown in Figure 9.6.1.1-1 is a chronological list of work sequences that are projected to be required for a typical LRB flow. The number and infrastructure of OMIs needed to be written to cover these steps should be defined through in-depth Phase-B studies. Many of the less complex tasks could easily be grouped as sequences in a single OMI.

The duration for individual tasks is important only in a relative sense. The times reflect parallel and serial work relationships at the LRB-HPF. The span of time for each the tasks was developed to display overall minimum serial time. A more detailed man-loaded version of stand alone LRB processing is included in Volume III, Section 2. It should also be noted that this task projection was performed only on the baselined LOX/RP-1 pump fed configuration. The processing tasks for other configurations would require some reassessment, but the overall HPF timelines would remain essentially the same.

#### 9.6.1.2 ET Processing OMIs - Vertical And Horizontal

Because this LRB study recommends the relocation of ET processing to a new horizontal processing facility, Figures 9.6.1.2-1 and 9.6.1.2-2 have been included to show the impact to the OMI schedule. As shown, only two of the tasks; OMI T5141 and OMI T1108 will have to be transferred to the integrated SSV processing. A more detailed look at ET OMIs is included in the appendix to this product (Volume V, Section 9).

#### 9.6.1.3 Integrated Processing OMIs

A listing of the LRB oriented tasks for MLP mate activities in the integration cell for a typical flow is presented in Figure 9.6.1.3-1.

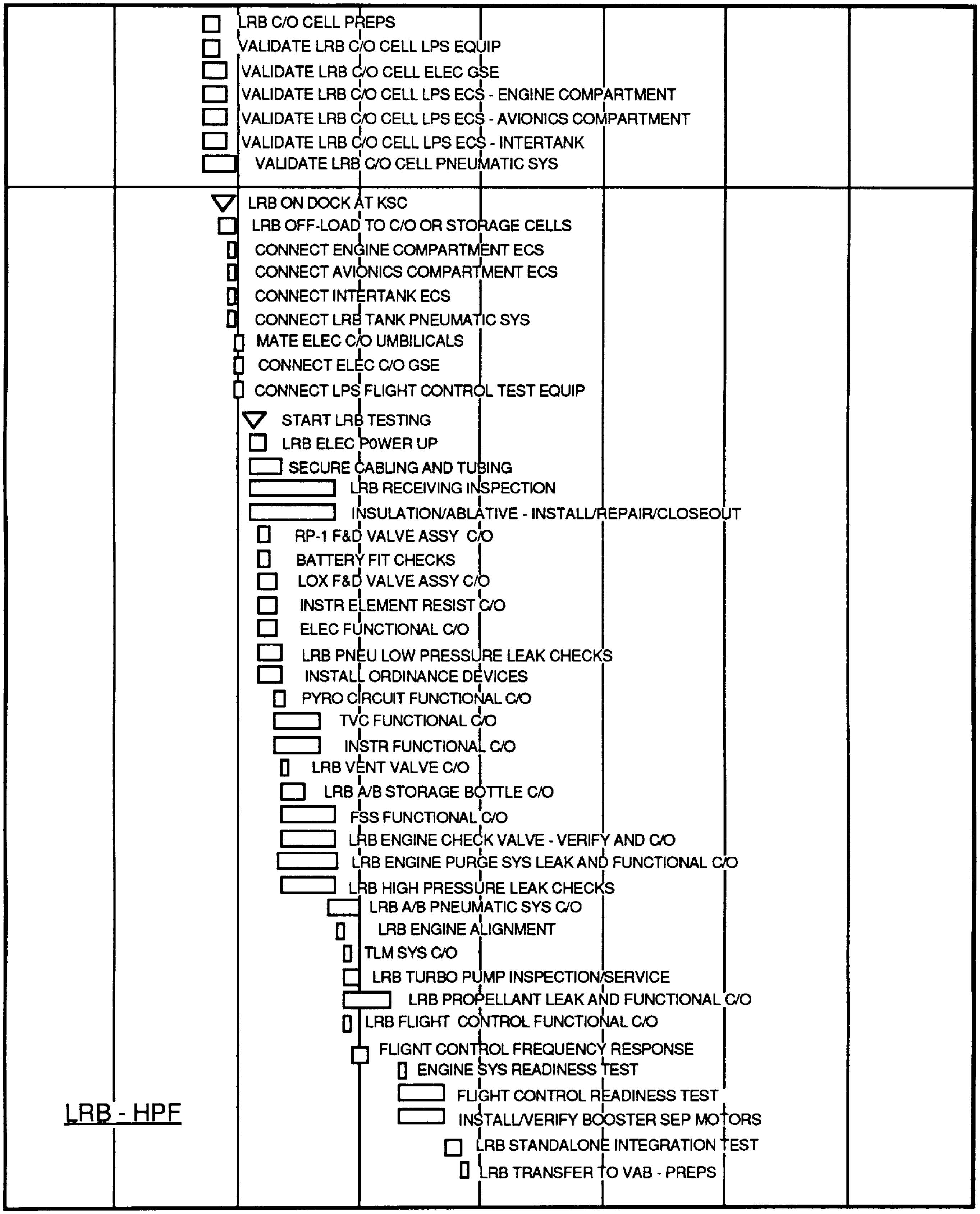

Figure 9.6.1.1-1. LRB Standalone Processing.

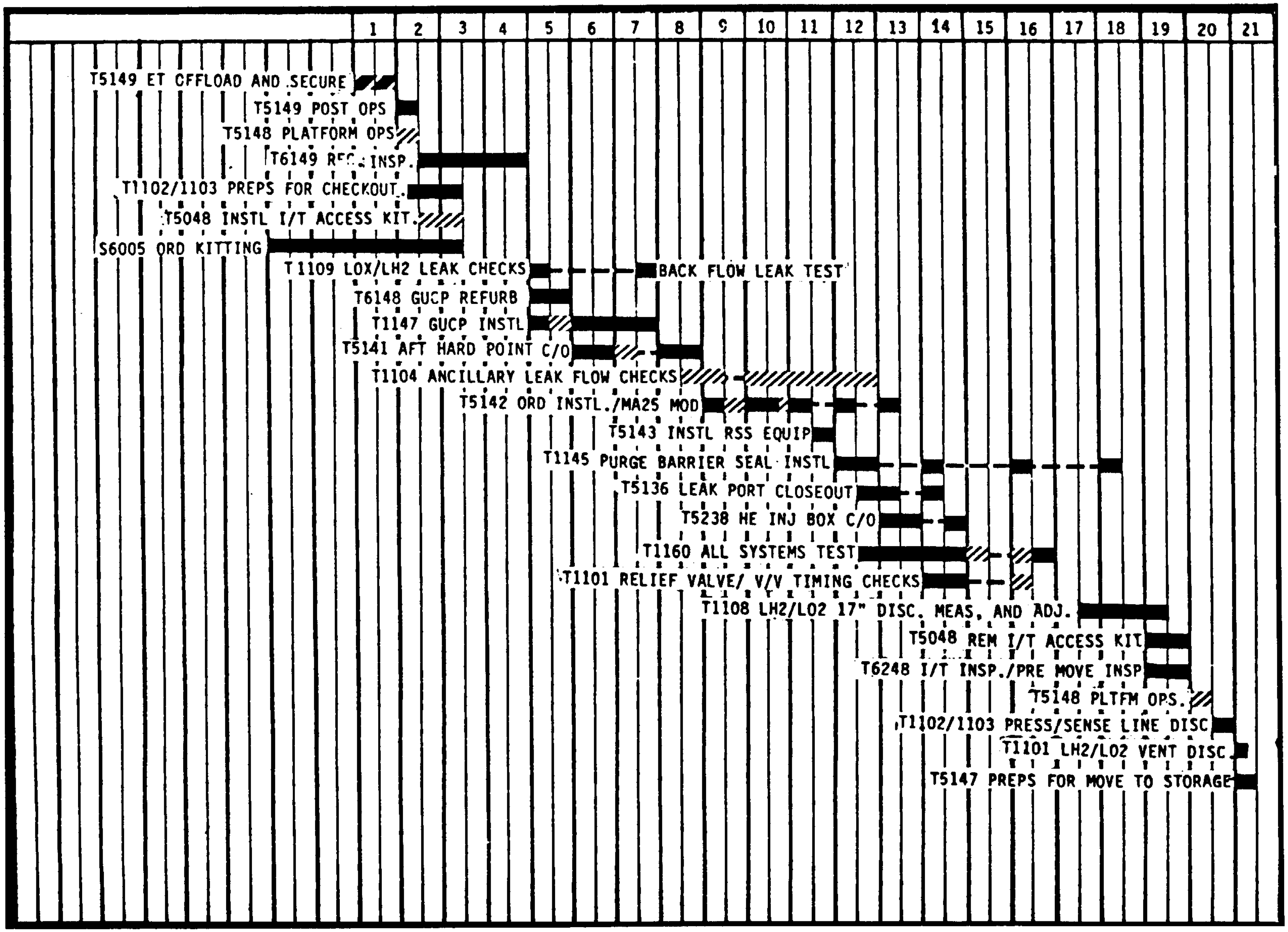

Figure 9.6.1.2-1. Standalone ET Test And Checkout OMIs (Standard Vertical Processing).

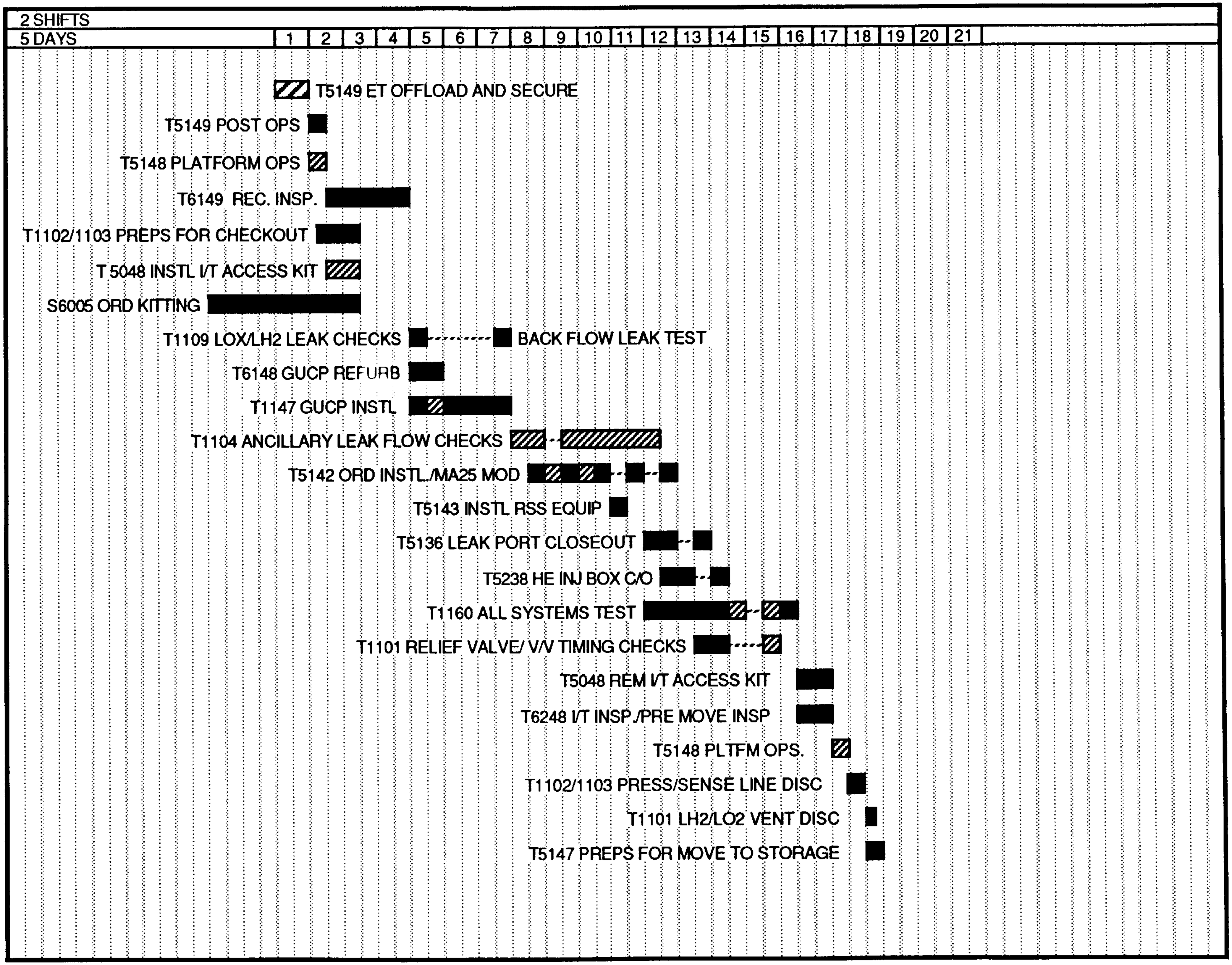

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Figure 9.6.1.2-2. Standalone ET Test and Checkout OMI's (Horizontal Processing Scenario). 3-9.6 11/129 11:00a

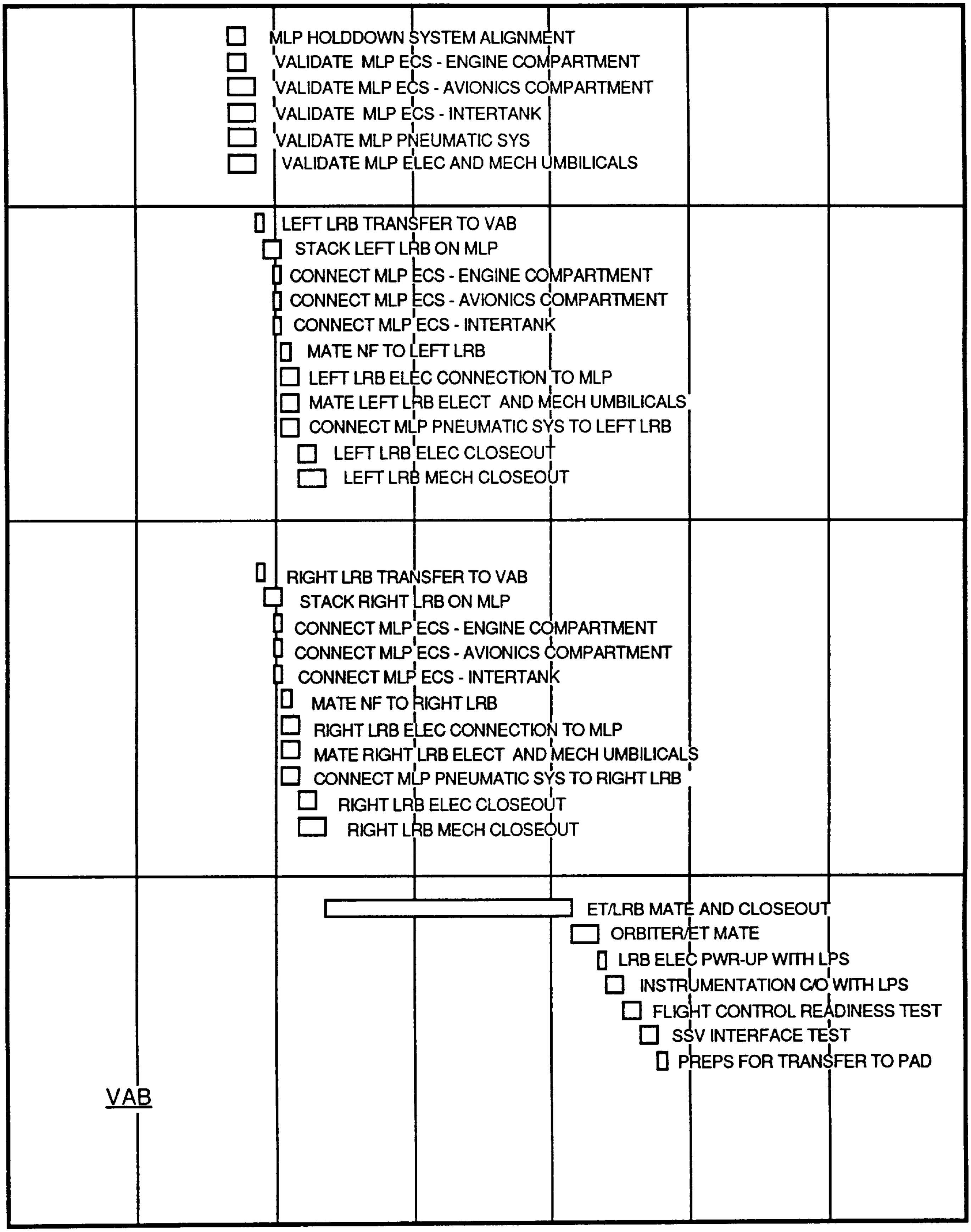

Figure 9.6.1.3-1. LRB Integrated Processing.

The revised integrated processing task schedule for the ET/LRB mate and closeout, in the integration cell, is presented in Figure 9.6.1.3-2 and 9.6.1.3-3. The two tasks moved from the standalone processing to the VAB are also highlighted.

### 9.6.1.4 Pad Processing OMIs

Figure 9.6.1.4-1 displays an LRB oriented list of pad processing tasks. Again the number and infrastructure of the new OMIs to be written is yet to be determined.

## 9.7 SUMMARY AND FOLLOW-ON RECOMMENDATIONS

To summarize the preliminary transition plan, a review of the major impacts and risks to on-going operations is in order.

Impacts for which insufficient data was available to evaluate included:

- Delayed or incomplete funding for recommended facilities
- Pathfinder flow-hardware configuration and specialization
- Expected flight hardware delivery dates
- KSC area LRB manufacturing potential and resultant transition effects
- LRB program interfaces with ASRM or Shuttle "C" programs

Impacts identified in the course of transition analysis include:

- MLP readiness criticality
- Pad modification and down-time constraints
- Manifest shifts due to multi-mission flow projections
- Manpower peaks required during the transition period
- Documentation, production and revision schedule

The larger schedule risks of LRB implementation at KSC are:

- Pathfinder identified problems stretching the transition period
- Mission payload launch window constraints affecting already tight MLP, VAB and Pad multi-mission flow accommodation

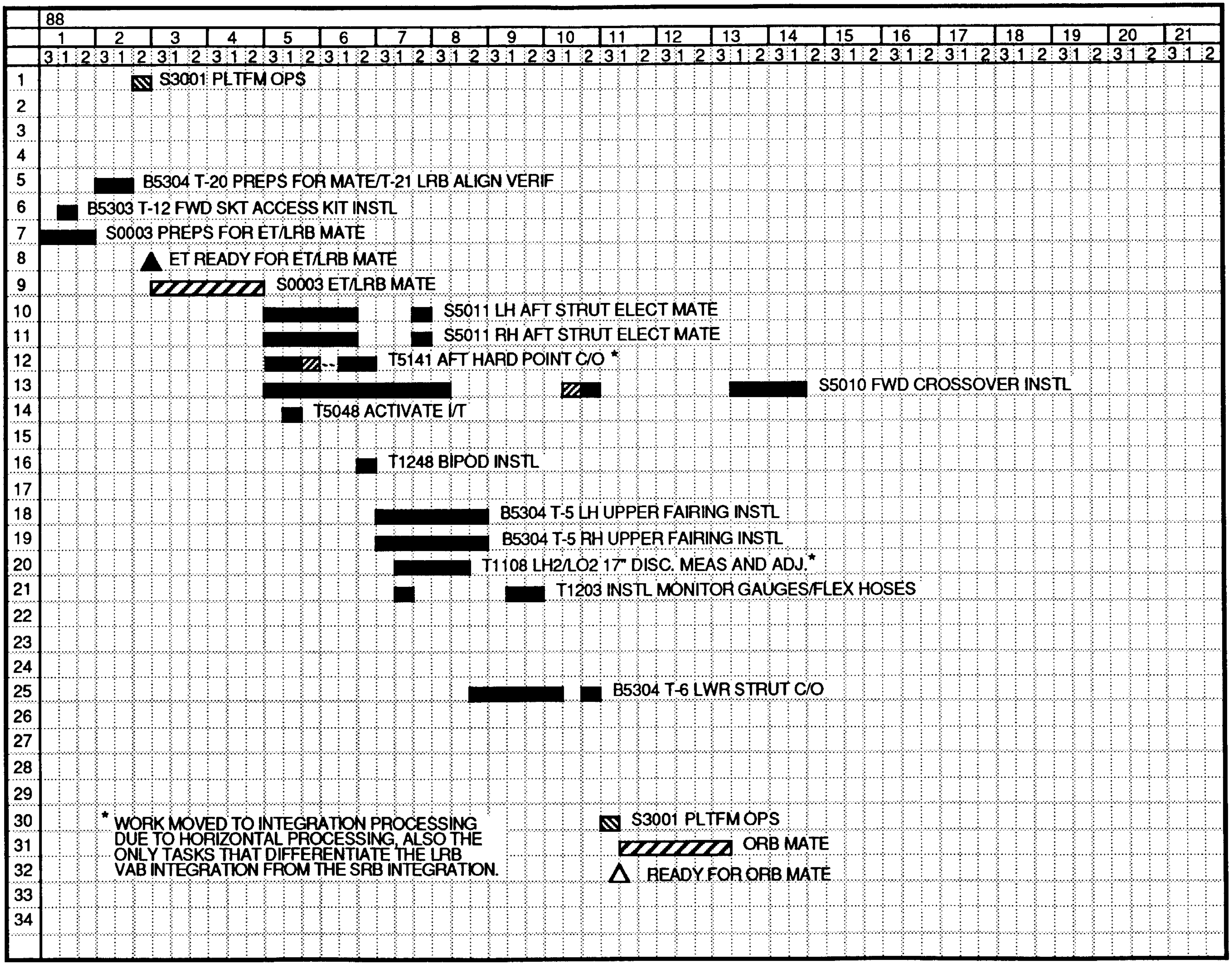

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Figure 9.6.1.3-2. ET/LRB MATE & C/O OMIs, Page 1.

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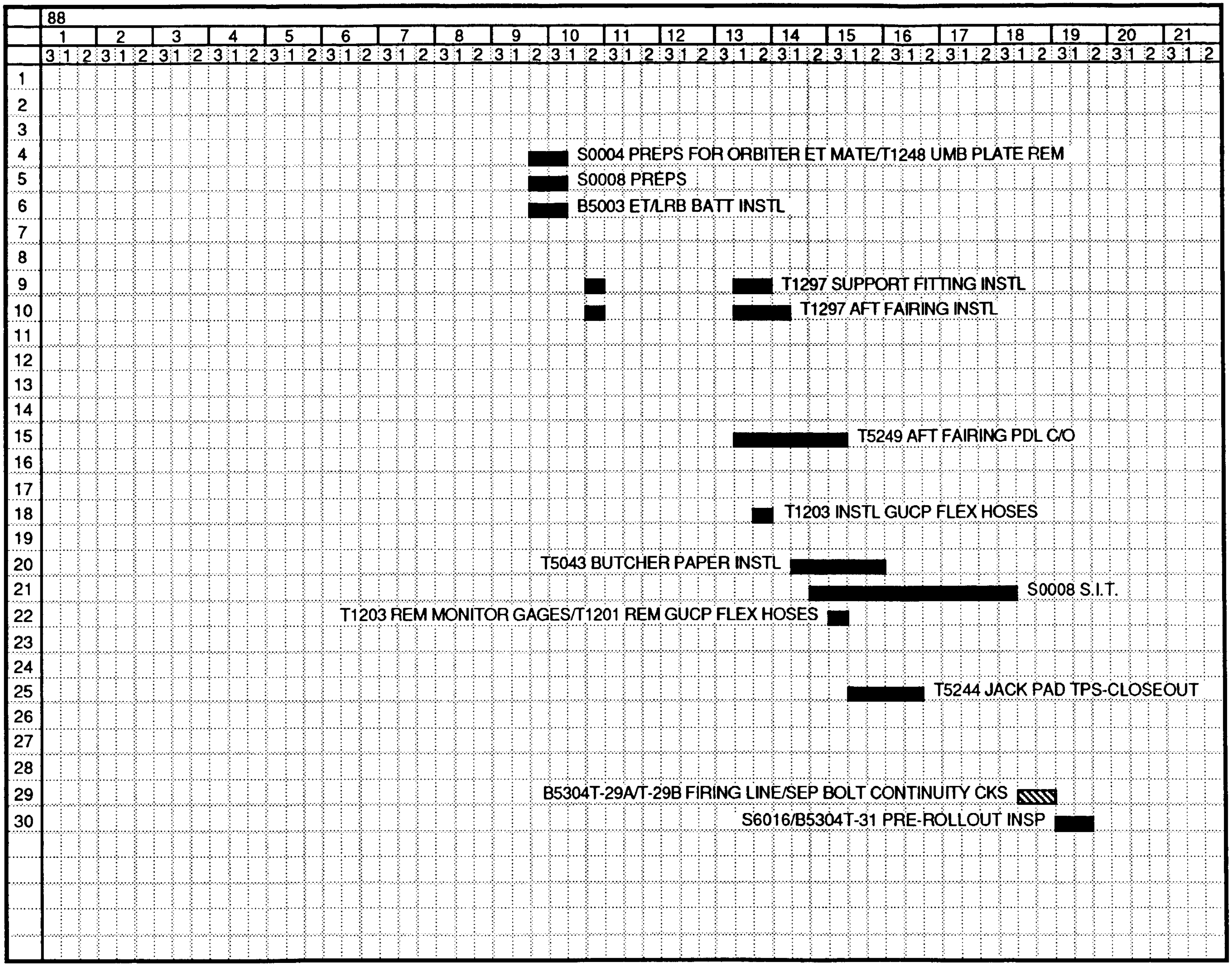

Figure 9.6.1.3-3. ET/LRB MATE & C/O OMIs, Page 2.

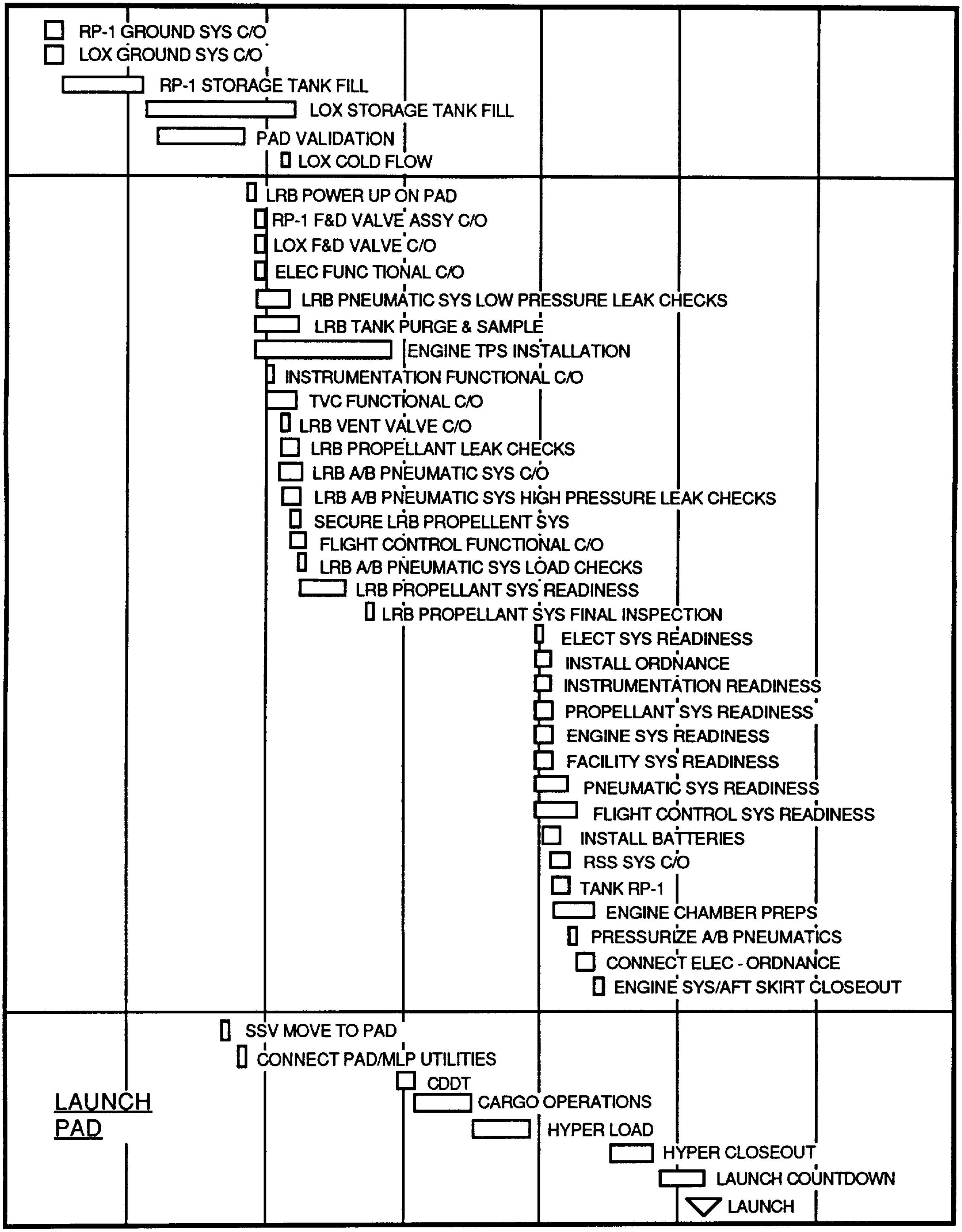

Figure 9.6.1.4.-1. LRB/SSV Pad Processing.

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The larger schedule risks of LRB implementation at KSC are:

- Pathfinder identified problems stretching the transition period
- Mission payload launch window constraints affecting already tight MLP, VAB and Pad multi-mission flow accommodation

Recommendations for follow-on studies to enhance transitional planning are:

- Further development of multi-mission ARTEMIS flexibility, to enable added facility and processing options to be input, analyzed and displayed
- Refinement of LRB and ET horizontal processing requirements
- Further exploration of launch site manufacturing efficiencies
- Continuation of launch site planning as more refined configurations and delivery dates become available.

# VOLUME III

## SECTION 10

## POTENTIAL ENVIRONMENTAL AND SAFETY IMPLICATIONS

# VOLUME III - SECTION 10
# SAFETY/ENVIRONMENTAL IMPACTS

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# SAFETY/ENVIRONMENTAL IMPACTS

The Safety/Environmental Impacts of the Liquid Rocket Booster (LRB) Integration Study were based on data provided by the Marshall Space Flight Center (MSFC) LRB Systems Studies being conducted by General Dynamics and Martin Marietta Corporations, and the LRB Integration Progress Review prepared by LSOC dated 24 August 1988. This report is based on the information contained in these reports submitted through June of 1988. In addition, information obtained from researching applicable documents and specifications, listed in the Reference Section, was used to determine impacts, recommendations and conclusions. During the course of the study, impacts on the design, construction and operational phases were addressed. Impacts addressed were based on the following assumptions:

- No change to Orbiter processing.
- LRB/ET Checkout/Processing conducted in new facility.
- LRB program to be integrated with as minimal impact as possible on current baseline (SRB).
- Primary propellants used in LRB RP-1/LO2, with LH2/LO2 and CH4/LO2 as proposed alternates.
- Expendable LRB (cursory look at retrievable).

An initial part of this study included determining the Safety and Environmental Impacts from the use of N2O4/MMH as propellants. This was conducted due to the serious implications, from a Safety and Environmental standpoint, from the use of N2O4/MMH as primary propellants for the LRB. Results of the findings from this portion of the study were incorporated into briefing charts which were presented during a conference held in January 1988. The charts are included in Volume V, Section 10, Appendix A. Subsequent to this briefing a decision was made to eliminate N2O4/MMH as candidate propellants. Thereafter, the study focussed on the Safety/Environmental Impacts of RP-1/LO2, which was proposed as the primary propellant, and LH2/LO2 and CH4/LO2, which were proposed as alternate propellants. The major portion of the Safety/Environmental Impacts study was directed toward RP-1/LO2, with cursory looks taken at LH2/LO2 and CH4/LO2. The findings and results of the study are included in the following impacts, conclusions and recommendations sections of the report.

## 10.1 SAFETY IMPACTS

### 10.1.1 Generic Safety Impacts

The safety impacts which are generic to any new program of this type, as well as those which are unique to the LRB, were addressed. The following is a summary of those impacts which are generic.

### 10.1.2 Personnel

Safety impacts on personnel include: (1) Safety professionals required to review design specifications, drawings and other technical data and provide input based on safety requirements of Federal, State, Local, NASA and Kennedy Standards, Rules and Regulations; (2) Personnel required to monitor construction activities during the construction phase. This will include ensuring proper safety practices are adhered to, proper personnel protective equipment is utilized, and discrepancies noted are corrected; (3) During the test, checkout and activation phases Safety concurrence will be required in many areas; (4) When the facilities and equipment enter the operational phase safety personnel will be required to monitor all hazardous operations.

### 10.1.3 Personnel Protective Equipment

Personnel protective equipment is determined by the nature of the hazard personnel are being exposed to. Examples are: (1) Personnel working in or around toxic vapors will be required to wear organic vapor respirators; (2) Personnel working with hazardous chemicals (i.e. acids) may be required to wear splash suits, goggles and faceshields, rubber gloves, and boots; (3) Personnel working with flammable liquids may be required to wear anti-static clothing, gloves, splash suits, etc.; (4) Air supplied breathing apparatus for personnel working in irrespirable atmospheres exceeding 30 minutes; (5) Personnel working at heights will be required to wear body harnesses, safety belts, life lines, lanyards and associated hardware.

Efforts to implement resolution of these safety impacts prior to and during LRB processing would be minimal because of their generic nature, as well as past and current program experience.

### 10.1.4 Fire Detection/Protection

The current Fire Detection/Protection requirements will also be levied on the LRB Program. In areas designated as hazardous or that contain mission essential material or equipment are required to have an automatic detection system. Construction requirements will be determined by the hazard classification. Emergency exits are determined by the size of the facility, number of occupants and nature of the hazards. Strict restrictions are placed on taking flame/spark producing material into certain areas (reference NFPA for more detail).

### 10.1.5 Hazardous Vapor/O2 Detection Equipment

Detection equipment for monitoring toxic, flammable or otherwise hazardous vapors and O2 concentrations are required. Typical detection equipment currently required is: (1) O2 meters used for determining oxygen concentration in confined spaces; (2) Lower explosive limit (LEL) meters used to determine concentration of flammable or explosive vapors in air; (3) Meters used to detect levels of MMH vapors in air to ensure that equipment unique to the LRB will be discussed in that section.

### 10.1.6 Weather Restrictions

The same weather restrictions which currently apply, such as, lightning, winds, hurricanes, tornadoes, flooding, hail, freezing, etc. will apply to the LRB Program (Reference GP-1098).

### 10.1.7 Paging and Area Warning Systems

All facilities are required to have paging and area warning systems installed (ref. GP-1098 and OSHA).

### 10.1.8 Pressure Vessel/System Certification

All pressure vessels/systems installed, unless specifically excluded, must be certified as safe to operate and must be periodically recertified to maintain personnel and equipment safety in compliance with the KSC Pressure Vessels/Systems Certification Program. The pressure vessels/ systems which are included in this program are in the following classifications:

- Unfired presure vessels/systems with non-toxic fluids at pressures of 15 psig or higher.
- Unfired pressure vessels/systems with toxic fluids using pressures of zero psig or higher.
- Vacuum systems greater than 100 cubic feet in evacuated volume.

Pressure vessels/systems which are excluded due to their low failure potential, low risk, and low potentially stored energy include HVAC systems and potable water systems.

### 10.1.9 HVAC Systems

Requirements for HVAC systems vary, depending upon the use for which they are intended. Personnel comfort is the primary function served and the American Conference of Government and Industrial Hygienist have set certain standards for air flow, air turnover rate, temperature and humidity controls. Certain operations, such as TPS, require strict temperature and humidity controls for processing. Certain facilities and equipment where hazardous commodities are used, transferred or mixed require non-recirculating ventilation systems. An area of increasing concern is ventilation systems in smoking areas. A future requirement may be separate ventilation systems in all new facilities for designated smoking areas.

### 10.1.10 Electrical

Electrical requirements will comply with the National Electric Code (NEC) and the KSC-STD-E-0002, Rev. B. These requirements will include, but not be limited to the following:

- Proper grounding, shielding, guards,covers barriers, conduits, etc.
- Clear identification of high voltage areas and other electrical hazards.

- Automatic bleed devices for capacitors in excess of 70 volts RMS or DC.
- Where possible, a main source cutoff.
- Explosion proofed electrical in hazard classified areas.
- Emergency back-up power for systems where failure could result in hazards to personnel.
- Proper installation of connectors, cabling, wiring and associated equipment.
- Overload protection for circuit breakers.
- Circuit breakers sized to protect the smallest wire in the system.
- Hazard detection and warning systems powered from independent circuit breakers to provide for continuous monitoring and have both audible and visual alarms.

### 10.1.11 Control Zones

Control zones are established based on the nature of the hazards associated with an operation that personnel or equipment might be exposed. Examples of control zones are radiation control zones, control zones established for lifting operations, venting operations control zones, control zones established when using hazardous chemicals and control zones established for movement of flight hardware.

### 10.1.12 Lifting Devices and Equipment

All lifting devices and equipment must comply with NASA Safety Standards for the design, testing, inspection, maintenance and use of overhead cranes, mobile cranes, and derricks, as well as hoist and winches, and associated lifting equipment such as hydrasets, hooks, and slings (ref. KSC-STD-Z-0002B and NSS/GO 1740.9).

### 10.1.13 Walking and Working Surfaces

Walking and working surfaces should be designed and constructed so as to provide the safest working environment feasible. This includes non-skid surfaces on floors, stairs and ladders in hazardous areas; guard rails and toe boards on elevated work surfaces, stairs, raised platforms and scaffolds; approved attach points for safety belts, lanyards and lifelines when working at elevated heights outside the confines of guard rails and secure footing; and guarding of floor and wall openings.

### 10.1.14 Training and Certification

Prior to the start of any hazardous operations all employees assigned to the operation must have received proper training, certification, equipment and briefings.

### 10.1.15 Work Authorizing Documents (WADs) - TPS, TOPs, OMIs, etc.

All WADs require review and technical input from Safety. The technical input includes hazard identifications, warnings, personnel protective equipment needed, establishment of control zones, monitoring requirements and Safety buy-offs.

### 10.1.16 Design Review Process (Safety Involvement)

An effective Safety and Hazard Analysis will accompany the design review process through the inception, actual design, and implementation phases. During the design phase a System Safety Engineer will participate in the design reviews developing safety criteria, and based on a safety analysis, will recommend methods of reducing risk, coordinate on the design of safety devices and suggest changes to remove or control hazards. If there is no control available, the safety analysis will be re- assessed and an accepted risk package will be prepared and submitted to NASA for approval. The complete process is shown on the flow diagram in Figure 10.1.16, and its logical order of application during the system development life cycle is detailed below.

1. The Preliminary Hazard Analysis is used in the early phases of the development to identify the energy sources being considered for use in the evolving system, together with the methods selected for the control of these energy sources.

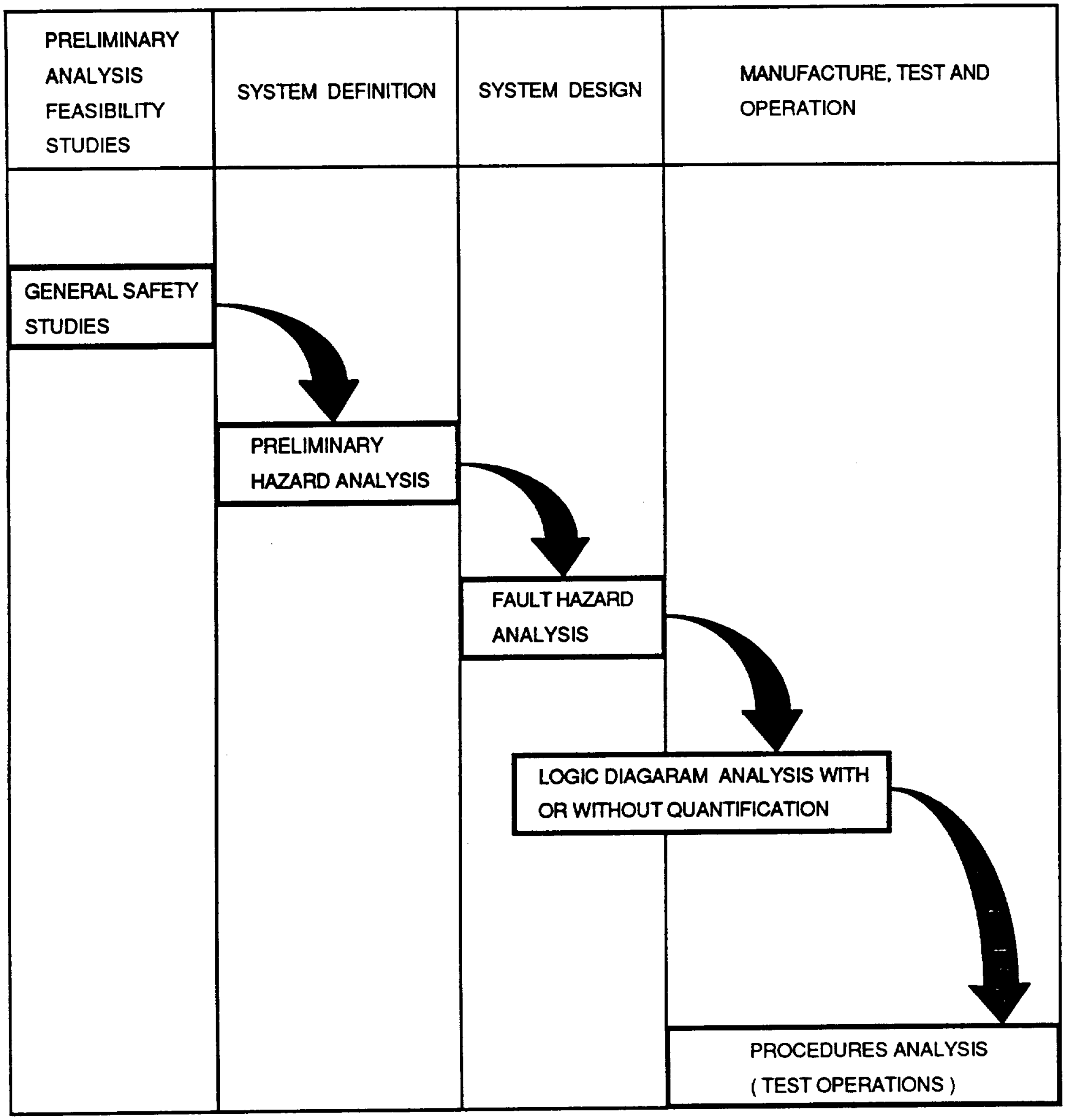

Figure 10.1.16. Safety Analysis - Program Activity Relationship

2. As the system becomes better defined and more detailed data evolve, the Fault Hazard Analysis can be undertaken. This analysis addresses the system down to the piece-part level, if necessary, and should include such items as mechanical linkages, wiring and ducting which connect the critical system elements or components.

3. The final analysis recommended for the more complex systems is the Logic Diagram Analysis which is used to identify critical failure paths. This analysis may be made quantitative using the Fault Tree Technique should the program manager require this amount of visibility.

4. Finally, manufacturing, test and operating procedures should be reviewed (Procedures Analysis) to assure they are fully annotated with cautions and warning notes and that their use does not initiate any out-of-sequence events.

Note: the above is taken from NHB 1700.1(V3) "SYSTEM SAFETY"

Variance, Waiver or Deviation:

If it is found that a specification or requirement cannot be achieved during the design/development phase of this project, a variance, waiver or deviation will be prepared and submitted for approval (type depends on situation). This document will be submitted to SPC Safety who will prepare a response for SPC Management and NASA Safety (Design Engineering, if necessary). If approved, the design can continue. If not approved corrective measures will have to be implemented. If this process is followed early in the design/development phase it should eliminate occurrence of this situation later.

## 10.2 UNIQUE SAFETY IMPACTS

The unique safety impacts of the LRB were addressed for each station set as shown in Figure 10.2. The following is a summarization of these impacts listed by station set.

### 10.2.1 Barge Delivery

Roadbed Structure and Underlying Piping

The roadbed structure needs to support the increased load of the LRB in excess of ET + transporter weight*. Past programs (eg. Apollo) or known heavy vehicle traffic have possibly validated that the roadbed structure will support required LRB loads. If not, validation with water tank and

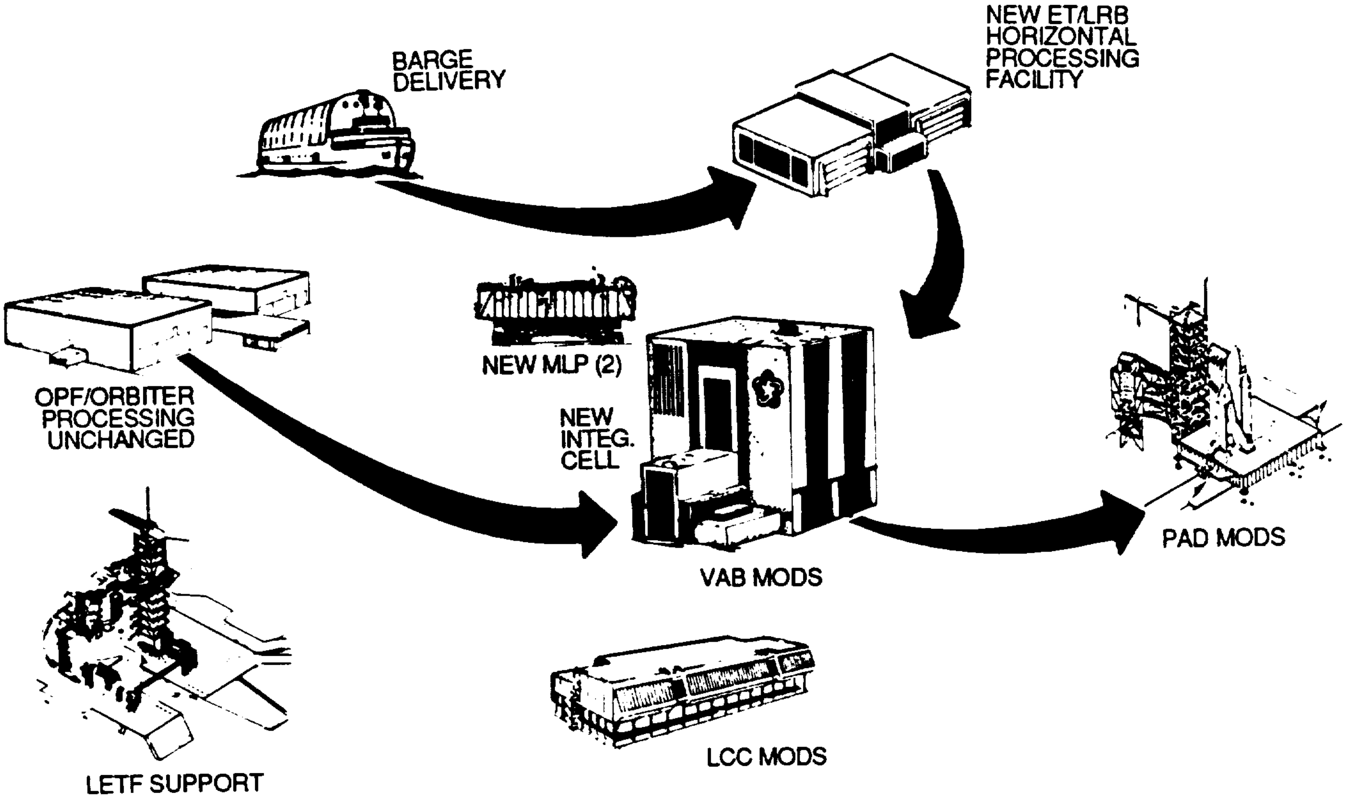

Figure 10.2. LRB Processing Station Sets.

transporter may be required.

* ET dry weight approximately = 80 KIP
Estimated LRB dry weight approximately = 109 to 200 KIP
(reference LRB Midterm Review for MSFC 8 March 88, pg 141)
Assume LRB and ET transporters have equivalent weights

Transporter

Design Safety Criteria for the LRB transporter must meet the NASA Design Criteria for GSE. Appropriate safety factors, validation, and testing must be incorporated.

### 10.2.2 ET/LRB Checkout and Processing Facility

Safety Concerns of Facility

Since the LRB/ET Checkout and Processing Facility is a new facility, there are numerous safety requirements to contend with during design, construction, and operating phases, such as : 1) fire protection/detection systems; 2) construction must meet fire ratings in hazard classified areas as shown in Figure 10.2.2-1) O2 and environmental monitoring for hazardous vapors must be considered; 4) ventilation systems to meet industrial hygiene requirements; 5) hazard/explosion proof electrical equipment in hazardous classified locations; 6) lighting must meet industrial hygiene requirements in different work areas. The lessons learned during the construction and validation of the OMRF systems will be used. More specific areas of concern with safety implications are listed below.

Electro Explosive Devices (EEDs)

If EEDs will be processed, handled, and/or installed in this facility, these devices must comply with JSC 08060 and GP-1098E.

Ground Support Equipment (GSE)

All GSE (handling, support, test, etc.) used in this facility must comply with requirements called out in SW-E-0002.

Lifting Devices and Equipment

All lifting devices and equipment used in this facility must comply with NSS/GO 1740.9, NASA Safety Standard for Lifting Devices and Equipment and also KSC-STD-Z-0002B, Design Re-

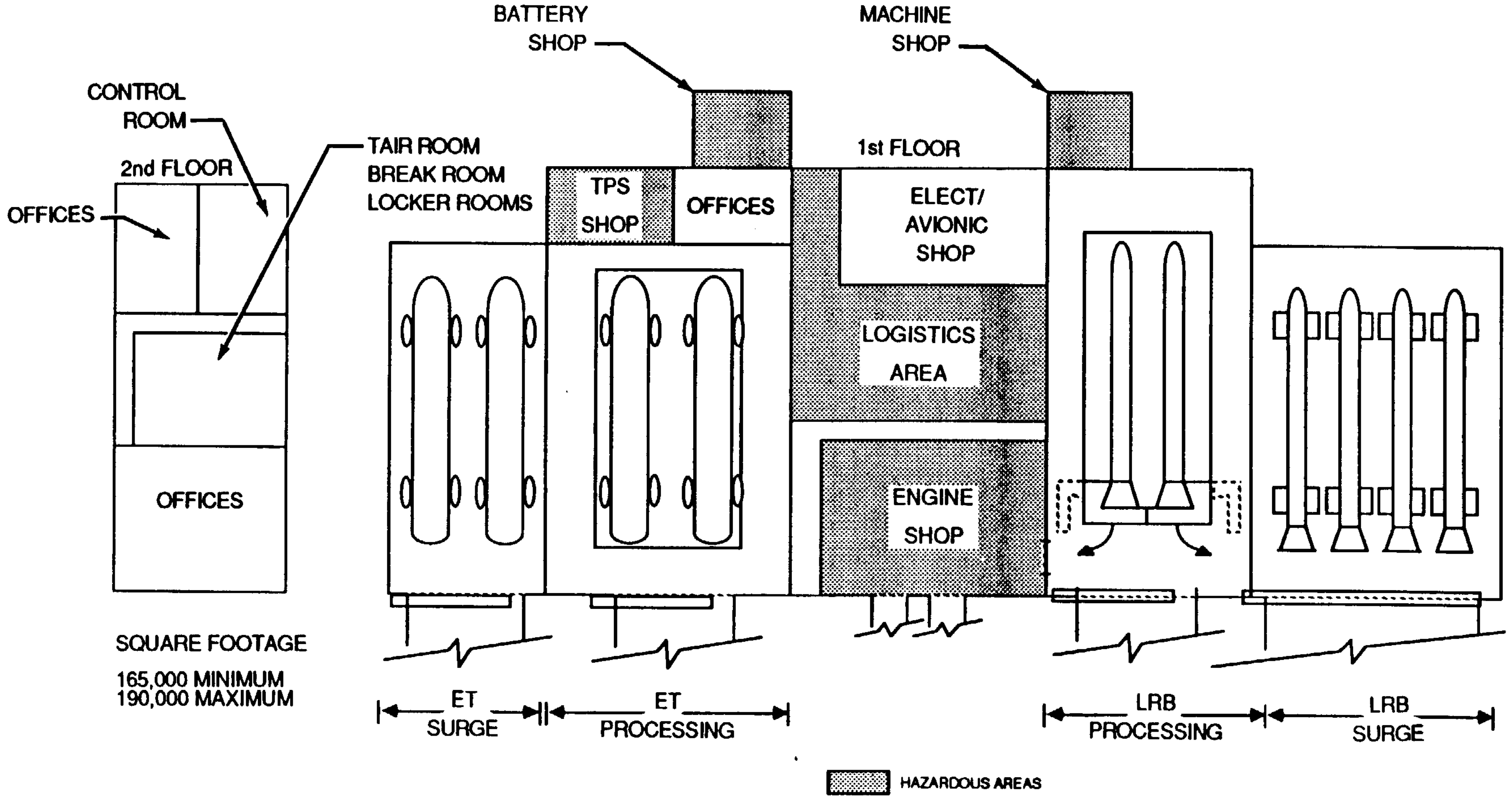

Figure 10.2.2-1. ET/LRB Checkout and Processing Facility Hazardous (Classified) Locations.

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quirements for Lifting and Hoisting Equipment (See Section 10.1.12 for a detailed list of the types of equipment).

### Hazardous Operations and Waste Removal

When applying the TPS material to the ET/LRB, personnel should use supplied breathing air, chemically impervious coveralls, and gloves and the area should be well ventilated. Any waste insulation must be disposed of properly. Also, proper personnel protective equipment must be provided to personnel working in the battery shops and the engine shops.

### Control Zones

Control zones will be established for any lifting or hazardous operations that will be performed.

### ET/LRB Checkout and Processing Facility Siting

Location of this facility in the general proximity of the current press site, adjacent to the barge turn basin, is recommended (Figure 10.2.2-2). Section 10.4, Recommendations, of this report provide details as to why this site was selected.

## 10.2.3 Vehicle Assembly Building (VAB)

### Platform Mods

There can be no gap or opening larger than 1 foot surrounding the platforms in any direction. Otherwise, lanyard attach points capable of supporting 5400 lbs. must be provided.

All drives that lift or move platforms above or around flight hardware require design per KSC-STD-Z-0002B and validation per KSC-STD-SF-0001D.

### Sling Design

Sling design must comply with KSC-STD-Z-0002, KSC-STD-SF-0001D and NSS-GO-1740.9.

### High Bay Four Mods

Safety impacts will be determined by specific mods needed to accommodate LRB, such as, pneumatic hookups, electrical, work/access platforms, lifting equipment, TPS close-out, etc. The construction activities required to make these modifications will be impacted by control zones established during certain operations. There are currently 65 control zones established for hazardous operations in the VAB (Figure 10.2.3-1), twenty- one of which could impact high bay four

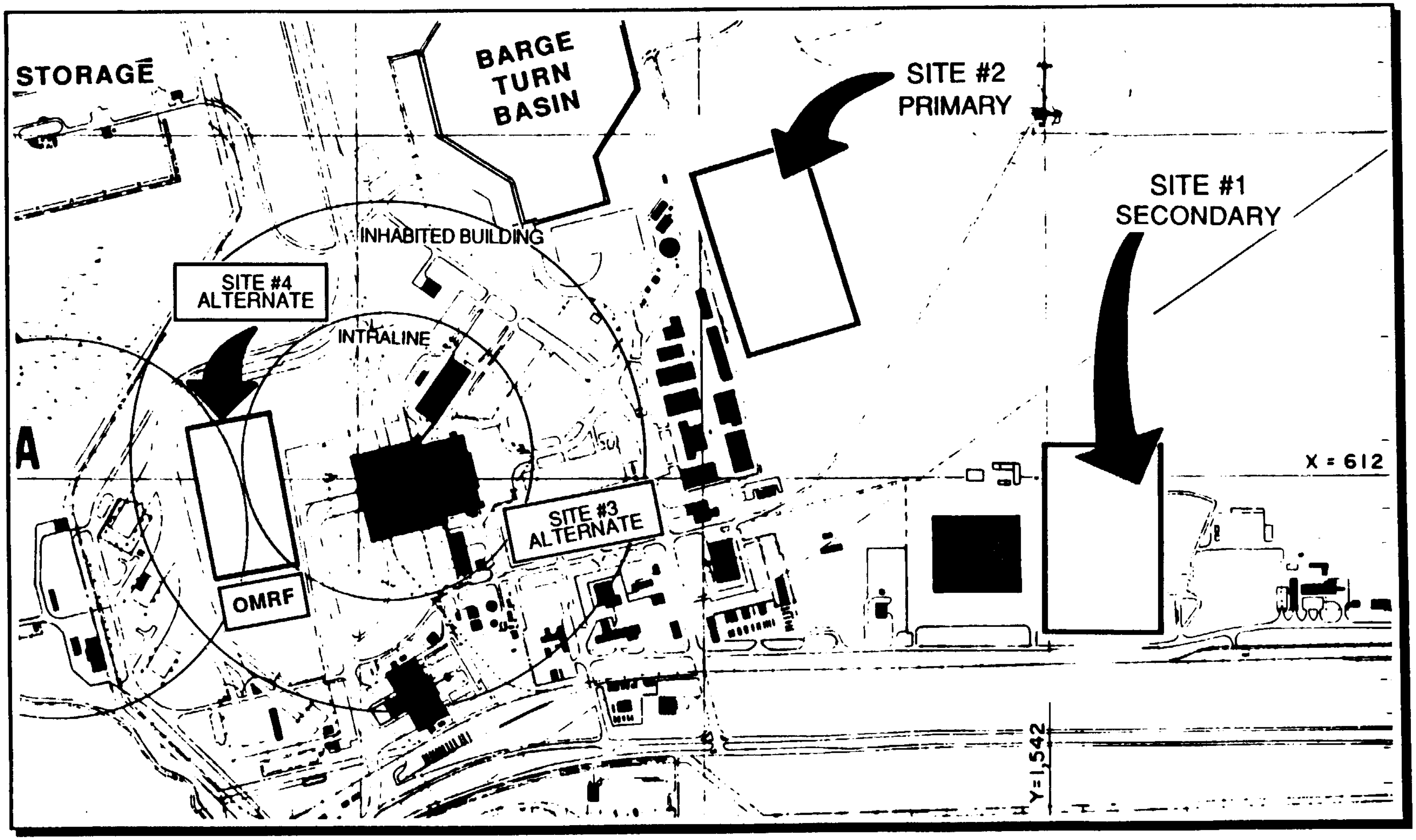

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Figure 10.2.2-2. ET/LRB Processing Facility-Site Plan.

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| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| * SRM SEGMENT SHIPPING COVER REMOVAL OR INSTALLATION. | CLEAR A 25-FT. AREA AROUND RAIL CAR AND ALONG PATH OF TRAVEL OF SUSPENDED COVER OF ALL NONESSENTIAL PERSONNEL. | THIS OPERATION IS LIMITED TO SHIPPING, COVER REMOVAL FROM A LOADED SEGMENT OR INSTALLATION OF AN EXPENDED SEGMENT CASE OR EMPTY RAIL CAR. |
| * SRM OFFLOAD AND ROTATION TO VERTICAL. | CLEAR HB-4 OF ALL NONESSENTIAL PERSONNEL (INCLUDING ET CHECKOUT CALLS). | SEGMENT OFFLOADING IS THE BEGINNING OF THE LIFT AND ENDS WITH COMPLETION OF LIFT. NO MORE THAN TWO SEGMENTS ARE ALLOWED IN HB-4 AT ANY ONE TIME. ADDITONAL SEGMENTS PERMITTED ONLY BY CONCURRENCE OF KSC SAFETY. |
| SRM SEGMENT LIFT FOR TANG CLEANING AND INSPECTION ONLY. | 50 FT. RADIUS. | HEIGHT OF LIFT WILL NOT BE MORE THAN FIVE FEET FROM GROUND LEVEL AFTER REMOVAL FROM PALLET. |
| * L & R AFT SKIRT ASSEMBLY FROM LOW BAY (RSF) TO HB-4. | CLEAR A 25-FT. RADIUS AROUND TRANSPORTER AND LIFTING OPERATION OF NONESSENTIAL PERSONNEL. THIS CONTROLLED AREA WILL MOVE WITH THE HARDWARE. | AREA IS OPEN FOR NORMAL WORK AFTER TRANSPORTER PASSES. |

NOTES:

1. HAZARDS AND CLEARED/CONTROLLED AREAS FOR SOME OPERATIONS MAY BE REVISED TO COVER SITUATIONS CAUSED BY TBD PAYLOADS.
2. PARALLEL MAJOR OPERATIONS (E.G.) SRB STACKING, ORBITER MATING/DEMATING, STS ROLLOUT IS PROHIBITED.
3. CLEARING OF D TOWER INCLUDES THE PERSONNEL CROSSOVER TO THE LOC. ALL FIRE DOORS SHALL BE CLOSED.
4. PERSONNEL REQUIRED TO SUPPORT NECESSARY INTEGRATION WORK IN THE ADJACENT HIGH BAY MAY BE MANLOADED INTO TOWER E. SPC SAFETY WILL CONTROL MANLOADING NOT TO EXCEED 75. FLAME RETARDANT COVERALLS NOT REQUIRED ON TOWER E IF INGRESS/EGRESS IS NOT THROUGH THE CONTROL AREA.

* NORMALLY PERFORMED IN RPSF; CONTINGENCY ONLY IN VAB.

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| • INSTALL R & R AFT SKIRT IN WORK STAND HB-4. | CLEAR A 25-FT. RADIUS AROUND LIFTING OPERATION OF NONESSENTIAL PERSONNEL UNTIL HOISTING IS COMPLETE. | SEPARATION MOTORS ARE INSTALLED. |
| • MATE L & R AFT SEGMENT TO AFT SKIRT HB-4. | CLEAR HB-4 OF ALL NONESSENTIAL PERSONNEL (INCLUDING ET CHECKOUT CELLS). | NO MORE THAN TWO SEGMENTS ARE ALLOWED IN HB-4 AT ANY ONE TIME. ADDITIONAL SEGMENTS PERMITTED ONLY BY CONCURRENCE BY KSC SAFETY. |
| FORWARD HANDLING RING REMOVAL (SEGMENT-VERTICAL). | FOR HB-1/3 OPERATIONS: CLEAR WORKING LEVEL ON EXTENSIBLE PLATFORM OF ALL NON-ESSENTIAL PERSONNEL. CLEAR 16TH FLOOR CROSSOVER AND TRANSFER AISLE WHEN CRANE TRAVERSES WITH SUSPENDED LOAD.<br>FOR (HB-4) OPERATIONS: CLEAR A 25-FT. RADIUS AT WORK LOCATION (E LEVEL OF STAND) AND FROM UNDER SUSPENDED LOAD OF ALL NON-ESSENTIAL PERSONNEL. | THE FORWARD HANDLING RING WILL BE RAISED 18 INCHES ABOVE SEGMENT AND THE H77-0412 SEGMENTED PROTECTIVE COVERS INSTALLED PRIOR TO TRANSFERRING THE HANDLING RINGS FROM LIVE SEGMENTS. |
| • SRM GRAIN INSPECTION-HORIZONTAL. | CLEAR HB-4 FLOOR AREA OF NONESSENTIAL PERSONNEL. | DURING HORIZONTAL GRAIN INSPECTION OF A THIRD SEGMENT, WORK MAY CONTINUE ON THE OTHER TWO SEGMENTS IN THE PSF STAND OF HB-4 PROVIDING PERSONNEL ARE MANLOADED AND THE WORK DOES NOT INVOLVE HOISTING, EXPLOSIVE, HYPERGOLIC, HIGH NOISE LEVEL, OR ANY OTHER OPERATIONS THAT ARE CONSIDERED HIGH HAZARD OR COULD INTERFERE WITH THE GRAIN INSPECTION. (THIRD SEGMENT REQUIRES KSC SAFETY CONCURRENCE PROIR TO COMING IN TO THE VAB). |

• NORMALLY PERFORMED IN RPSF;
CONTINGENCY ONLY IN VAB

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

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| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| OFFLOAD NOZZLE EXTENSIONS HB-4 | CLEAR 25-FT. AROUND OFFLOAD OPERATION OF NONESSENTIAL PERSONNEL. | |
| * INSTALL L & R NOZZLE EXTENSION | CLEAR WORK STAND WHERE WORK IS BEING PERFORMED OF NONESSENTIAL PERSONNEL FROM NOZZLE INTERFACE TO GROUND LEVEL. | |
| * INSTALL L & R ETA STRUTS | CLEAR TOP LEVEL OF WORK STAND OF NONESSENTIAL PERSONNEL. | |
| ET ARRIVAL | CLEAR 25 FT. AROUND THE ET AND TRANSPORTING EQUIPMENT OF NONESSENTIAL PERSONNEL. | |
| ET SLING BUILDUP | CLEAR 50 FT. AROUND TRANSFER AISLE BUILDUP AREA OF NONESSENTIAL PERSONNEL. | |
| PAYLOAD CANISTER ROTATION | CLEAR TRANSFER AISLE 100 FT. NORTH AND SOUTH FROM CENTER OF THE LIFT OF NONESSENTIAL PERSONNEL. | |
| ET LIFT AND TRANSFER TO C/O CELL FROM THE H.B. TRANSFER AISLE. | FOR HB-4 OPERATION: CLEAR ENTIRE HB-4 AND HB-3 GROUND FLOOR AND TRANSFER AISLE TO TOWERS A & D SOUTH LINE OF NONESSENTIAL PERSONNEL. FOR HB-2 OPERATIONS: CLEAR ENTIRE HB-2 AND HB-1 GROUND FLOOR AND ENTIRE TRANSFER AISLE OF NONESSENTIAL PERSONNEL. | ESSENTIAL PERSONNEL ARE THE CRANE CREW ONLY. AFTER CLEARING THE TRANSOM, TRANSFER AISLE AND OPPOSITE HIGH BAYS ARE OPEN, BUT HB-4/2 GROUND FLOORS REMAIN CLEARED OF NONESSENTIAL PERSONNEL UNTIL ET IS OVER THE CHECKOUT CELL SUPPORT. |
| ET TRANSFER BETWEEN THE C/O AND HOLDING CELLS. | CLEAR NONESSENTIAL PERSONNEL FROM HB-2, HB-4, C/O AND HOLDING CELLS. | CONTROL AREA MAY BE OPEN WHEN THE TANK IS IN THE RECEIVING CELL SUPPORT ARM. |
| * SRM PREP FOR HOISTING | CLEAR HB-4 FLOOR AREA OF NONESSENTIAL PERSONNEL. | ESTABLISHED CLEARED AREA JUST PRIOR TO LIFTING BEAM BEING POSITIONED OVER THE SEGMENT. |

* NORMALLY PERFORMED IN RPSF;
CONTINGENCY ONLY IN VAB

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Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

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| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| HB-1/3 SRM PIE COVER REMOVAL (OPEN GRAIN) PREPS FOR STACKING. | CLEAR NONESSENTIAL PERSONNEL FROM WORK LEVEL INVOLVING OPEN GRAIN OPERATION. | ALL PERSONNEL ON WORK LEVEL SHALL WEAR FLAME RETARDANT COVERALLS DURING OPEN GRAIN EXPOSURE. |
| * SRM HOISTING/TRANSFER FROM HB-4 TO TRANSFER AISLE. | CLEAR NONESSENTIAL PERSONNEL FROM HB-4, HB-3 GROUND FLOOR, TOWERS B & C, AND HB TRANSFER AISLE TO TOWERS A & D SOUTH LINE. | |
| * SRM HOISTING/STACKING FROM HB-4 TO HB-3. | CLEAR NONESSENTIAL PERSONNEL FROM HB-3 AND HB-4, TOWERS B, C, E, F AND HB TRANSFER AISLE TOP TOWERS A & D SOUTH LINE. | THE CONTROL AREA FOR ALL STACKING OPERATION (EXCEPT FOR AFT SEGMENT) SHALL BE MAINTAINED UNTIL COMPLETION OF SOFTMATE (SOFTMATE IS SEGMENT MATE AND 15 PINS INSTALLED).<br>REF. NOTE 4, PAGE B1. |
| SRM HOISTING/STACKING FROM HB TRANSFER AISLE TO HB-3, AFT CENTER, FORWARD CENTER, FORWARD SEGMENTS ONLY. | CLEAR NONESSENTIAL PERSONNEL FROM HB-3, HB-4 GROUND FLOOR, TOWERS E, F, AND HB TRANSFER AISLE TO TOWERS A & D SOUTH LINE. | REF. NOTE 4, PAGE B-1. |
| SRM HOISTING/STACKING FROM HB TRANSFER AISLE TO HB-1, AFT CENTER, FORWARD CENTER, FORWARD SEGMENT ONLY. | CLEAR NONESSENTIAL PERSONNEL FROM HB-1, HB-2 GROUND FLOOR, TOWERS D, E. ENTIRE VAB TRANSFER AISLE, LOW BAY OPEN CELLS AND LOW BAY THIRD FLOOR M & N SECTION. | REF. NOTE 3, PAGE B-1.<br>REF. NOTE 4, PAGE B-1. |
| SRM HOISTING/STACKING FROM HB TRANSFER AISLE TO HB-3, AFT SEGMENT ASSEMBLIES ONLY. | CLEAR NONESSENTIAL PERSONNEL FROM HB-3 HB-4 GROUND FLOOR, TOWERS E, F, AND HB TRANSFER AISLE TO TOWER A & D SOUTH LINE UNTIL SOFTMATE. AFTER SOFTMATE UNTIL THE COMPLETION OF SHIM OR LIFT OPERATIONS THE CONTROLLED AREA IS THE HIGH BAY, INCLUDING MLP, AND ADJACENT TRANSFER AISLE. | SOFTMATE IS SEGMENT ASSEMBLY RESTING ON HOLDDOWN POSTS. SEGMENT HOIST TO 3 FEET MAX. LIFT FOR SHIM ADJUSTMENT MAY BE PERFORMED IF NECESSARY WITHIN THE SOFTMATE CONTROLLED AREA.<br>REF. NOTE 4, PAGE B-1. |

* NORMALLY PERFORMED IN RPSF; CONTINGENCY ONLY IN VAB

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

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| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| SRM HOISTING/STACKING FROM HB TRANSFER AISLE TO HB-1, AFT SEGMENT ASSEMBLIES ONLY. | CLEAR NONESSENTIAL PERSONNEL FROM HB-1, HB-2 GROUND FLOOR, TOWERS D, E, ENTIRE VAB TRANSFER AISLE, LOW BAY OPEN CELLS, UNTIL SOFTMATE. AFTER SOFTMATE AND UNTIL THE COMPLETION OF SHIM OR LIFT OPERATIONS THE CONTROLLED AREA IS THE HIGH BAY, INCLUDING THE MLP, AND ADJACENT TRANSFER AISLE. | REF. NOTE 3, PAGE B-1.<br>SOFT MATE IS SEGMENT ASSEMBLY RESTING ON HOLDDOWN POSTS. SEGMENT HOIST TO 3 FEET MAX. LIFT FOR SHIM ADJUSTMENT MAY BE PERFORMED IF NECESSARY WITH THE SOFT MATE CONTROLLED AREA. |
| GROUND UMBILICAL CARRIER PLATE INSTALLATION (ET). | CLEAR HB-4/2 LEVEL 6 ET INTERTANK AREA OF NONESSENTIAL PERSONNEL. | REF. NOTE 4, PAGE B-1. |
| SRSS S & A INSTALLATION (ET) | CLEAR HB-4/2 LEVEL 6 ET INTERTANK AREA OF NONESSENTIAL PERSONNEL. | ELECTRICAL CONNECTIONS REMAIN DISCONNECTED. |
| INSTALL TUMBLE VALVE NSI. | CLEAR HB-4/2 LEVEL 9 ET INTERTANK AREA OF NONESSENTIAL PERSONNEL. | ELECTRICAL CONNECTIONS ARE NOT ALLOWED. |
| SRSS S & A FUNCTION CHECK-ET/SRB (ROTATE BARRIER). | CLEAR HB-4/2 LEVEL 6 ET INTERTANK AREA OF NONESSENTIAL PERSONNEL FOR ET OPERATIONS. CLEAR HB-1/3 INTERIOR OF FWD SKIRT OF NONESSENTIAL PERSONNEL FOR SRB OPERATIONS. | NSI ELECTRICAL CONNECTIONS ARE NOT ALLOWED. CDF IS DISCONNECTED DOWNSTREAM OF S & A DEVICE. |
| EXPLOSIVES INSTALLATION ONLY. | SRB IN HB-1/3: CLEAR E PLATFORM N OR S AS APPLICABLE, A 10 FT. RADIUS OF AFT SKIRT, INTERIOR OF TSM, A 10 FT. RADIUS OF THE TSM DOOR AND T-0 UMBILICAL AREA OF NONESSENTIAL PERSONNEL. ET/ORBITER IN HB-13: CLEAR A 10 FOOT RADIUS ON D2 PLATFORM, AND ORBITER AFT FUSELAGE OF NONESSENTIAL PERSONNEL. | ELECTRICAL CONNECTIONS ARE NOT PERMITTED. |
| PIC RESISTANCE TEST. | | NOT PERMITTED IN VAB. |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| ET LSC INSTALLATION. | CLEAR OPERATION LEVEL, LEVEL ABOVE AND BELOW OF NONESSENTIAL PERSONNEL. | |
| CDF INSTALLATION. | CLEAR OPERATION LEVEL OF NONESSENTIAL PERSONNEL. | |
| SRM LSC INSTALLATION. | CLEAR PLATFORMS B, D, AND E OF NONESSENTIAL PERSONNEL. | |
| RANGE SAFETY SYSTEM S & A AND CDF COMPONENT INSTALLATION INTO FORWARD SKIRT (SRB). | CLEAR FORWARD SKIRT PLATFORM OF NONESSENTIAL PERSONNEL. | ELECTRICAL CONNECTIONS ARE NOT ALLOWED. CDF REMAINS DISCONNECTED. |
| ET MOVE AND MATE TO SRB. | FOR HB-3 OPERATION: CLEAR HB-3, HB-4, TOWERS E & F, AND TRANSFER AISLE TO TOWERS A & D SOUTH LINE OF NONESSENTIAL PERSONNEL. | AFTER THE TRANSOM OF HB-3/1 IS CLEARED, HB-4/2 AND TRANSFER AISLE MAY BE OPENED. HB-3/1, ADJACENT TOWERS WILL REMAIN CONTROLLED UNTIL ET IS SOFTMATED (SOFTMATE IS ET OVER FWD ATTACH POINTS). |
| | FOR HB-1 OPERATION: CLEAR HB-1, HB-2, TOWERS D & E, 3RD FLOOR M & N SECTION AND ENTIRE TRANSFER AISLE OF NONESSENTIAL PERSONNEL. | REF. NOTE 3, PAGE B-1.<br>REF. NOTE 4, PAGE B-1. |
| FREON 21 SERVICE (BREAKING INTO SYSTEM). | CLEAR NONESSENTIAL PERSONNEL 10 FT. FOR OPERATIONS. (100 FT. OF LINE BREAK IF 1 PINT OR MORE WILL BE RELEASED; 3 FT. FOR LESS THAN 1 PINT). | OFFSHIFT OR WEEKEND OPERATIONS MAY BE NECESSARY. INSURE ADEQUATE VENTILATION. |
| ORBITER ARRIVAL IN VAB. | CLEAR NONESSENTIAL PERSONNEL OVERHEAD AND FOR HB-3 OPERATION CLEAR TRANSFER AISLE NORTH OF TOWER B/E SOUTH LINE. FOR HB-1 OPERATION CLEAR TRANSFER AISLE NORTH OF TOWERS AND SOUTH LINE. | WITH OR WITHOUT PROPELLANTS ABOARD. |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| ORBITER SLING BUILDUP. | CLEAR 50 FT. AROUND TRANSFER AISLE BUILDUP AREA OF NONESSENTIAL PERSONNEL. | |
| ORBITER LIFT AND ROTATION TO VERTICAL (TRANSFER AISLE). | 1. HB-1 OPERATION: CLEAR HB-1 AND HB-2 GROUND FLOOR, ENTIRE TRANSFER AISLE OF NONESSENTIAL PERSONNEL.<br>2. HB-3 OPERATION: CLEAR HB-3 AND HB-4 GROUND FLOOR. TRANSFER AISLE TO TOWER A & D SOUTH LINE OF NONESSENTIAL PERSONNEL. | WITH OR WITHOUT PROPELLANTS ABOARD. |
| ORBITER LIFT, TRANSLATION AND MATE TO ET. | HB-1 OPERATIONS:CLEAR HB-1, TOWERS D & E, HB-2 GROUND FLOOR, AND ENTIRE TRANSFER AISLE OF NONESSENTIAL PERSONNEL. HB-3 OPERATION; CLEAR HB-3, TOWERS E & F , HB-4 GROUND FLOOR AND TRANSFER AISLE TO TOW A & D SOUTH LINE OF NON-ESSENTIAL PERSONNEL. | AFTER THE ORBITER IS LIFTED INTO THE APPLICABLE HB THE CONTROLLED ACCESS AREAS FOR THE LIFT (EXCEPT FOR HB-1 OR 3 AND THE ADJACENT TOWERS) SHALL BE OPENED FOR SCHEDULED WORK. THE HB AND TOWERS SHALL REMAIN CLOSED UNTIL COMPLETION OF "SOFTMATE". SOFTMATE IS AFTER THE INITIAL TORQUE OF ORBITER/ET SEPARATION BOLTS. REF. NOTE 3, PAGE B-1. |
| MLP ROLLOUT/IN PREP (STS OR SRB SEGMENT). | CONTROL HB-1/3 AND ADJACENT TRANSFER AISLE. | REF. NOTE 4, PAGE B-1. |
| MLP ROLLOUT/IN (STS OR SRB SEGMENT). | CONTROL HB-1/3 AND ADJACENT TRANSFER AISLE. | CONTROL AREA WILL BE MAINTAINED UNTIL ORBITER CLEAR 650 FT. FROM VAB, INCLUDING EAST AND NORTH LCC PARKING TO AND GROUND LEVEL WALKWAY TO THE VAB.<br>DURING HB TO HB TRANSFER THE CONTROL AREA SHALL BE ESTABLISHED IN BOTH HB'S PRIOR TO START. |

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Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| MLP ROLLOUT/IN (EMPTY) | CONTROL HB GROUND LEVEL, PATH AND 25 FT. OF CT. | |
| ORDINANCE RING BUILDUP | CLEAR ROOM 1C4 TOWER C, OF ALL NONESSENTIAL PERSONNEL. | |
| AFT SEPARATION MOTOR BUILDUP | CLEAR ROOM 1C4, TOWER C, OF ALL NONESSENTIAL PERSONNEL. | MOTOR MUST BE ORIENTED NOZZLE SOUTH. |
| SRB/ET STRUT BUILDUP AND CHECKOUT. | CLEAR ROOM 1C4, TOWERC, OF ALL NONESSENTIAL PERSONNEL. | |
| ORDINANCE RING TRANSFER FROM TOWER C TO LOW BAY (RSF). | CLEAR 25 FT. AROUND TRANSPORTER OF NONESSENTIAL PERSONNEL. | THIS HAZARDOUS CIRCLE WILL TRAVEL WITH THE TRANSPORTER. AREA WILL BE OPEN FOR NORMAL WORK AFTER TRANSPORTER PASSES. |
| ORDINANCE RING AND FRUSTUM MATE. | CLEAR 25 FT. RADIUS OF NONESSENTIAL PERSONNEL. | |
| BOOSTER SEPARATION MOTORS/ROCKET MOTORS OPEN GRAIN INSPECTION, AERO HEAT SHIELD INSTALLATION OR REMOVAL. | RSF LOW BAY AREA, CELL 2/7-J CLEAR ALL NONESSENTIAL PERSONNEL FROM A 25- FOOT RADIUS AROUND TH E BSM'S. | |
| ORDNANCE BUILDUP (ROOM 1C4) BOOSTER SEPARATION MOTOR HOISTING, OR OPEN GRAIN OPERATIONS. | CLEAR ALL PERSONNEL NOT ESSENTIAL TO THE SPECIFIC OPERATION FORM 1C4. | ROOM 1C4 IS A CONTROLLED AREA LIMITED TO 18 PEOPLE EXCEPT FOR BSM HOISTING OR OPEN GRAIN OPERATION. CONCURRENT ORDNANCE OPERATIONS ARE PERMITTED. |
| AFT SEPARATION MOTOR ARRIVAL AND OFFLOAD TOWER C. | CLEAR A 25 FT. RADIUS AROUND OFFLOADING OF NONESSENTIAL PERSONNEL. | THIS HAZARDOUS CIRCLE WILL TRAVEL WITH THE TRANSPORTER. AREA IS OPEN FOR NORMAL WORK AFTER TRANSPORTER PASSES. |
| AFT SEPARATION MOTOR ASSEMBLY TRANSFER TO AND FROM TOWER C AND LOW BAY. | CLEAR 25 FT. AROUND TRANSPORTER OF NONESSENTIAL PERSONNEL. | |
| AFT SEPARATION MOTOR ASSEMBLY MATE TO SKIRT. | CLEAR 25 FT. RADIUS OF NONESSENTIAL PERSONNEL. | |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| AFT SEPARATION MOTOR ASSEMBLY MATE TO SKIRT. | CLEAR 25 FT. RADIUS OF TRANSPORTER OF NONESSENTIAL PERSONNEL. | |
| FORWARD SEPARATION MOTOR ARRIVAL AND OFFLOAD RSF. | CLEAR 25 FT. RADIUS OF TRANSPORTER OF NONESSENTIAL PERSONNEL. | |
| FORWARD SEPARATION MOTOR ARRIVAL AND INSTALLATION INTO FRUSTUM. | CLEAR 25 FT. RADIUS OF TRANSPORTER OF NONESSENTIAL PERSONNEL. | |
| NOSE CAP THRUSTERS AND CDF COMPONENT INSTALLATION INTO FRUSTUM. | CLEAR ALL NONESSENTIAL PERSONNEL FROM THE INTERIOR OF FLIGHT HARDWARE AND A 5-FT. EXTERNAL AREA SURROUNDING THE HARDWARE INCLUDING ANY MOBILE ASSEMBLY AND REFURBISHMENT STAND (MARS) WHICH ARE WITHIN THE AREA. | |
| ALL FRUSTUM AND FORWARD ASSEMBLY LIFTING OPERATION WHEN BSM'S AND/OR NSI'S HAVE BEEN INSTALLED. | CLEAR ALL NONESSENTIAL PERSONNEL FROM A 25-FOOT RADIUS AROUND FRUSTUM/FORWARD ASSEMBLY AND ALONG PATH OF TRAVEL. | |
| ORDNANCE RING CDF HOOKUP. | CLEAR FORWARD SKIRT OF NONESSENTIAL PERSONNEL. | |
| NOSE CAP THRUSTER MATING HARDWARE INSTALLATION. | CLEAR ALL NONESSENTIAL PERSONNEL FROM MOBILE ASSEMBLY AND REFURBISHMENT STANDS (MARS). | |
| SRB FORWARD ASSEMBLY FROM LOW BAY (RSF) TO HB 1/3. | CLEAR 50 FT. RADIUS AROUND THE OPERATION OF NONESSENTIAL PERSONNEL UNTIL HOISTING IS COMPLETE AT RSF. CLEAR 24 FT. AROUND TRANSPORTER OF NONESSENTIAL PERSONNEL. | AREA WILL BE OPEN FOR NORMAL WORK AFTER TRANSPORTER PASSES. |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

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| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| SRB FORWARD ASSEMBLY HOIST FROM TRANSFER AISLE TO HB1/3. | FOR HB-3 OPERATION: CLEAR HB-3 AND TRANSFER AISLE TO TOWER B/E SOUTH LINE OF NONESSENTIAL PERSONNEL.<br>FOR HB-1 OPERATION: CLEAR HB-1 AND TRANSFER AISLE A/D SOUTH TO B/E NORTH OF NONESSENTIAL PERSONNEL. | CLEAR TRANSFER AISLE OF NONESSENTIAL PERSONNEL UNTIL LOAD PASSES OVER TRANSOM. |
| CRANE HOOK LOWER/RAISE. | CLEAR 25 FT. RADIUS FROM UNDER HOOK OF NONESSENTIAL PERSONNEL. | |
| MERCURY HANDLING. | LOCAL CLEAR TBD BY CONDITIONS AND LOCATION. | SPLASH SUITS AND FACE SHIELDS REQUIRED FOR HANDLERS. |
| IGNITER INSTALLATION/REMOVAL-SRB | FOR HB-3 OPERATION: CLEAR HB-3 AND TOWERS E AND F OF NONESSENTIAL PERSONNEL.<br>FOR HB-1 OPERATION: CLEAR HB-1 AND TOWERS D, E, OF ESSENTIAL PERSONNEL | REF. NOTE 3, PAGE B-1. |
| INSTALLATION AND REMOVAL OF SRB S & A DEVICE. | CLEAR NONESSENTIAL PERSONNEL FROM E MAIN PLATFORM NORTH OR SOUTH SIDE WHERE OPERATION IS BEING PERFORMED. | |
| SRM GRAIN INSPECTION-VERTICAL. | FOR HB-3 OPERATION: CLEAR HB-3 AND TOWERS E AND F OF NONESSENTIAL PERSONNEL.<br>FOR HB-1 OPERATION: CLEAR HB-1 AND TOWERS D, E, OF ESSENTIAL PERSONNEL. | REF. NOTE 3, PAGE B-1. |
| TPS WATERPROOFING (CONDOR OPERATION). | CLEAR OPERATION AREA OF NONESSENTIAL PERSONNEL 100FT. RADIUS TO THE ORBITER OUTER PERIMETER. | ALL PERSONNEL IN 100 FT. AREA SHALL WEAR PROTECTIVE CLOTHING AND SELF-CONTAINED BREATHING APPARATUS. |
| EXPLOSIVES INSTALLATION AND REMOVAL ORBITER TO ET AFT SEPARATION AND ET UMBILICAL. | CLEAR 25 FT. RADIUS OF NONESSENTIAL PERSONNEL. | |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

| | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| EXPLOSIVES ELECTRICAL CONNECTION/ DISCONNECTION (CABLES CONNECTED TO PIC OR OTHER FIRNG CIRCUIT). | FOR HB-3 OPERATION: CLEAR HB-3 TOWERS E & F OF NONESSENTIAL PERSONNEL, CLOSE HB-1 & 3 DOORS.<br>FOR HB-1 OPERATION: CLEAR HB-1, TOWERS D & E, AND LOW BAY 3RD FLOOR M AND N OF NONESSENTIAL PERSONNEL, CLOSE HB-1 & 3 DOORS. | REF. NOTE 3, PAGE B-1. |

Figure 10.2.3-1. VAB Control Areas For Hazardous Operations.

(HB4) modifications needed for LRB support. The floor plan for the VAB (Figure 10.2.3-2) shows the layout of the high bays and transfer aisle. An example of a control zone established for a hazardous operation is represented by the shaded area, which is the control zone established for SRM Hoisting and Stacking Operations in high bay three (HB3). As can be seen, the entire transfer aisle between towers A/D and C/F, HB3 and 4, and towers B, C, E, and F require clearing of all non-essential personnel. These same control zones will effect LRB processing in the VAB during phase-in when simultaneous LRB and SRB processing occurs.

NOTE: It was pointed out during the course of the study that, should anything happen to the RPSF, HB4 is the fallback facility for those operations currently being conducted in the RPSF. It is unlikely that this situation would occur, however, should it happen, the control zones for these operations are included in the listing of control zones for the VAB (Figure 10.2.3-1). Prior to commencement of modifications to HB4, in order to preclude disruption of ET processing for the current baseline, the new ET/LRB Checkout and Processing Facility should be complete and operational.

### 10.2.4 Mobile Launch Platform (MLP)

#### Laser Alignment

Laser alignment is currently used to align the MLP to the facility at which it is located, either the VAB or the pads. All personnel involved in the laser operation are required to be certified and trained. Laser alignment equipment must comply with non-ionizing radiation requirements called out in KMI 1860.1.

#### Structural Integrity

Design and construction must comply with requirements called out in KSC-STD-Z-0003. Critical welds shall be identified and a non-destructive evaluation performed to assure structural integrity. Critical weldment is defined as the single failure of a weld, which during any operational condition could result in injury to personnel or damage to property or flight hardware. Critical weldments should be avoided whenever possible. Proof loading is required where low factors of safety must be structurally proven for the safety of personnel. If major modifications are performed on the MLP, the structural integrity must be maintained and shown by analyses.

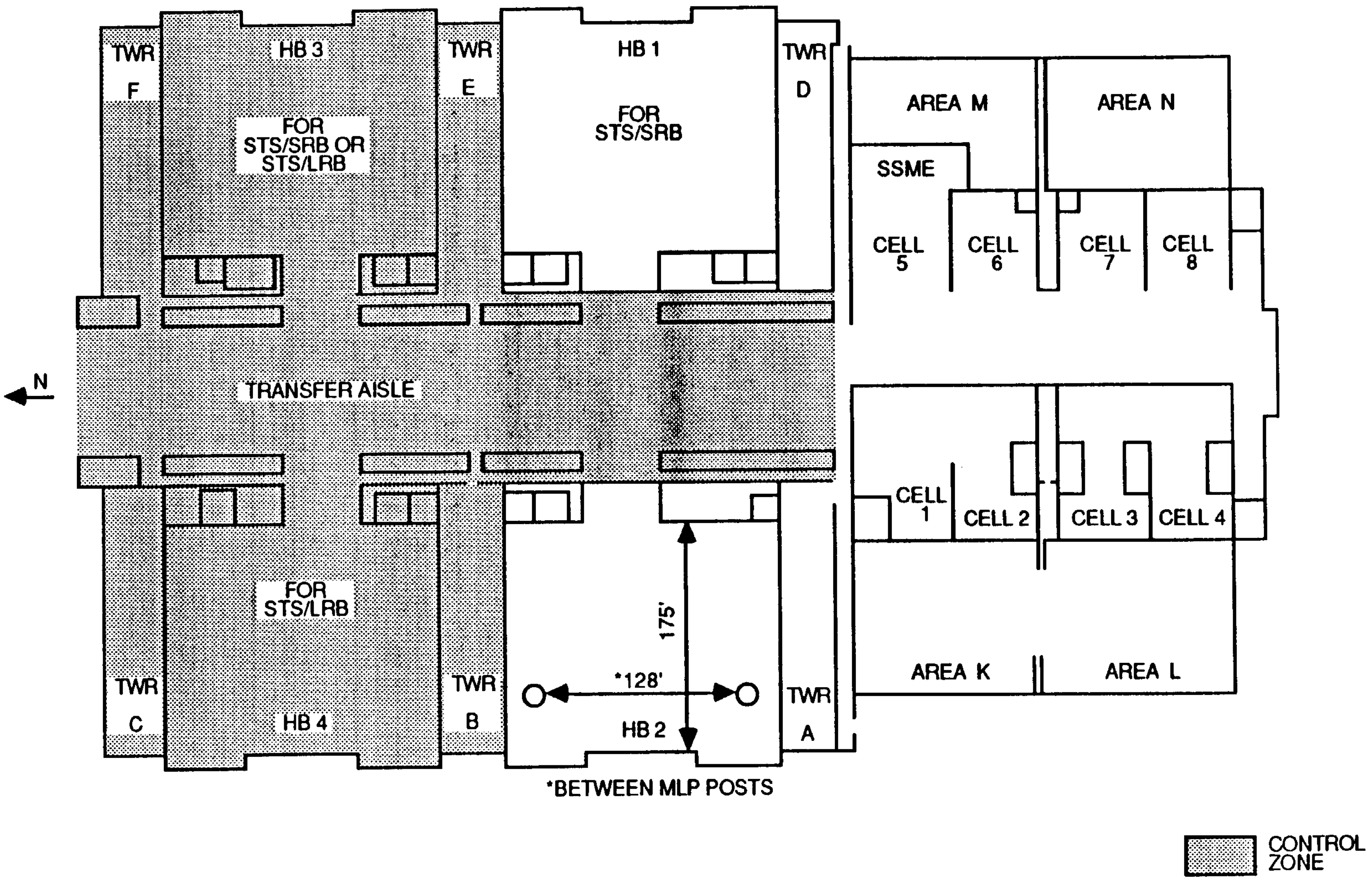

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Figure 10.2.3-2 Control Zone for SRM Hoisting and Stacking Operations in the VAB.

3-10 11/14 7:00a

### Umbilicals

Umbilicals must be in accordance with GP-986. Electrical umbilical connectors must be provided with an inert safety purge. Leak detection is also required. Grounding is required per KSC-STD-E-0012.

### Flexhoses

Incorporation of SPI SP-611(2)K would provide for the protection of personnel and equipment in the event of flexhose failure.

### Piping

MLP piping must be in compliance with Safety Standards for Ground Piping Systems, KSC-STD-SF-0004.

### Bonding and Grounding

Must comply with KSC-STD-E-0012. The performance of ground continuity checks at regular intervals is required to assure adequate low levels of resistance to facilitate static charge dissipation and to provide lightning protection. This action should be incorporated into all applicable OMRSDs as a critical requirement.

### Control Components (HIMs)

HIMs require purged or pressurized enclosures to prevent the build-up of flammable/explosive vapors. Electrical impacts will determine the increased number of HIMs required to support the LRB.

### Fire Suppression and Leak Detectors

The existing system must be upgraded or redesigned if different propellants are used (LO2/RP-1 or LO2/CH4) to ensure the proper leak detectors and suppression system is used.

## 10.2.5 Launch Pads

### Propellant Storage Quantity Distance Requirements

All data used in this section was obtained from the Liquid Rocket Booster Integration Progress Review prepared by LSOC dated 24 August 1988, pages IA32A through IA-35. Two propellant scenarios were looked at; LO2/LH2 and LO2/RP-1. The following calculations and results show the quantity distance requirements for the storage of these propellants. AFR 127-100, " Explosive

Safety Standards" and AFM 161-30, " Liquid Propellants" were used to compute these results. The propellant quantities are based on the quantity needed to load booth the ET and LRB. From the LSOC study referenced above the quantities are as follows:

1. LOX requires 2(two) 900,000 gallon storage tanks to support independent loading of the ET and LRB and this will permit a scrub/turnaround without storage vessel replenishment.

2. LH2 requires 2(two) 900,000 gallon storage tanks to support loading of the ET and LRB, however this will not allow a scrub/turnaround.

3. The proposed RP-1 concept will use 3(three) 85,000 gallon storage vessels which is sufficient for all LRB configurations.

NOTE: To convert gallons of propellants into pounds, conversion factors contained in Figure 10.2.5-1 were extracted and used in the calculations below. To determine propellant hazard and compatibility groups, data from Figure 10.2.5-2 was used.

As per AFR 127-100, Explosive Safety Standards, section D, paragraph 5-26b(1), " When storage containers are not separated from each other by required distances, calculate the quantity of propellant on the basis of the total contents of all such storage containers." Quantity distance requirements for the proposed propellants were calculated based on this statement. The values obtained were based on the data currently available, and are subject to change and revision as new data is obtained.

Quantity Distance Requirements For RP-1

| Quantity(Each tank) | Total(3 tanks) | Density (lbs/gal) | Total (lbs) |
|---|---|---|---|
| RP-1 = 85,000 gal x 3 = | 255,000 gal x | 6.8 = | 1,734,000 |

RP-1 Quantity Distance
Classification: Hazard Group I
Compatibility Group - Liquid C
Quantity: 1,734,000lbs (255,000 gal)

For this quantity of RP-1, storage must be 235 feet from inhabited buildings, public traffic routes,

| ITEM | POUNDS PER GALLON | AT TEMP DEGREE F |
|---|---|---|
| ANHYDROUS AMMONIA | .5.1 | 68 |
| ANILINE | 8.5 | 68 |
| BROMINE PENTAFLUORIDE | 20.7 | 68 |
| CHLORINE TRIFLUORIDE | 15.3 | 68 |
| ETHYL ALCOHOL | 6.6 | 68 |
| ETHYLENE OXIDE | 7.3 | 68 |
| FLUORINE | 12.6 | -306 |
| FURFURYL ALCOHOL | 9.4 | 68 |
| HYDROGEN PEROXIDE (90 PERCENT) | 11.6 | 68 |
| HYDRAZINE | 8.4 | 68 |
| ISOPROPYL ALCOHOL | 6.6 | 68 |
| LIQUID HYDROGEN | 0.59 | -423 |
| LIQUID OXYGEN | 9.5 | -297 |
| METHYL ALCOHOL | 6.6 | 68 |
| MONOMETHYLHYDRAZINE | 7.3 | 68 |
| NITROMETHANE | 9.5 | 68 |
| NITROGEN TETROXIDE | 12.1 | 68 |
| OTTO FUEL | 10.3 | 77 |
| OXYGEN DIFLUORIDE | 12.7 | -229 |
| OZONE DIFLUORIDE | 14.6 | -227 |
| PENTABORANE | 5.2 | 68 |
| PERCHLORYL FLUORIDE | 12.0 | 68 |
| RED FUMING NITRIC ACID (III A) | 12.5 | 68 |
| FP-1 | 6.8 | 68 |
| TETRANITROMETHANE | 13.6 | 78 |
| UDFH | 6.6 | 68 |
| UDMN/HYDRAZINE | 7.5 | 68 |

Figure 10.2.5-1. Factors for Converting Gallons of Propellant Into Pounds.

| PROPELLANT | LIQUID PROPELLANT HAZARD GROUP (NOTE 1) | LIQUID PROPELLANT COMPATIBILITY STORAGE GROUP (NOTE 2) |
|---|---|---|
| THE ALCOLHOLS: CH2 OH, C2H3OH, (CH3)2CHOH | I | LIQ-C |
| ANHYDROUS AMMONIA, NH3 | I | LIQ-C |
| ANILINE, C6H5NH2 | I | LIQ-C |
| HYDROCARBON FUELS, JP-4, JP-5, RP-1 | I | LIQ-C |
| NITOGEN TETROXIDE, N2O4 | I | LIQ-A |
| OTTO FUEL II | I | LIQ-G |
| RED FUMING NITRIC ACID, HNO3 | I | LIQ-A |
| NOS-58-6 MONOPROPELLANT | I | LIQ-G |
| BOMINE PENTAFLUORIDE, BrF5 | II | LIQ-A |
| CHLORINE TRIFLUORIDE, C1F3 | II | LIQ-A |
| HYROGEN PEROXIDE GREATER THAN 52% H202 | II (NOTE 3) | LIQ-A |
| LIQUID FLUORINE, LF2 | II | LIQ-A |
| LIQUID OXYGEN, LO2 (NOTE 5) | II | LIQ-A |
| PERCHLORYL FLUORIDE, C103F | II | LIQ-A |
| OXYGEN DIFLUORIDE, O3F2 | II | LIQ-A |
| OZONE DIFLUORIDE, O3F2 | II | LIQ-A |
| ETHYLEZE OXIDE, C2H4O | III | LIQ-D |
| HYDRAZINE, N2H4 | III | LIQ-C |
| HYDRAZINE-UDMH MIXTURES | III | LIQ-C |
| LIQUID HYDROGEN, LH2 | III | LIQ-C |
| MIXED AMINE FUELS | III | LIQ-C |
| MONOMETHYLHYDRAZINE, CH3NHNH2 | III | LIQ-C |
| PENTABORANE, B5H9 | III | LIQ-D |
| UDMH, (CH3)2NNH2 | III | LIQ-C |
| FIRE SYMBOL 1<br>(REF) 3-13a pg. 18 | | |

Figure 10.2.5-2. Propellant Hazards And Compatibility Groups.

and incompatible storage groups (i.e. LOX) unless the LOX or LH2 quantity dictates a greater distance (which they do). The Intragroup/Intraline distance for compatible storage groups (Hazard Group I, Liquid C commodities as listed in Figure 10.2.5-3) is 175 feet.

Quantity Distance Requirements for LOX

| Quantity (Each tank) | | Total (2 tanks) | | Density (lbs/gal) | | Total (lbs) |
|---|---|---|---|---|---|---|
| LOX = 900,000 gal | x 2 = | 1,800,000 gal | x | 9.53 | = | 17,154,000 |

LOX Quantity Distance (from AFR 127-100)
Classification: Hazard Group II
Compatibility Group - Liquid A
Quantity: 17,154,000 lbs (1,800,00 gal)

It should be noted that Figure 10.2.5-4 only provides the quantity distance data up to 10,000,000 pounds of propellant. The values shown below are based on extrapolation of this figure and may not be exact.

From the extrapolation of the data provided, for this quantity of LOX, storage must be 700 feet from inhabited buildings (structures or other places not directly related to explosive operations where people work), public traffic routes, and incompatible storage groups.

The Intragroup/Intraline distance for compatible storage groups (Hazard Group II Liquid A commodities as listed Figure 10.2.5-4) is 350 feet.

Quantity Distance Requirements for LH2

| Quantity (each tank) | | Total (2 tanks) | | Density (lbs/gal) | | Total (lbs) |
|---|---|---|---|---|---|---|
| LH2 = 900,000 gal | x 2 = | 1,800,000 gal | x | 0.59 | = | 1,062,000 |

LH2 Quantity Distance
Classification: Hazard Group III
Compatibility Group - Liquid C
Quantity: 1,062,000 lbs (1,800,000 gal)

| POUNDS OF PROPELLANT | | INHABITED BUILDINGS, PUBLIC TRAFFIC ROUTE, AND INCOMPATIBLE STORAGE GROUPS.[2] | INTRAGROUP/ INTRALINE FOR COMPATIBLE STORAGE GROUPS.[3] |
|---|---|---|---|
| OVER | NOT OVER | DISTANCE IN FEET | DISTANCE IN FEET |
| Col 1 | Col 2 | Col 3 | Col 4 |
| | 100[1] | 30 | 25 |
| 100 | 200[1] | 35 | 30 |
| 200 | 300[1] | 40 | 35 |
| 300 | 400[1] | 45 | 35 |
| 400 | 500[1] | 50 | 40 |
| 500 | 600 | 50 | 40 |
| 600 | 700 | 55 | 40 |
| 700 | 800 | 55 | 45 |
| 800 | 900 | 60 | 45 |
| 900 | 1,000 | 60 | 45 |
| 1,000 | 2,000 | 65 | 50 |
| 2,000 | 3,000 | 70 | 55 |
| 3,000 | 4,000 | 75 | 55 |
| 4,000 | 5,000 | 80 | 60 |
| 5,000 | 6,000 | 80 | 60 |
| 6,000 | 7,000 | 85 | 65 |
| 7,000 | 8,000 | 85 | 65 |
| 8,000 | 9,000 | 90 | 70 |
| 9,000 | 10,000 | 90 | 70 |
| 10,000 | 15,000 | 95 | 75 |
| 15,000 | 20,000 | 100 | 80 |
| 20,000 | 25,000 | 105 | 80 |
| 25,000 | 30,000 | 110 | 85 |
| 30,000 | 35,000 | 110 | 85 |
| 35,000 | 40,000 | 115 | 85 |
| 40,000 | 45,000 | 120 | 90 |
| 45,000 | 50,000 | 120 | 90 |
| 50,000 | 60,000 | 125 | 95 |
| 60,000 | 70,000 | 130 | 95 |
| 70,000 | 80,000 | 130 | 100 |
| 80,000 | 90,000 | 135 | 100 |
| 90,000 | 100,000 | 135 | 105 |
| 100,000 | 125,000 | 140 | 110 |
| 125,000 | 150,000 | 145 | 110 |
| 150,000 | 175,000 | 150 | 115 |
| 175,000 | 200,000 | 155 | 115 |
| 200,000 | 250,000 | 160 | 120 |
| 250,000 | 300,000 | 165 | 125 |
| 300,000 | 350,000 | 170 | 130 |
| 350,000 | 400,000 | 175 | 130 |
| 400,000 | 450,000 | 180 | 135 |
| 450,000 | 500,000 | 180 | 135 |
| 500,000 | 600,000 | 185 | 140 |
| 600,000 | 700,000 | 190 | 145 |
| 700,000 | 800,000 | 195 | 150 |
| 800,000 | 900,000 | 200 | 150 |
| 900,000 | 1,000,000 | 205 | 155 |
| 1,000,000 | 2,000,000[4] | 235 | 175 |
| 2,000,000 | 3,000,000[4] | 255 | 190 |
| 3,000,000 | 4,000,000[4] | 265 | 200 |
| 4,000,000 | 5,000,000[4] | 275 | 210 |
| 5,000,000 | 6,000,000[4] | 285 | 215 |
| 6,000,000 | 7,000,000[4] | 295 | 220 |
| 7,000,000 | 8,000,000[4] | 300 | 225 |
| 8,000,000 | 9,000,000[4] | 305 | 230 |
| 9,000,000 | 10,000,000[4] | 310 | 235 |

Figure 10.2.5-3 Hazard Group I Separation Distances.

| POUNDS OF PROPELLANT<br>OVER | NOT OVER | INHABITED BUILDINGS, PUBLIC TRAFFIC ROUTE, AND INCOMPATIBLE STORAGE GROUPS.[2] DISTANCE IN FEET | INTRAGROUP/ INTRALINE FOR COMPATIBLE STORAGE GROUPS.[3] DISTANCE IN FEET | POUNDS OF PROPELLANT<br>OVER | NOT OVER | INHABITED BUILDINGS, PUBLIC TRAFFIC ROUTE, AND INCOMPATIBLE STORAGE GROUPS.[2] DISTANCE IN FEET | INTRAGROUP/ INTRALINE FOR COMPATIBLE STORAGE GROUPS.[3] DISTANCE IN FEET |
|---|---|---|---|---|---|---|---|
| Col 1 | Col 2 | Col 3 | Col 4 | Col 1 | Col 2 | Col 3 | Col 4 |
|  | 100[1] | 60 | 30 | 60,000 | 70,000 | 255 | 130 |
| 100 | 200[1] | 75 | 35 | 70,000 | 80,000 | 260 | 130 |
| 200 | 300[1] | 85 | 40 | 80,000 | 90,000 | 265 | 135 |
| 300 | 400[1] | 90 | 45 | 90,000 | 100,000 | 270 | 135 |
| 400 | 500[1] | 100 | 50 | 100,000 | 125,000 | 285 | 140 |
| 500 | 600 | 100 | 50 | 125,000 | 150,000 | 295 | 145 |
| 600 | 700 | 105 | 55 | 150,000 | 175,000 | 305 | 150 |
| 700 | 800 | 110 | 55 | 175,000 | 200,000 | 310 | 155 |
| 800 | 900 | 115 | 60 | 200,000 | 250,000 | 320 | 160 |
| 900 | 1,000 | 120 | 60 | 250,000 | 300,000 | 330 | 165 |
| 1,000 | 2,000 | 130 | 65 | 300,000 | 350,000 | 340 | 170 |
| 2,000 | 3,000 | 145 | 70 | 350,000 | 400,000 | 350 | 175 |
| 3,000 | 4,000 | 150 | 75 | 400,000 | 450,000 | 355 | 180 |
| 4,000 | 5,000 | 160 | 80 | 450,000 | 500,000 | 360 | 180 |
| 5,000 | 6,000 | 165 | 80 | 500,000 | 600,000 | 375 | 185 |
| 6,000 | 7,000 | 170 | 85 | 600,000 | 700,000 | 385 | 190 |
| 7,000 | 8,000 | 175 | 85 | 700,000 | 800,000 | 395 | 195 |
| 8,000 | 9,000 | 175 | 90 | 800,000 | 900,000 | 405 | 200 |
| 9,000 | 10,000 | 180 | 90 | 900,000 | 1,000,000 | 410 | 205 |
| 10,000 | 15,000 | 195 | 95 | 1,000,000 | 2,000,000[4] | 470 | 235 |
| 15,000 | 20,000 | 205 | 100 | 2,000,000 | 3,000,000[4] | 505 | 255 |
| 20,000 | 25,000 | 215 | 105 | 3,000,000 | 4,000,000[4] | 535 | 265 |
| 25,000 | 30,000 | 220 | 110 | 4,000,000 | 5,000,000[4] | 555 | 275 |
| 30,000 | 35,000 | 225 | 110 | 5,000,000 | 6,000,000[4] | 570 | 285 |
| 35,000 | 40,000 | 230 | 115 | 6,000,000 | 7,000,000[4] | 585 | 295 |
| 40,000 | 45,000 | 235 | 120 | 7,000,000 | 8,000,000[4] | 600 | 300 |
| 45,000 | 50,000 | 240 | 120 | 8,000,000 | 9,000,000[4] | 610 | 305 |
| 50,000 | 60,000 | 250 | 125 | 9,000,000 | 10,000,000[4] | 620 | 310 |

NOTES:

1. See paragraph 5-26a(2)(c) and (d).
2. See paragraph 5-26e(7).
3. See paragraph 5-26e(6).
4. CAUTION: Extrapolations above 1,000,000 pounds extend well outside data included in the BuMines report forming the original basic criteria. However, they are supported by independent calculations and knowledge of like phenomena.

Figure 10.2.5-4 Hazard Group II Separation Distances.

For this quantity of LH2 (Figure 10.2.5-5) gives two distances from inhabited buildings, public traffic routes, and incompatible storage groups; unprotected and protected. The unprotected distance relates to areas that may be damaged by fragments from an explosion if the storage vessel is left unprotected. The unprotected distance is 1,800 feet and the protected distance is 630 feet.

The Intraline/Intragroup distance for compatible storage groups (Hazard Group III Liquid C commodities as listed in Figure 10.2.5-5) is 235 feet.

### Conclusions for Quantity Distance Requirements

From the data provided and the quantity distance values determined from AFR 127-100, it is concluded that storage of the propellants within the Pad perimeter is acceptable, as shown in Figure 10.2.5-6. The RP-1 and LH2 can be stored in proximity to each other because they are both from the same compatibility group (Liquid C). However, since they are different hazard groups, the greatest intragroup/intraline distance will prevail (in this case the LH2 dictates the quantity distance which is 235 feet). If it is more economical and/or feasible to have a centralized storage facility for RP-1 between Pads A and B then this would also meet the quantity distance requirements. The major concern with this location is the storage and transfer lines on and over protected wetlands. This matter would need to be researched more to determine the actual environmental impacts as more data is made available and a decision is made on the RP-1 use and storage.

The quantity of LOX required (17,154,000 lbs), although extremely large, can also be stored within the Pad perimeter. This is based on the extrapolation of the quantity distance values in Figure 10.2.5.1-4. A more detailed look at the accuracy of the extrapolated values is required.

### Propellant Storage Containers and Appurtenances

Containers and appurtenances used to store flammable or combustible liquids must be in compliance with NFPA 30, Flammable and Combustible Liquids Code, Chapters 2, 3 and 5. The existing RP-1 storage containers and appurtenances, which were used during the Apollo Program, may not meet current requirements. Extensive modifications may be required to bring the facility into compliance. In order to determine the physical condition and usability of the existing storage facility it is recommended that a non-destructive evaluation be performed.

### Clear Areas and Control Zones

According to GP-1098, there are 65 control areas (Figure 10.2.5-7) established for current hazardous operations at the LC39 Launch Pad areas (these include operations such as cryogenic and

| POUNDS OF PROPELLANT | | INHABITED BUILDINGS, PUBLIC TRAFFIC ROUTE, AND INCOMPATIBLE STORAGE GROUPS[3]<br>DISTANCE IN FEET | | INTRAGROUP/INTRALINE FOR COMPATIBLE STORAGE GROUPS (COMMODITIES OF THE SAME COMPATIBILITY GROUP FALLING WITHIN HAZARD GROUP III)[4] |
|---|---|---|---|---|
| OVER COL. 1 | NOT OVER COL. 2 | UNPROTECTED COL. 3 | PROTECTED[5] COL. 4 | DISTANCE IN FEET COL.5 |
| | 100[2] | 600 | 80 | 30 |
| 100 | 200[2] | 600 | 100 | 35 |
| 200 | 300[2] | 600 | 110 | 40 |
| 300 | 400[2] | 600 | 120 | 45 |
| 400 | 500[2] | 600 | 130 | 50 |
| 500 | 600 | 600 | 135 | 50 |
| 600 | 700 | 600 | 140 | 55 |
| 700 | 800 | 600 | 145 | 55 |
| 800 | 900 | 600 | 150 | 60 |
| 900 | 1,000 | 600 | 150 | 60 |
| 1,000 | 2,000 | 600 | 175 | 65 |
| 2,000 | 3,000 | 600 | 190 | 70 |
| 3,000 | 4,000 | 600 | 200 | 75 |
| 4,000 | 5,000 | 600 | 210 | 80 |
| 5,000 | 6,000 | 600 | 220 | 80 |
| 6,000 | 7,000 | 600 | 225 | 85 |
| 7,000 | 8,000 | 600 | 230 | 85 |
| 8,000 | 9,000 | 600 | 235 | 90 |
| 9,000 | 10,000 | 600 | 240 | 90 |
| 10,000 | 15,000 | 1,200 | 260 | 95 |
| 15,000 | 20,000 | 1,200 | 275 | 100 |
| 20,000 | 25,000 | 1,200 | 285 | 105 |
| 25,000 | 30,000 | 1,200 | 295 | 110 |
| 30,000 | 35,000 | 1,200 | 300 | 110 |
| 35,000 | 40,000 | 1,200 | 310 | 115 |
| 40,000 | 45,000 | 1,200 | 315 | 120 |
| 45,000 | 50,000 | 1,200 | 320 | 120 |
| 50,000 | 60,000 | 1,200 | 330 | 125 |
| 60,000 | 70,000 | 1,200 | 340 | 130 |
| 70,000 | 80,000 | 1,200 | 350 | 130 |
| 80,000 | 90,000 | 1,200 | 360 | 135 |
| 90,000 | 100,000 | 1,200 | 365 | 135 |
| 100,000 | 125,000 | 1,800 | 380 | 140 |
| 125,000 | 150,000 | 1,800 | 395 | 145 |
| 150,000 | 175,000 | 1,800 | 405 | 150 |
| 175,000 | 200,000 | 1,800 | 415 | 155 |
| 200,000 | 250,000 | 1,800 | 425 | 160 |
| 250,000 | 300,000 | 1,800 | 440 | 165 |
| 300,000 | 350,000 | 1,800 | 455 | 170 |
| 350,000 | 400,000 | 1,800 | 465 | 175 |
| 400,000 | 450,000 | 1,800 | 475 | 180 |
| 450,000 | 500,000 | 1,800 | 485 | 180 |
| 500,000 | 600,000 | 1,800 | 500 | 185 |
| 600,000 | 700,000 | 1,800 | 515 | 190 |
| 700,000 | 800,000 | 1,800 | 530 | 195 |
| 800,000 | 900,000 | 1,800 | 540 | 200 |
| 900,000 | 1,000,000 | 1,800 | 550 | 205 |
| 1,000,000 | 2,000,000 | 1,800 | 630[6] | 235 |
| 2,000,000 | 3,000,000 | 1,800 | 675[6] | 255 |
| 3,000,000 | 4,000,000 | 1,800 | 710[6] | 265 |
| 4,000,000 | 5,000,000 | 1,800 | 740[6] | 275 |
| 5,000,000 | 6,000,000 | 1,800 | 760[6] | 285 |
| 6,000,000 | 7,000,000 | 1,800 | 780[6] | 295 |
| 7,000,000 | 8,000,000 | 1,800 | 800[6] | 300 |
| 8,000,000 | 9,000,000 | 1,800 | 815[6] | 305 |
| 9,000,000 | 10,000,000 | 1,800 | 830[6] | 310 |

Figure 10.2.5-5 Hazards Group III Separation Distances.

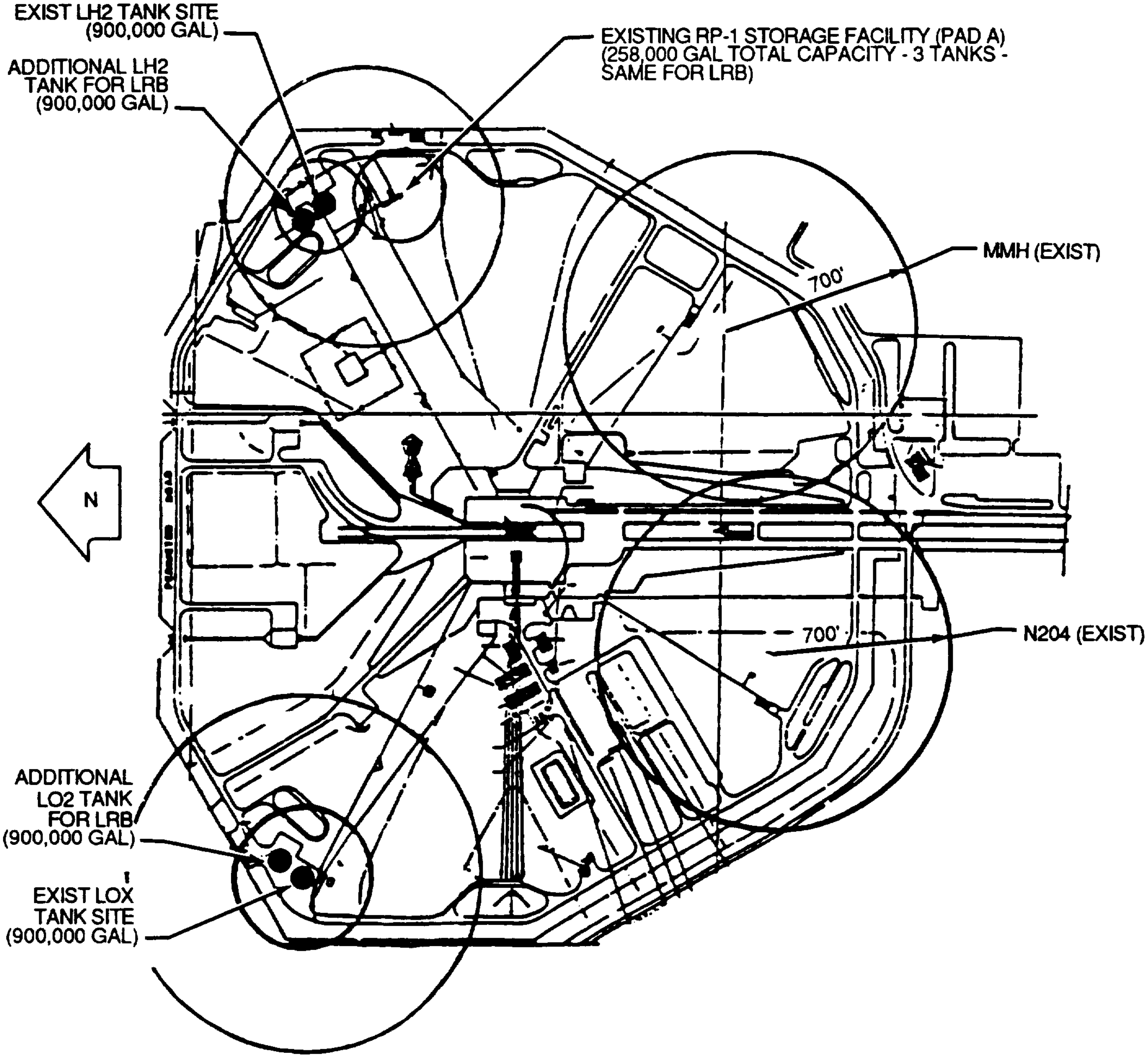

Figure 10.2.5-6 Propellant Storage Quantity Distance Requirements at the Launch Pads.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 1. SHUTTLE TRANSFER FROM VAB TO PAD OR RETURN TO VAB. | a. CONTROL A 650 FT. RADIUS CENTERED AROUND CRAWLER, WHILE ENROUTE TO/FROM PAD. | EMPLOYEE AND GOVERNMENT VEHICLES WILL NOT STOP OR PARK IN CONTROLLED AREA. TOUR BUSES WILL NOT BE PERMITTED TO PASS THROUGH CONTROLLED AREA. EMPLOYEES IN SUPPORT BUILDINGS ALONG CRAWLERWAY MAY REMAIN AT THEIR WORK STATIONS INSIDE FACILITIES. |
|  | b. CONTROL PAD SLOPE AND ABOVE UPON PAD GATE ENTRY TO STS VEHICLE. | SMOKING AT PAD GATE AREA PROHIBITED DURING STS MOVEMENT THROUGH THAT AREA. |
| 2. APU SERVICE CARTS LOADING:<br>a. RSS (HYDRAZINE). | a. CONTROL AREA INSIDE COMPLEX FENCE. | SCAPE OPERATION. SCAPE PERSONNEL ESSENTIAL TO THE OPERATIONS WILL BE PERMITTED ACCESS TO THE SCAPE TRAILER AREA AFTER MANNED ROAD BLOCKS ARE ESTABLISHED AT THE ENTRANCE TO PERIMETER RD. EAST, PERIMETER RD. WEST, AND B ROAD. |
| b. MMH STORAGE FACILITY. | b. CONTROL 200 FT. RADIUS OF MMH FACILITY AND 700 FT. DOWNWIND. | SCAPE OPERATION. |

NOTES:

1. THE MLP IS HARD DOWN WHEN THE WEIGHT OF THE MLP HAS BEEN TRANSFERRED FROM THE TRANSPORTER TO THE PEDESTALS.
2. NORMAL WORK MEANS OPEN FOR SCHEDULED OPERATIONS.
3. CONTROLLED AREA IS THAT AREA WHERE A HAZARDOUS CONDITION EXISTS OR A HAZARDOUS OPERATION IS IN PROGRESS; NONESSENTIAL PERSONNEL ARE PROHIBITED FROM ENTERING.
4. CLEARED AREA IS AN AREA WHERE A HAZARDOUS CONDITION EXISTS OR A HAZARDOUS OPERATION IS IN PROGRESS; PERSONNEL ARE PROHIBITED FROM ENTERING.
5. HAZARDS AND CLEARED/CONTROLLED AREAS FOR SOME OPERATIONS MAY BE REVISED TO COVER SITUATIONS CAUSED BY TBD PAY LOADS.
6. REFERENCED LEVELS WILL VARY FROM PAD A TO PAD B. (PAD B IS 5 FT. HIGHER).

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 3. APU/HPU SERVICE CART HOISTING TO RSS/MLP. | CONTROL A 200 FT. RADIUS AND 700 FT. DOWNWIND OF FSS FOR APU. CONTROL 25 FT. RADIUS FOR HPU HIOSTING AND POSITIONING. | |
| 4. APU/HPU HYDRAZINE SERVICING | CONTROL AREA INSIDE COMPLEX FENCE. | SCAPE OPERATION. SCAPE PERSONNEL ESSENTIAL TO THE OPERATION WILL BE PERMITTED ACCESS TO THE SCAPE TRAILER AREA AFTER MANNED ROADBLOCKS ARE ESTABLISHED AT THE ENTRANCE TO PERIMETER RD. EAST, PERIMETER RD. WEST, AND B ROAD. |
| 5. ORBITER CATCH BOTTLE DRAIN | CONTROL RSS 130, 120, 107, FT. LEVEL, PCR, TSM's MLP ZERO LEVEL SOUTH OF TSM's HANDRAIL (SIDE 2) TO HAND RAIL (SIDE 4), AND MLP (SIDE 1). | |
| 6. HYPERGOLIC PROPELLANT SYSTEM (EM CHECKS) TEST: | | |
| a. MMH/N2 O4 FDS AUTO EM CHECKS (MINOR VENTING ONLY) | a. MMH/N2O4 STORAGE FAC: CLEAR 50 FT. RADIUS AND 100 FT. DOWNWIND. | ESSENTIAL PERSONNEL MAY ENTER STORAGE FACILITY UPON COMPLETION OF AUTO EM CHECKS FOR MANUAL VALVE OPERATIONS, FOLLOWING ACCEPTABLE TOXIC VAPOR CHECKS. |
| | b. RSS FDS SKIDS: CLEAR FSS 275 FT. LEVEL AND ABOVE. | TOXIC VAPOR CHECKS OF FSS 275 AND 295 FT. LEVELS REQUIRED PRIOR TO OPENING CONTROL AREA.. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| b. MMH/N204 STORAGE FACILITY LEAK CHECKS (SYSTEM PRESSURIZATION). | CLEAR 200 FT. RADIUS AND 700 FT. DOWNWIND. | SAFETY MONITOR PEL DOWNWIND OUTSIDE 700 FT. CONTROL AREA DURING VENTING. |
| c. FDS PRESSURE DECAY LEAK CHECK (ENTIRE FDS PRESSURIZATION AND VENTING, IE., STG. FAC., CROSS-COUNTRY LINES AND RSS). | CLEAR 200 FT. RADIUS AND 700 FT. DOWNWIND OF MMH/N2O4 STORAGE FACILITY, PAD SURFACE AND ABOVE, PAD TUNNEL (N2O4 ONLY), 25 FT. OF MMH/N2O4 CROSS-COUNTRY LINES. | CROSS-COUNTRY LINES CONTROL AREA MAINTAINED BY VISUAL MONITORING. TOXIC VAPOR CHECKS REQUIRED PRIOR TO OPENING CONTROL AREAS |
| 7. RSS RETRACT/EXTEND. | CLEAR AREA UNDER AND AROUND MOVABLE STRUCTURE. | MAKE PA ANNOUNCEMENT PRIOR TO MOVEMENT; CLEAR RSS FLOATS, LADDERS AND SCAFFOLDS. |
| 8. MPS LO2 AUTO LOAD/DETANK TEST. | CLEAR AREA INSIDE COMPLEX FENCE. | |
| 9. MPS LH2 AUTO LOAD/DETANK TEST. | | |
| 10. PRSD (FUEL CELLS) DEWAR LOAD (LH2/LO2). | CONTROL PAD APRON AND STRUCTURE, CLEAR LO2 DUMP BASIN, LH2 BURN POND, AND 50 FT. OF LO2/LH2 CROSS-COUNTRY DUMP LINES. CLOSE PAD E ROAD IF GOX PRESENT IN DUMP BASIN. | LO2/LH2 FLOW WILL BE IN SERIES. IF H2 CONCENTRATIONS EXCEED 1% OF HAZARDOUS GAS DETECTION SYSTEM, OPERATIONS WILL BE EVALUATED TO DETERMINE APPROPRIATE ACTION. |
| 11. PRSD (FUEL CELL) COLD FLOW LH2/LO2 (CLOSED LOOP FSS TO RSS). | CONTROL PAD APRON AND STRUCTURES, GH2/GO2 STORAGE FACILITIES, CLEAR 50 FT. OF LO2/LH2 CROSS-COUNTRY DUMP LINES, LO2 DUMP BASIN, BURN POND, 50 FT. OF GH2 CROSS-COUNTRY LINES. CLOSE E ROAD IF GOX PRESENT IN DUMP BASIN. | LO2/LH2 FLOW WILL BE IN SERIES. IF H2 CONCENTRATION EXCEED 1% ON HAZARDOUS GAS DETECTION SYSTEM, OPERATIONS WILL BE EVALUATED TO DETERMINE APPROPRIATE ACTION. |
| 12. PRSD (FUEL CELLS) DEWAR DUMP (LO2 & LH2). | CONTROL FSS, PAD APRON UNDERNEARTH AND NORTH OF FSS. CLEAR 50 FT. OF LO2/LH2 CROSS-COUNTRY DUMP LINE, AND LO2 DUMP BASIN AND BURN POND AREA. CLOSE E ROAD PRIOR TO DUMP. | |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 13. PRSD (FUEL CELLS) CRYO LOAD | CONTROL AREA INSIDE COMPLEX FENCE. CLOSE PAD E ROAD PRIOR TO OPENING COMPLEX IF GOX PRESENT AT DUMP BASIN. | LO2,LH2 FLOW WILL BE IN SERIES. IF H2 CONCENTRATIONS EXCEED 1% OF HAZARDOUS GAS DETECTION SYSTEM, OPERATIONS WILL BE EVALUATED TO DETERMINE APPROPRIATE ACTION. |
| 14. PRSD (FUEL CELLS) CRYO DETANK. | CONTROL FSS, RSS 130 FT. LEVEL AND ABOVE, AND ORBITER CABIN. CLEAR 50 FT. OF CROSS-COUNTRY DUMP LINES, LH2/LO2 DISCONNECT TOWERS, N. BRIDGE, LO2 DUMP BASIN AND BURN POND. CLOSE E ROAD. | |
| 15. PRSD (FUEL CELL LOAD SHARING). GO2 FLOW. | CONTROL 25 FT. RADIUS OF GO2 STORAGE BOTTLES. CLEAR ORBITER MIDBODY, AFT FUSELAGE, LO2 TSM. | |
| 16. PRSD (FUEL CELL LOAD SHARING) GH2 FLOW. | CONTROL GH2 STORAGE FACILITY. CLEAR MIDBODY AND AFT FUSELAGE, LH2 TSM, FRCS ROOM AND 50 FT. OF GH2 CROSS-COUNTRY LINE. | FRCS ROOM MUST BE CLEARED IF RSS IS IN MATE POSITION (VENTING). |
| 17. PRSD (FUEL CELL) REACTANT PURGE (GO2/GH2) | CONTROL GH2 STORAGE FACILITY, AND 25 FT. RADIUS OF GO2 STORAGE BOTTLES. CLEAR 50 FT. OF GH2 CROSS-COUNTRY LINES, DUMP BASIN, BURN POND, TSM's AND ORBITER MIDBODY AND AFT FUSELAGE. | IN ADDITION CONTROL THE FSS, RSS 130 FT. LEVEL AND ABOVE DURING REACTANT PURGING OF OMBUU GSE VIA FSS 155 FT. LEVEL.<br>WHEN NOT FLOWING THE CROSS-COUNTRY LINES, PRESSURE SHALL NOT EXCEED 50 PSI (STANDBY MODE). |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| | | PAD PERIMETER ROAD AT THE GH2 FACILITY SHALL BE CLOSED UNTIL CROSS-COUNTRY LINES ARE PRESSURIZED AND STABLE, THEN PAD PERIMETER ROAD SHALL BE OPEN.<br>SCO's MAY BE MANLOADED IN CREW CABIN DURING PURGING OF THE OMBUU. |
| 18. ECLSS O2 SERVICING | CLEAR THE ORBITER MIDBODY/AFT FUSELAGE AND LO2 TSM. CONTROL 25 FT. RADIUS OF GO2 STORAGE BOTTLES. | CONTROL N2 SERVICING IF IN CLOSED AREA. |
| 19. OMS/RCS HELIUM PRESSURIZATION | a. PRESSURIZATION OF HELIUM BOTTLES TO 50% DOES NO REQUIRE CLEARING OF ORBITER.<br>b. PRESSURIZATION OF He TANKS TO REGULATOR LOCKUP-CONTROL RSS 107 FT. AND 207 FT. LEVELS AND CLEAR ORBITER MIDBODY AFT FUSELAGE.<br>c. OMS/RCS PROPELLANT TANKS TO REGULATOR LOCKUP THROUGH HELIUM TANKS REQUIIRES PAD SLOPE AND ABOVE CLEARED. | |
| 20. FUEL SYSTEMS ALCOHOL FLOW (UP TO SKIDS ON RSS AND BACK) | CONTROL RSS, 50 FT. OF CALIBRATION/STORAGE TANKS, AND 10 FT. OF PANELS AND LINES. | |
| 21. HYPERGOL FUEL THEN OXIDIZER FLOW (UP TO SKIDS/TANKS ON RSS AND BACK) | CONTROL AREA INSIDE OF THE COMPLEX FENCE. | SCAPE OPERATION. SCAPE PERSONNEL ESSENTIAL TO THE OPERATON WILL BE PERMITTED ACCESS TO THE SCAPE TRAILER AREA AFTER MANNED ROADBLOCKS ARE ESTABLISHED AT THE ENTRANCE TO PERIMETER RD. EAST, PERIMETER RD. WEST, AND B ROAD. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 22. OMS/RCS FUEL AND OXIDIZER TANK AND DETANK TEST | CONTROL AREA INSIDE THE COMPLEX FENCE. | SCAPE OPERATION. SCAPE PERSONNEL ESSENTIAL TO THE OPERATON WILL BE PERMITTED ACCESS TO THE SCAPE TRAILER AREA AFTER MANNED ROADBLOCKS ARE ESTABLISHED AT THE ENTRANCE TO PERIMETER RD. EAST, PERIMETER RD. WEST, AND B ROAD. |
| 23. NH3 (AMMONIA SERVICING) | CONTROL RSS 207 FT. , 130 FT., 107 FT., AND O LEVEL OF THE MLP UNDER THE RSS INCLUDING THE TSM's, AND SOUTH OF TSM. CREW CABIN AND OMBUU WILL REMAIN OPEN FOR WORK. | |
| 24. WET CDDT/FRF (FLIGHT READINESS FIRING) | CLEAR BLAST DANGER AREA (4485 FT. ) | |
| 25. SOUND SUPPRESSION TANK FILL | CLEAR FLAME TRENCH AND ENGINE SERVICE PLATFORM WHEN TANK VERTICAL LINE IS FILLED ABOVE 48 FT. LEVEL. CONTROL 100 FT. RADIUS OF SS TANK AND 100 FT. EACH SIDE OF TRANSFER LINES. | ANY ACCESS TO MLP ZERO LEVEL AFTER VERTICAL LINE FILL ABOVE THE 105 FT. LEVEL REQUIRES LOCKS INSTALLED ON 48-INCH VALVES, GN2 PRESSURE TO CLOSED POSITION, AND LOCKOUT CONTROL SIGNAL TO VALVES. |
| 26. SOUND SUPPRESSION WATER TEST | CLEAR FSS 95 FT. LEVEL AND BELOW, MLP (ZERO AND INTERIOR), PAD APRON 25 FT. OF MLP, FLAME TRENCH, CATACOMBS, 100 FT. RADIUS AROUND THE WATER TANK. AND 100 FT. ON EACH SIDE OF THE TRANSFER LINES. | MAKE PA ANNOUNCEMENT PRIOR TO WATER TEST. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 27. LH2 FLOW TO MLP SKID AND BACK TO BURN POND. | CONTROL 600 FT. CENTERED ON MLP, 600 FT. CENTERED ON LH2 STORAGE TANK, 300 FT. ON EACH SIDE OF CROSS-COUNTRY LINES AND BURN POND. | IF CONCENTRATIONS EXCEED 1% ON HAZARDOUS GAS DETECTION SYSTEM, OPERATIONS WILL BE EVALUATED TO DETERMINE APPROPRIATE ACTION. |
| 28. LO2 FLOW TO MLP SKID AND BACK TO DUMP POND. | CONTROL 600 FT. CENTERED ON MLP, 600 FT. CENTERED ON LO2 STORAGE TANK, 150 FT. EACH SIDE OF THE CROSS-COUNTRY LINES, AND THE LO2 DUMP BASIN. CLOSE E ROAD. | |
| 29. SRB/ET EXPLOSIVES INSTALLATION/ REMOVAL (DESTRUCT S & A DEVICES, NSI's). | CONTROL SRB FORWARD SKIRT, ET INTERTANK, AND ACCESS ARM; SRB PLATFORM. | ELECTRICAL CONNECTIONS ARE NOT PERMITTED. |
| 30. POWER OFF STRAY VOLTAGE TESTS; NSI ELECTRICAL CONNECTIONS (EXCEPT SRSS). | CONTROL INSIDE COMPLEX FENCE. | |
| 31. PAYLOAD POWER OFF STRAY VOLTAGE TEST; NSI ELECTRICAL CONNECTIONS/REMOVAL. | CONTROL INSIDE COMPLEX FENCE. | FOR CATEGORY B ORDNANCE REFERENCE VOLUME 1, SECTION II, PARAGRAPH 2.7. |
| 32. SRB HD POST/TSM ORDNANCE INSTALLATION ONLY.(CONTINGENCY). | a. CONTROL A 10 FT. RADIUS OF THE AFT SKIRT.<br>b. CONTROL OF INTERIOR OF TSM, A 10 FT. RADIUS OF THE TSM DOOR AND T-O UMBILICAL AREA. | THESE TASKS PERFORMED WITH LOCAL CONTROL AREA ONLY, OTHER ORDNANCE TASK OR ELECTRICAL CONNECTION IS NOT PERMITTED. |
| 33. SRB IGNITION S & A ROTATION (FIRING LINES DISCONNECTED). | CLEAR INSIDE COMPLEX FENCE. | S & A ROTATION DURING EXPLOSIVE BRIDGEWIRE (PIC RESISTANCE) TEST REQUIRE BDA CLEAR. |
| 34. SRB IGNITION S & A ROTATION (FIRING LINES CONNECTED). | CLEAR BLAST DANGER AREA (4485 FT.) | |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 35. EXPLOSIVES BRIDGEWIRE (PIC RESISTANCE) TEST (EXCEPT SRSS, SRB IGNITION). | CLEAR INSIDE COMPLEX FENCE. | |
| 36. SRB IGNITION/SRSS EXPLOSIVE BRIDGEWIRE (PIC RESISTANCE) TEST. | CLEAR BLAST DANGER AREA (4485 FT.) | ELECTRICAL FIRING/CDF LINES CONNECTED. |
| 37. SRSS (S & A POWER OFF STRAY VOLTAGE TEST AND NSI CONNECTIONS). | CONTROL INSIDE COMPLEX FENCE. | |
| 38. SRSS (RANGE SAFETY SYSTEM) S & A ROTATION. | | |
| a. CDF CONNECTED AND NSI's CONNECTED OR DISCONNECTED. | CLEAR BLAST DANGER AREA (4485 FT.) | |
| b. CDF DISCONNECTED AND NSI's CONNECTED. | CLEAR FORWARD SKIRTS (10 FT. RADIUS). | |
| 39. PAYLOAD/PAYLOAD BOOSTER S & A ROTATION. | | |
| a. CDF CONNECTED AND NSI's CONNECTED OR DISCONNECTED. | CLEAR BLAST DANGER AREA (4485 FT.) | |
| b. CDF DISCONNECTED AND NSI's CONNECTED. | CLEAR 10 FT. RADIUS MINIMUM. | |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 40. LH2 TANKING STORAGE. | CONTROL 200 FT. RADIUS CENTERED ON LH2 STORAGE TANK. | |
| 41. LO2 TANKING STORAGE. | CONTROL 150 FT. RADIUS CENTERED ON LO2 STORAGE TANK. | |
| 42. MMH TANKING STORAGE. | CONTROL 200 FT. RADIUS CENTERED ON THE MMH STORAGE TANK AND 700 FT. DOWNWIND. | SCAPE OPERATION. |
| 43. N2O4 TANKING STORAGE. | CONTROL 200 FT. RADIUS CENTERED ON THE N2O4 STORAGE TANK AND 700 DOWNWIND. | SCAPE OPERATION. |
| 44. LO2 RECHARGE (H.P. GAS FACILITY). | CONTROL 150 FT. RADIUS CENTERED ON RECHARGER. | FOR GO2 CROSS-COUNTRY LINE PRESSURIZATION, CONTROL 25 FT. OF BOTTLES/PANEL IN GO2 STORAGE FACILITY. |
| 45. LH2 RECHARGE (GH2 STORAGE FACILITY). | CONTROL 200 FT. RADIUS CENTERED ON THE GH2 BOTTLE/RECHARGER (INCLUDES PAD PERIMETER RD). | FOR CROSS-COUNTRY LINE PRESSURIZATION, CONTROL 200 FT. RADIUS. CONTROL AREA MAY BE REDUCED UPON COMPLETION OF CROSS-COUNTRY LINE PRESSURIZATION AND STABILIZATION. THE GH2 STORAGE FACILITY WILL REMAIN CLOSED. PERIMETER ROAD SHALL BE OPENED. |
| 46. BREAKING INTO MMH/N2O4 NON-PURGED SYSTEM. | CONTROL 200 FT. RADIUS CENTERED ON THE BREAK AND 700 FT. DOWNWIND. | SCAPE OPERATION. |
| 47. BREAKING INTO MMN/N2O4 PURGED SYSTEM. | CONTROL 200 FT. RADIUS AROUND THE BREAK. | SCAPE OPERATION. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 48. SERVICING HYPERGOLIC PAYLOAD (INCLUDING PRESSURIZATION, LINE DRAIN AND PURGE). | CONTROL AREA INSIDE COMPLEX FENCE. | SCAPE OPERATION. CONTROL AREA MAY VARY DEPENDING ON TYPE AND QUANTITIY OF PROPELLANT BEING SERVICED. THE GENERAL BASELINE FOR ALL HYPERGOLIC PROPELLANT FLOWS IS TO CLEAR INSIDE COMPLEX FENCE. SCAPE PERSONNEL ESSENTIAL TO THE OPERATION WILL BE PERMITTED<br>ACCESS TO THE SCAPE TRAILER AREA WHEN MANNED ROADBLOCKS ARE ESTABLISHED AT THE ENTRANCE TO PERIMETER RD. EAST, PERIMETER RD. WEST AND B ROAD. |
| 49. TRANSPORTER PAYLOAD WITH HAZARDOUS MATERIAL TO AND FROM PAD. | CONTROL 200 FT. RADIUS WHICH WILL TRAVEL WITH THE PAYLOAD. | SEE NOTE 5. |
| 50. ASSEMBLE/DISASSEMBLE OF PAYLOAD CANISTER LIFTING SLING. | CONTROL 100 FT. RADIUS OF THE SLING ON THE PAD SURFACE. | SEE NOTE 5. |
| 51. HOIST/LOWER OF PAYLOAD LIFTING SLING. | CONTROL 100 FT. RADIUS OF THE SLING ON THE PAD SURFACE. CLEAR UNERNEATH SLING. | |
| 52. PAYLOAD HOIST/LOWER WITH HAZARDOUS MATERIALS. | CONTROL AREA INSIDE COMPLEX FENCE. | THE CONTROL AREA MAY BE REDUCED TO A 200 FT. RADIUS OF THE PAYLOAD CANISTER UPON PIN INSTALLATION OF CANISTER TO THE TRANSPORTER. SEE NOTE 5. |
| 53. PAYLOAD HOIST/LOWER WITHOUT HAZARDOUS MATERIALS. | CONTROL RSS SIDE 1, FRCS ROOM AND SOUTHWEST QUADRANT OF PAD SURFACE BENEATH RSS. (100 FT. RADIUS OF PAYLOAD CANISTER). | |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 54. PAYLOAD HANDLING OPERATIONS (RSS). | | SEE NOTE 5. |
| a. ORBITER/CANISTER INSTALLATION/ REMOVAL OF PAYLOAD. | CONTROL RSS PCR. | |
| b. PAYLOAD RTG HOIST TO RSS. | CLEAR 50 FT. RADIUS OF RTG AT PAD SURFACE AND LIFT ZONE. | ENVIRONMENTAL HEALTH SHALL MONITOR RADIATION LEVELS; CONTROL AREA MAY BE EXTENDED BY SAFETY AS REQUIRED. |
| c. PAYLOAD INSTALLATION/ REMOVAL OF RTG. | CONTROL RSS PCR. | |
| 55. LO2 VEHICLE TANKING. | CONTROL AREA INSIDE COMPLEX FENCE. | |
| 56. LO2 AND LH2 VEHICLE TANKING. | CLEAR BLAST DANGER AREA (4485 FT.). | |
| 57. FREON 21 SERVICE (BREAKING INTO SYSTEM). | CONTROL 10 FT. RADIUS OF OPERATIONS IF NO RELEASE IS EXPECTED. (CONTROL 100 FT. RADIUS OF LINE BREAK IF 1 PINT OR MORE WILL BE RELEASED;30 FT. RADIUS IF LESS THAN 1 PINT). | |
| 58. HAMMERHEAD CRANE OPERATIONS. | CLEAR 25 FT. RADIUS FROM UNDER HOOK OF NONESSENTIAL PERSONNEL. | ACCESS TO FSS 295 FT. LEVEL RESTRICTED DURING WINDS 20 KNOTS AND UP. |
| 59. MERCURY HANDLING. | LOCAL CLEAR TBD BY CONDITIONS AND LOCATION. | SPLASH SUITS AND FACE SHIELDS REQUIRED FOR HANDLERS. ENVIRONMENTAL HEALTH/SAFETY WILL MONITOR. |
| 60. IGNITER INSTALLATION/REMOVAL SRB. | CONTROL AREA INSIDE COMPLEX FENCE.<br>CONTROL BLAST DANGER AREA (4885 FT.). | NO PROPELLANTS LOADED.<br>PROPELLANTS LOADED. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 61. REMOVING/REPLACING COMPONENTS IN SCAPE-107 FT. LEVEL. | CLEAR MLP 0 LEVEL UNDER RSS INCLUDING TSM's: CONTROL RSS 107 FT. LEVEL AND CLEAR 120 FT. LEVEL. | VERIFY SOUTHSIDE OF FLAME TRENCH CLEARED. SYSTEM SHALL BE PURGED AND VENTED THROUGH SCRUBBER AND ASPIRATOR STANDBY. |
| 62. REMOVING/REPLACING COMPONENTS IN SCAPE-207 FT. LEVEL. | CONTROL 207 FT. LEVEL AND CLEAR 193 FT. LEVEL. | OAA WILL NORMALLY NOT BE CLEARED, BUT ACCESS ACROSS THE ARM SHALL BE RESTRICTED WHEN DOWNWIND. SYSTEM SHALL BE PURGED AND VENTED THROUGH SCRUBBER AND ASPIRATOR STANDBY. |
| 63. SCRUBBER FLUID SAMPLING. | CONTROL 75 FT. LEVEL AND AREA BELOW INCLUDING PAD SURFACE.<br>STORAGE FACILITY CLEAR 25 FT. OF SCRUBBER. | |
| 64. SCRUBBER FLUID DRAIN AND FILL. | CONTROL 200 FT. RADIUS AND 700 FT. DOWNWIND. | SCAPE OPERATION. UPON COMPLETION OF DRAIN, FLUSH AND ACCEPTABLE PEL READING, THE CONTROL AREA MAY BE REDUCED TO FSS 75 FT. LEVEL AND BELOW (NO RESTRICTION TO ELEVATOR PASSING THROUGH AREA) ON THE FSS AND TO 25 FT. RADIUS OF SCRUBBERS IN STORAGE FACILITIES. SCAPE MAY BE DOWNGRADED TO FACE SHIELD, RUBBER APRON AND GAUNTLET GLOVES WITH SAFETY CONCURRENCE. |
| 65. ECS GN2 SWITCH OVER AND FLOW | | AS APPLICABLE THE FOLLOWING REMARKS APPLY TO ITEMS A,B, C, AND D. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

| OPERATION | CLEARED/CONTROLLED AREA | REMARKS |
|---|---|---|
| 65. a. MANUAL VALVES OPEN (REMOTE VALVE STANDBY). | CLEAR ORBITER MID AND AFT FUSELAGE, MLP INTERIOR, PTCR, AND TSM's.<br>CONTROL ECS ROOM (STANDBY BREATHING UNITS REQUIRED IN ECS ROOM), OAA WHITE ROOM AND CREW CABIN. | PTCR CLEAR NOT REQUIRED FOR SOME TEST FLOWS IF PTCR IS NOT PRESSURIZED. NASA/SPC SAFETY CONCURRENCE REQUIRED. |
| b. GN2 FLOW (LAUNCH). | CLEAR MLP, PTCR AND ECS ROOM (RSS MUST BE RETRACTED TO PREVENT ACCESS TO ORBITER).<br>CONTROL ORR WHITE ROOM AND CREW CABIN DURING FINAL LAUNCH PREPS. | SAFETY DANGER WARNING SIGNS MUST BE POSTED ACROSS ALL ENTRANCES TO MLP, PTCR, ECS ROOM, TSM's AND ORBITER (IF PRESENT OR NOT CLOSED FOR LAUNCH) PRIOR TO ONE VALVE (REMOTE) STANDBY OR GN2 FLOW. |
| c. GN2 FLOW (ORBITER TES). | CLEAR PTCR, ECS ROOM, MLP, RSS (IF IN MATED POSITION), OAA WHITE ROOM, AND CREW CABIN. | WARNING SIGNS SHALL BE REMOVED FROM MLP/ORBITER BY SAFETY UPON CLEARING THE PAD FOR LAUNCH. |
| d. GN2 TEST FLOW TO 9099 I/F TOWER. | CLEAR ECS BRIDGE, LOX DISCONNECT TOWER, LOW RISE ELEVATOR, 25 FT. RADIUS OF 9099 I/F TOWER, INCLUDING GROUND LEVEL. (CONTROL AREA MAY BE EXTENDED BY SAFETY TO MEET OSHA NOISE LEVEL REQUIREMENTS).<br>CONTROL ECS ROOM (STANDBY BREATHING AIR UNITS REQIRED). | POST-TEST O2 CHECK REQUIRED TO MLP INTERIOR, PTCR, ECS ROOM, TSM's , ORBITER CREW CABIN, WHITE ROOM, MID AND AFT FUSELAGE BY SAFETY PRIOR TO ENTRY BY OTHER PERSONNEL.<br>O2 MONITORS REQUIRED IN OAA WHITE ROOM AND CREW CABIN DURING ONE SWITCH MODE AND GN2 FLOW TO ORBITER.<br>FOR 9099 FLOW TEST SAFETY WARNING SIGNS SHALL BE POSTED AT ENTRANCE TO ECS BRIDGE, LOX DISCONNECT TOWER, LOW RISE ELEVATOR AND GROUND LEVEL AREA.<br>ACTIVATION OF ONE VALVE (REMOTE) STANDBY SHALL BE PERFORMED LATE AS POSSIBLE TO MEET TEST/LAUNCH SCHEDULE JUST PRIOR TO ESSENTIAL PERSONNEL CLEARING ECS ROOM. EXCEPT FOR LAUNCH COUNTDOWN GN2 FLOW WILL NOT BE INITIATED UNTIL AFTER PAD CLEAR. |

Figure 10.2.5-7. Launch Pad Control Areas For Hazardous Operations.

hypergolic loading, lifting operations, EED installations, etc.). Many of these control zones baselined under the current shuttle configuration would impact construction activities required to modify the Pads and surrounding Pad perimeter areas for LRB support. In addition, many of these control zones will impact LRB processing activities during program phase-in. However, these conflicts can be minimized by advanced planning and scheduling. After integration of the LRB baselined shuttle into the launch schedule, different control zones will be established and will have to be incorporated into the existing or new KSC Ground Safety Plan.

#### Fire Detection/Protection

Current Fire Detection/Protection system will need to be modified and increased to include requirements for RP-1 (or CH4) and additional quantities of LO2 (or LH2).

#### Vapor/O2 Detectors

Commodity storage areas, make/break fittings, and valves should be equipped with devices suitable for the detection of hazardous vapors and oxygen deficiencies.

#### Safety Equipment

The following safety equipment is required for the RP-1 storage area: Safety Showers, Fire Blankets, Eye Wash, Rescue Equipment and Storage Facility for personnel protective equipment.

### 10.2.6 LCC

#### Software Safety

To ensure Software Safety an analysis must be performed in accordance with NSTS 22254. This software will need integration with the overall ground software development activity.

#### Hardware Safety

LRB Safety critical measurements and functions must be integrated into CCMS/LPS in the LCC. Real-Time Safety critical operations require hardwire safing located in the LCC/CCC.

### 10.2.7 Launch Equipment Test Facility (LETF)

Safety impacts for the LETF will be comparable to those encountered at the MLP, LCC and Pad with respect to specific testing and operations. Detailed safety requirements will be established when the specific operations are determined for the LETF.

### 10.2.8 LRB Retrieval

Safety Impacts from LRB retrieval, for the most part, will be almost identical to those for the SRBs, with respect to lifting equipment and other GSE. If RP-1 is used as the primary fuel personnel protective equipment requirements will be less stringent because personnel will not be exposed to hazards like asbestos. If CH4 is the primary fuel personnel protective equipment will be more complicated and will require more precautions. If LH2 is the primary fuel more precautions will be required for detecting leaks due to the flammable/explosive nature of Hydrogen in a wide range of concentrations (4-75%). However, the extent of the Safety Hazards will be determined, in large part, by the amount of residual fuels left on the LRB after launch. A more detailed look at this operation will be conducted if it is determined that the LRBs will be retrieved rather than expendable as is the current assumption.

### 10.2.9 Methane (CH4)

A cursory look was taken at the use of CH4 in combination with LO2 as propellants for the LRB. CH4 is also known as Liquified Natural Gas (LNG). After some research into LNG it was determined that it should not be considered as a primary propellant from a safety standpoint. Reasons for this decision are listed below:

- Transportation of LNG is difficult and expensive. It must meet strict DOT requirements for transport.
- No Aerospace experience in using CH4. Very high risk with limited use.
- Forms flammable mixture with air (5-15%) and is easily ignitable.
- Construction of completely new storage area, GSE, transfer lines, etc.
- Considered a simple asphyxiant by displacing air.

## 10.3. ENVIRONMENTAL IMPACTS

### 10.3.1 Hazardous Waste

Hazardous waste generated will come mainly from the LRB Processing Facility, VAB, Pad and LRB Recovery (if required) in the forms of TPS waste material; surface preparation, such as, rags, solvents, paints, adhesives, etc.; waste hydraulic fluids and oils; and waste waters associated with the LRB recovery and flush operations. The current method of disposing of waste hydrocarbons, such as RP-1, if it cannot be used at the heating plant is to pass it through an oil and water separator at Complex 34 until the water effluent contains less that 15 ppm hydrocarbons. The water is then discharged to a sand filter. The recovered RP-1 is then disposed of through the Defense Properties Reutilization Office. Figure 10.3.1 provides a flow chart as to how waste hydrocarbons are disposed of. All waste generated must be handled in accordance with RCRA requirements contained in 40 and 49 CFRs, as well as KHB and KMI 8800.7 and KHB 1840.2.

### 10.3.2 Air Quality

Air Quality impacts from the LRB are much less severe than those of the SRB. The exhaust products for a normal Shuttle launch for the current SRB baseline are included in Figure 10.3.2. The projected exhaust products from LRB ignition are particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, and volatile organics. The quantity of exhaust products from an LRB launch has not been calculated at this time, because they will be dependent, to a great deal, on the combustion efficiency of the selected LRB engines. The emissions can be calculated, based on the engine manufacturer's data and the air emission factors contained in the "EPA Compilation of Air Emission Factors", AP- 42. It has not been determined at this point as to whether or not any type of emission control devices will be required for RP-1 or CH-4 vapors generated during servicing and storage. If required, possible options include incinerators, scrubbers or recirculating vapor recovery similar to that used in gasoline servicing. Regulatory agencies will be contacted to establish what requirements, if any, will be enforced.

### 10.3.3 Water Quality

Water quality impact will come mostly in the form of non- contained spills of RP-1. However, these can be held to a minimum by the use of proper storage and handling, containment, monitoring and emergency procedures for spill clean up. Strict EPA and State of Florida Regulations have been implemented which regulate the storage of hazardous materials for the purpose of

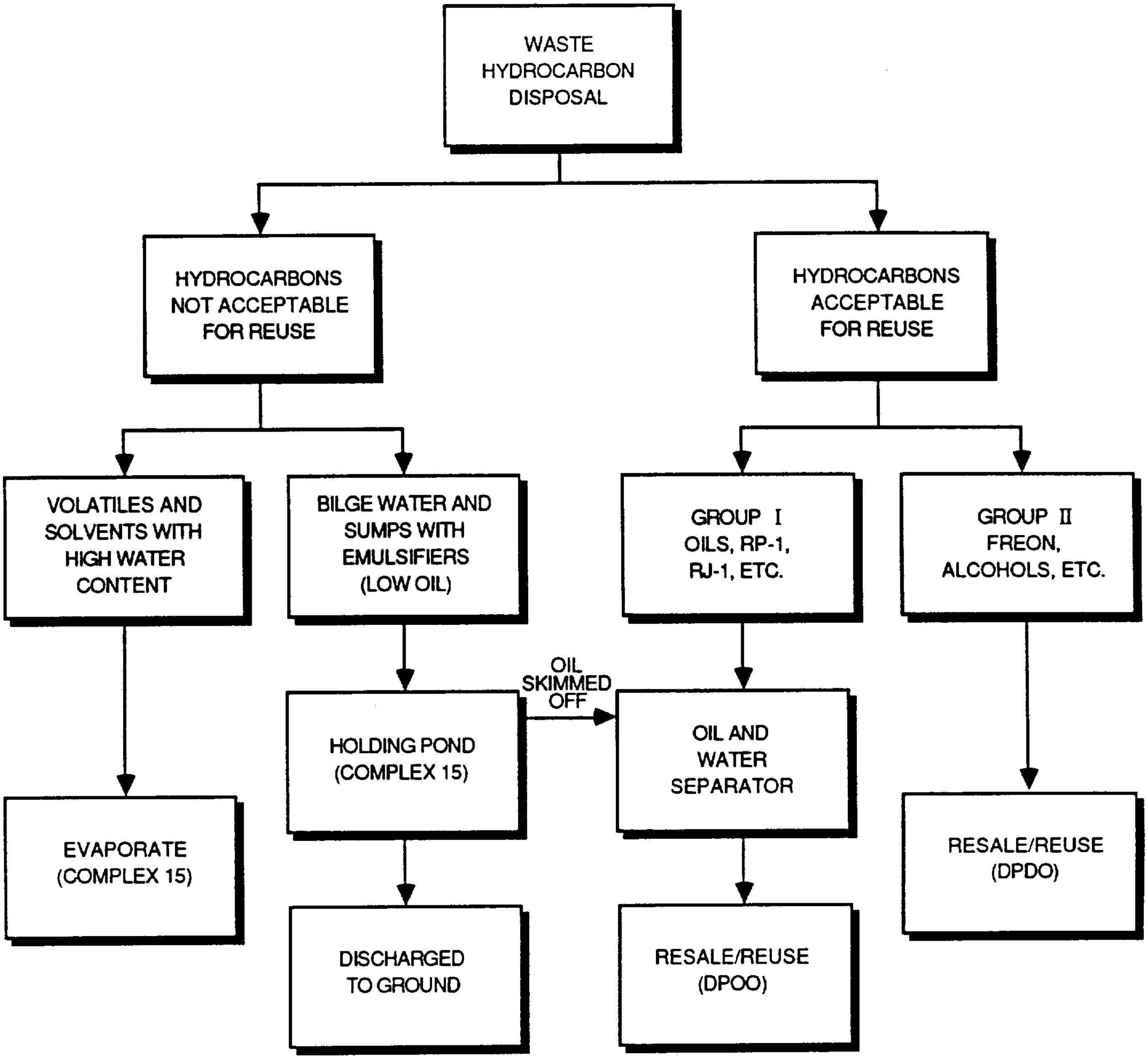

Figure 10.3.1. Methods of Disposal of Waste Hydrocarbons.

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| PRODUCT | NOZZLE EXIT ① PLANE-SRM | NOZZEL EXIT ② PLANE-ORBITER | DOWNSTREAM OF ③ PLANE (1 km ) |
|---|---|---|---|
| ALUMINUM CHLORIDE | 0.02 | | 0.000 |
| ALUMINUM OXIDE | 30.10 | | 18.279 |
| ARGON AND OTHER | 0.00 | 0.60 | 0.000 |
| CARBON DIOXIDE | 3.40 | | 25.029 |
| CARBON MONOXIDE | 24.10 | | 0.042 |
| CHLORINE ($C_1$) | 0.30 | | 0.000 |
| CHLORINE ($C_2$) | 0.00 | | 1.309 |
| HYDROGEN | 2.10 | 3.50 | 0.000 |
| HYDROGEN CHLORIDE | 21.20 | | 11.460 |
| HYDROXYL AND ATOMIC HYDROGEN | 0.02 | | 0.000 |
| IRON CHLORIDE | 0.97 | | 0.000 |
| NITRIC OXIDE | 0.00 | | 0.819 |
| NITROGEN | 8.70 | | ④ |
| WATER | 9.30 | 95.90 | 43.063 |

① SRM (AVERAGE MASS FLOW 9400 KG PER SEC FOR TWO MOTORS)

② ORBITER (AVERAGE MASS FLOW 1410 KG PER SEC FOR THREE ENGINES)

③ AFTERBURNING OF COMBINED SRM'S AND MAIN ENGINES IS COMPLETE, AND THESE CALCULATIONS INCLUDE INTERACTIONS WITH AIR, ASSUMING OXIDATION WITH APPROXIMATELY 4670 KG OF OXYGEN PER SECOND

④ ASSUMED TO BE PART OF AIR

Figure 10.3.2. Exhaust Products for a Normal Space Shuttle Burn (Percent by Weight, Mass Flow).

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protection of ground and surface waters from contamination of such commodities. These regulations impose requirements, such as, leak detection, ground water monitoring, inventory records and reporting. The current program NASA has for monitoring for leaks with vapor detectors and ground water monitoring from test wells and surface water, and analysis constantly being conducted on fish, wildlife and plant analysis to determine effects of launch fallout and spills could be expanded to meet additional requirements imposed on for the LRB.

### 10.3.4 Weather Impact

The weather impacts from the LRB in terms of contribution to acid rain, are practically non-existent when compared to the problem posed by SRBs.

### 10.3.5 Noise

Noise impacts from LRB have not yet been assessed. However, it is perceived that they will be less than those of the SRBs.

### 10.3.6 Transportation of RP-1

Transportation of RP-1 will be required to comply with requirements of transporting hazardous materials called out in the 49 CFR. Transportation of CH4 poses a more serious problem. Strict DOT requirements for transportating CH4 make it difficult to transport large quantities over public highways. In addition there are limited number of transport vehicles available for transport of the commodity.

### 10.3.7 Community Right-to-Know and SARA Requirements

Storage of large quantities of RP-1 will impact SARA and Community Right-To-Know Laws in dealing with emergency preparedness for catastrophic events. However, the threat is insignificant when compared to that posed by hypergols.

### 10.3.8 Impact on Endangered or Threatened Species

The confines of KSC encompasses the habitat of several of endangered or threatened species, both fauna and flora. The endangered or threatened fauna species are included in Figure 10.3.8-1. The most notable endangered species in the area is the Manatee. Based on the " Environmental Impact Statement for the Kennedy Space Center", October 1979, the manatee population in the United States was estimated to between 750 and 850. It is estimated to be that 10% of the remaining population live in the waters surrounding Kennedy Space Center. The most significant threat posed by the LRB Program is that from barge delivery. Barge traffic will double that currently required for ET delivery when delivery of the LRBs begin. However, this threat can be minimized by imposing controls similar to those on the barge delivery of the ET, which includes posting manatee observers and placing guards over the propeller blades on the barge. Based on information gathered during the study the LRB Program appears to poses no significant threat to the other endangered or threatened fauna species unless a large spill of RP-1 occurred and migrated to waters which were the habitat of any species.

The endangered or threatened flora species are contained in Figure 10.3.8-2. Other than through an uncontrolled spill of large quantities of RP-1, the LRB program posess very little, if any danger to any of the flora species.

### 10.3.9 Environmental Impacts

The National EnvironmentalPolicy Act of 1969 (NEPA) requires Federal agencies to prepare detailed documentation on any action undertaken that could result in a significant impact on the existing environment. This policy is fomalized in NHB 8800.11. The LRB Program will require an environmental impact assessment due to the significant modifications to and construction of new and existing facilities. An Environmental Analysis Checklist is provided in Figure 10.3.9. which should be used as a guide in determining the need for a detailed environmental assessment

for proposed action at KSC. The past Environmental Impact Statement for the Shuttle Program covers the current baseline and will be used to the fullest extent possible for the LRB Program.

## 10.4. RECOMMENDATIONS

Based on data gathered during the study and weighing the factors the following recommendations

| COMMON NAME | TAXONOMIC CLASSIFICATION | STATUS - U.S. DOI LIST | STATUS - FLORIDA LIST |
|---|---|---|---|
| EASTERN BROWN PELICAN | PELECANUS OCCIDENTALIS CAROLINENSIS | ENDANGERED | THREATENED |
| SOUTHERN BALD EAGLE | HALIAEETUS LEUCOCEPHALUS LEUCOCEPHALUS | ENDANGERED | THREATENED |
| ARCTIC PEREGRINE FALCON | FALCO PEREGRINUS TUNDRIUS | ENDANGERED | ENDANGERED |
| DUSKY SEASIDE SPARROW | AMMOSPIZA MARITIMA NIGRESCENS | ENDANGERED | ENDANGERED |
| WOOD STORK | MYCTERIA AMERICANA | - | ENDANGERED |
| FLORIDA SCRUB JAY | APHELOCOMA COERULESCENS COERULESCENS | - | THREATENED |
| LEAST TERN | STERNA ALBIFRONS | - | THREATENED |
| ROSEATE TERN | STERNA DOUGALLII | - | THREATENED |
| AMERICAN OYSTERCATCHER | HAEMATOPUS PALLIATUS | - | THREATENED |
| SOUTHEASTERN AMERICAN KESTREL | FALCON SPARVERIUS PAULUS | - | THREATENED |
| OSPREY | PANDION HALIAETUS CAROLINENSIS | - | THREATENED |
| MAGNIFICENT FRIGATEBIRD | FREGATA MAGNIFICENS ROTHSCHILDI | - | THREATENED |
| FLORIDA MANATEE | TRICHECHUS MANATUS | ENDANGERED | ENDANGERED |
| FLORIDA MOUSE | PEROMYSCUS FLORIDANUS | - | THREATENED |
| ATLANTIC RIDLEY TURTLE | LEPIDOCHELYS KEMPII | ENDANGERED | ENDANGERED |
| ATLANTIC GREEN TURTLE | CHELONIS MYDAS MYDAS | ENDANGERED | ENDANGERED |
| ATLANTIC LOGGERHEAD TURTLE | CARETTA CARETTA CARETTA | THREATENED | ENDANGERED |
| GOPHER TORTOISE | GOPHERUS POLYPHEMUS | - | THREATENED |
| AMERICAN ALLIGATOR | ALLIGATOR MISSISSIPPIENSIS | THREATENED | THREATENED |
| ATLANTIC SALT MARSH SNAKE | NERODIA FASCIAT A TAENIATA | THREATENED | ENDANGERED |
| EASTERN INDIGO SNAKE | DRYMARCHON CORAIS COUPERI | THREATENED | THREATENED |

Figure 10.3.8-1. Endangered and Threatened Fauna.

| COMMON NAME | TAXONOMIC CLASSIFICATION | STATUS - FLORIDA LIST |
|---|---|---|
| SEA LAVENDER | TOURNEFORTIA GNAPHALODE | ENDANGERED |
| COONTIE | ZAMIA INTEGRIFOLIA | THREATENED |
| HAND FERN | OPHIOGLOSSUM PALMATUM | ENDANGERED |
| POND APPLE | ANNONA GLABRA | ENDANGERED |
| SATIN LEAF | CHRYSOPHYLLUM OLIVIFORME | ENDANGERED |
| CURTIS MILKWEED | ASCLEPIAS CURTISSII | THREATENED |
| GOLDEN LEATHER FERN | ACROSTICHUM AUREUM | RARE |
| WATER SUNDEW | DROSERA INTERMEDIA | RARE |
| FLORIDA PEPEROMIA | PEPEROMIA OBTUSIFOLIA | RARE |
| RED MANGROVE | RHIZOPHORA MANGLE | SPECIAL CONCERN |
| BLACK MANGROVE | AVICENNIA GERMINANS | SPECIAL CONCERN |

Figure 10.3.8-2. Endangered and Threatened Flora.

- DISCHARGE OF ANY SUBSTANCES ON THE GROUND OR INTO THE AIR OR WATER
- REMOVAL OF VEGETATION, DESTRUCTION OF WILDLIFE HABITAT, OR CHANGES IN CURRENT LAND USE PATTERNS
- WORK WITH TOXIC OR HAZARDOUS SUBSTANCES OF ANY KIND (ACQUISITION, USE, GENERATION, STORAGE, OR DISPOSAL)
- ALL WORK IN WETLANDS AND FLOODPLAINS
- ANY ACTION THAT MAY AFFECT ENDANGERED OR THREATENED SPECIES OR THEIR HABITAT (SEE TABLE 19-3)
- ANY DREDGING, FILLING, OR WORK REQUIRING BORROW MATERIALS
- ACTIVITIES GENERATING NOISES OF HIGH LEVELS (ABOVE 80 dBA) OR FOR PROLONGED TIMES (1 HOUR OR MORE)
- ACTIVITIES GENERATING HAZARDOUS RADIATION (IONIZING OR NONIONIZING) ABOVE THRESHOLD LIMIT VALUES (TLV's)
- ACTIVITIES RESULTING IN CHANGES OF 10 PERCENT OR MORE IN CENTER ENERGY CONSUMPTION
- ACTIVITIES AFFECTING THE SURFACE OR GROUND WATERS INCLUDING INJECTION, LEACHING, AND THE ADDED USE OF POTABLE WATER IN AMOUNTS GREATER THAN 1,000 GALLONS PER DAY
- ACTIVITIES CHANGING VEHICULAR TRAFFIC OR PARKING PATTERNS BY MORE THAN 10 PERCENT
- GENERATION OF WASTES OF A SIGNIFICANT NATURE; SOLID WASTES AND SEWAGE IN LARGE AMOUNTS, ANY CHEMICAL, TOXIC, OR RADIOLOGICAL WASTES; OR WASTES REQUIRING SPECIAL HANDLING
- HANDLING, STORAGE, OR DISPOSAL OF OILS, HYPERGOLS, CRYOGENS, OR HAZARDOUS OR TOXIC MATERIALS
- USE OF FERTILIZERS, INSECTICIDES, HERBICIDES, RODENTICIDES, BIOCIDES, OR FUNGICIDES
- ACTIVITIES AFFECTING AREAS OF HISTORICAL, ARCHEOLOGICAL, OR RECREATIONAL SIGNIFICANCE OR PUBLIC SERVICES OR EMPLOYMENT LEVELS

Figure 10.3.9. Environmental Analysis Checklist.

are made:

1. RP-1/LO2 should be used as the propellant for the LRB. From a Safety standpoint, RP-1 is less hazardous than LH2 or CH4. RP-1 is much safer to handle as opposed to LH2 and CH4, both of which present significant flammable and explosive hazards (LH2 flammable/explosive in concentrations of 4-75% and CH4 flammable in concentrations of 5-15%). LH2 requires constant venting and quantities needed for the LRB may require more extensive use of the flare stack for burn- off. The use of CH4 will require completely new and innovative storage facilities for the quantities needed for LRB.

2. Storage facilities for RP-1 should be of the above ground type due to extensive monitoring, leak detection, containment and construction of underground facilities. If storage facilities are constructed on each pad, bunkers for protection from blast are required for protection of the storage facility.

3. From the Propellant Storage Quantity Distance Requirements (section 10.2.5), storage of the propellants within the Pad perimeter is acceptable.

4. If possible, locate the LRB/ET Checkout and Processing Facility in the general proximity of the current press site adjacent to the barge turn basin. This location is out of the Quantity Distance Requirements currently established for the VAB, RPSF, and the OPF and would not require a waiver for this area (see Figure 10.2.2.7). A transport route can be easily constructed using the current ET tow-route as a baseline.

## 10.5. CONCLUSIONS

From a Safety and Environmental standpoint the LRB offers very significant improvements over the current SRB baseline. Some of he improvements are as follows:

1. There will be no handling of live propellants during processing operations. Propellants will not be handled (loaded) until the vehicle is at the Pad. This will eliminate the need for establishing many of the control zones which are currently required when processing the SRBs.

2. The hazardous operations of processing live SRB segments in the RPSF and stacking the segments in the VAB will be eliminated.

3. The quantity distance requirements currently established for the VAB and RPSF will be drastically reduced or eliminated.

4. The LRB will reduce or eliminate the hazard associated with personnel working under suspended loads that currently exists while processing SRBs.

5. There will be no operations involved requiring personnel to be lowered into live SRB segments.

6. There will be no APU/Hypergolic booster operations.

7. The hazard of exposing personnel to asbestos when processing the SRBs (at the RPSF and Hangar AF) will be eliminated if asbestos is not required on the LRB for thermal insulation and adhesive seals.

8. The LRB will eliminate the use of O-Rings as a seal to contain the hot gases which will eliminate the possibility of O-Ring burn through and cause a catastrophic failure.

9. The ability to abort after ignition provides added safety features should problems arise after ignition and prior to launch.

10. Ignition by-products from the LRB pose less of a threat from an environmental standpoint than those of the SRB.

In summation, the proposed LRB system should be implemented for the Shuttle Program because of the Safety/Environmental enhancements over the SRB and the other advantages discussed in this report.

## 10.6 REFERENCES

AFM 161-30: Liquid Propellants
AFR 127-100: Explosive Safety Standard
AP-42: EPA Compilation of Air Emission Factors
ASME Pressure Vessel Codes

EPA Underground Storage Tank Regulations, 40 CFR 280
Florida, Title 17: Underground Tank Rules
GP-1098E: KSC Space Transportation System Ground Safety Plan
KHB 1040.1D: Emergency Preparedness Plan
KHB 1700.7A: Space Transportation System Payload Ground Safety Plan
KHB 1710.2B: KSC Safety Practices Handbook
KHB 1710.15A: KSC Pressure Vessel/System Recertification Handbook
KMI 1730.1E: Protective Clothing and Safety Equipment
KMI 1800.1: KSC Environmental Health Protection Programs
KMI 1800.2: Chemical Hazard Communication
KHB 1840.1: Industrial Hygiene Handbook
KHB 1840.2: Toxics Materials Handbook
KHB 1870.1S: Environmental Sanitation Handbook
KMI 5300.1A: Lifting of Hardware
KHB 5310.1B: KSC Reliability and Quality Assurance Handbook
KPD 5310.4B: KSC Safety, Reliability and Quality Assurance
KMI 5310.9B: Safety Hazard and Reliability Analyses of GSE and Facilities, and Launch Operations and Integrated Hazards Analyses
KMI 8800.6A: KSC Environmental Control
KMI 8800.7: Management of Hazardous Waste for Compliance Handling, Treatment, and Disposal/Reclamation
KHB 8800.7: Hazardous Waste Management
KSC-STD-E-0002: Hazard Proofing of Electrically Energized Equip.
KSC-STD-Z-0002B: Design Requirements for Lifting and Hoisting Equipment
KSC-STD-Z-0003: The Integrity of Structures, Establishing and Maintaining
KSC-STD-E-0012: Bonding and Grounding
KSC-STD-SF-0004: Safety Standard for Ground Piping Systems Color Coding and Identification

NASA Environmental Impact Statement Space Shuttle Program, Final, April 1978
National Fire Protection Association Codes
National Electric Codes
NHB 7320.1B: Facilities Engineering Handbook
NSS/GO 1740.9: NASA Safety Standard for Lifting Devices and Equipment
NSTS 07700: Space Shuttle Flight and Ground Systems Specs

# VOLUME III

## SECTION 11

## PROPELLANT ACQUISITION STORAGE AND HANDLING REQUIREMENTS

## VOLUME III SECTION 11
## PROPELLANT ACQUISITION, STORAGE, AND HANDLING

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## SECTION 11
## PROPELLANT ACQUISITION, STORAGE, AND HANDLING

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# SECTION 11

# PROPELLANT ACQUISITION, STORAGE, AND HANDLING

This study product will assess the propellant requirements of the various Liquid Rocket Boosters (LRBs). The study will determine the storage requirements, define scrub/turnaround options, and provide design concepts for the loading systems. The analyses of LRB requirement and loading concepts will provide a rationale for acquisition, storage, and handling and provide a definition of the required Propellant Ground System. The propellents reviewed include liquid oxygen (LOX), liquid hydrogen (LH2), rocket grade, kerosene (RP-1), and liquid methane (LCH4). Figure 11.0 shows a plan view of the Pad propellant storage areas.

## 11.1 ASSUMPTIONS AND GROUNDRULES

### 11.1.1 Assumptions

All LRB configurations requiring cryogenic propellants can be filled, drained, and vented through lift-off umbilicals. These cryogenic propellants are LOX LH2 and LCH4. This assumption avoids the requirement for arms and towers for fueling and a tail service mast currently used for the Orbiter.

LOX is assumed to vent overboard to the atmosphere to avoid a GOX vent capture system similar to the present ET GOX vent arm system.

RP-1, which is a petroleum product and considered a storable propellant, will be assumed to be loaded in prelaunch operations similar to present hypergol Orbiter loading (OMI S0024). This will allow for removal of loading ground support equipment (GSE) prior to launch operations (OMI S0007).

The cryogenic propellants (LOX, LH2, LCH4) will require replenishment up to launch and, therefore, are assumed to be in launch operation (OMI S0007).

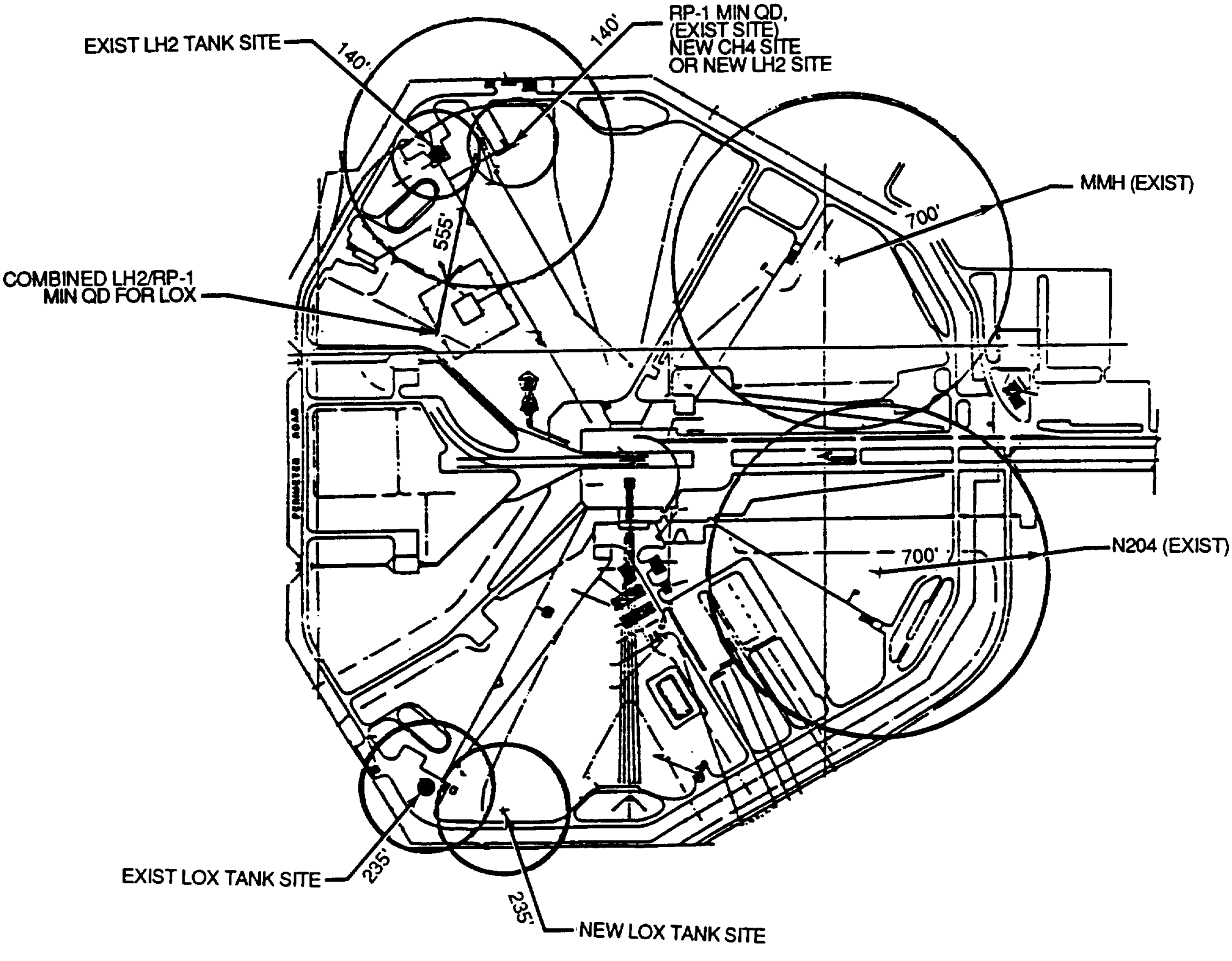

Figure 11.0. PAD Propellant Storage Areas.

### 11.1.2 Groundrules

Discussion of pneumatic GSE and electrical controls are contained in Section 5; discussion of umbilicals and mechanisms are contained in Section 4.

This section will be limited to the propellants. The LOX and LH2 systems will schematically and functionally be like the present MPS LOX and LH2 Systems. The LCH4 System will be functionally and schematically like the MLP LH2 System except that pumps will be used to transfer the propellant.

The baselined system for RP-1 will be similar to the Saturn V RP-1 System. Also, during the evaluation the 600-gallon per day boiloff (loss) of the LOX storage vessel will be ignored. This loss is negligible and would complicate the analysis.

## 11.2 LIQUID OXYGEN

The analysis of the LRB LOX requirements is based on data provided by General Dynamics and Martin Marietta, known External Tank (ET)/Space Shuttle Main Engine (SSME) processing operational data, and present Space Shuttle Vehicle (SSV) interface control requirements. The six LRB configurations are analyzed to define fill and drain requirements, including anticipated boiloff results; define scrub/turnaround options; define LOX storage and acquisition requirements; and provide a description of a LRB LOX facility and ground systems.

The approach to determine the LOX facility requirements to support the LRB configurations is accomplished by baselining the present ET loading system and interpolating the LRB requirement. Assumptions of the analysis include: the insulation quality of the ET and the LRB is the same, the transfer system insulation for the ET and the LRB is the same, and the engine bleed for each LRB engine and each SSME is the same. These assumptions allow a correlation of facility and loading requirement for the six LRB configurations based on ET/SSME.

### 11.2.1 LRB Loading Requirements

Currently, the ET loading operation consumes approximately 1,840,000 pounds of LOX (194,289 gallons). The ET will contain 132,129 gallons at launch, which means 62,130 gallons are lost to chilldown, boiloff, replenish, and engine bleed during loading. Figure 11.2.1 illustrates and breaks down the data in the "ET" column.

The GDSS Data gives the on-board LOX requirement for their four boosters in pounds. Figure 11.2.1 converts pounds to gallons at 100 psia and 165°R.

The MMC data gives the on-board LOX requirement for their two boosters in tank volume. Using a 3% ullage and LOX at 100 psia and 165 °R the on-board LOX requirement was obtained as shown in Figure 11.2.1.

The LOX loading requirements (including loading losses) for each LRB was obtained by interpolating LRB tank quantity and ET tank quantity with the ET losses. The LOX loading losses for each LRB are shown in Figure 11.2.1.

LRB Engine Bleed requirements for each engine, as stated earlier, are assumed to be the same as for each SSME. This results in each LRB with four engines consuming 51,134 gallons for engine bleed. Figure 11.2.1 shows the total LOX quantity needed to load and provide engine bleed for each LRB.

#### 11.2.1.1 Existing Storage Capability

The existing LOX storage vessels at Launch Complex 39A and 39B have a 900,000-gallon capacity. With a 6% ullage, they each contain a maximum of 846,000 gallons of LOX. The minimum allowed quantity for these vessels is 330,000 gallons. The minimum was established during the Apollo program and is maintained in the STS program. The minimum requirement was established to prevent a thermal cycle on the vessel so as not to cause an extreme temperature gradient from top to bottom and to maintain a minimum load pressure without ullage pressurization to meet the net pressure suction head (NPSH) of the LOX transfer pumps.

Figure 11.2.1 shows the minimum LOX necessary to load the LRB/SSV (ET plus two LRBs). The results indicate that, except for the GDSS LOX/RP-1 pressure-fed, the present storage vessels contain sufficient LOX to fill LRB/SSV once. For the GDSS LOX/RP-1 pressure-fed, further analysis to lower the 330,000 gallon minimum must be accomplished, since the existing vessel is short 46,184 gallons.

| | | ET ONLY | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/LH2 PUMP-FED | GDSS LOX/CH4 PUMP-FED | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED |
|---|---|---|---|---|---|---|---|---|
| TOTAL QTY REQ FOR ET (I = ICD DATA) NOTE 1 | (LB) | 1840000.00 I | | | | | | |
| | (GAL) | 194258.51 | | | | | | |
| VEHICLE LOX TANK VOL (X = GIVEN DATA) | (CF) | 19627.00 X | 9924.83 | 15514.83 | 8028.94 | 10208.32 | 9934.00 X | 11724.00 X |
| ULLAGE | (%) | 10.00 | 3.00 | 3.00 | 3.00 | 3.00 | 10.00 | 10.00 |
| | (CF) | 1962.70 | 297.74 | 465.45 | 240.87 | 306.25 | 993.40 | 1172.40 |
| VEHICLE LOX QUANTITY (X = GIVEN DATA) | (CF) | 17664.30 | 9627.08 | 15049.39 | 7788.07 | 9902.07 | 8940.60 | 10551.60 |
| | (LB) | 1251514.24 | 682078.00 X | 1066248.00 X | 551784.00 X | 701561.00 X | 633440.79 | 747580.02 |
| | (GAL) | 132128.96 | 72010.57 | 112569.43 | 58254.75 | 74067.50 | 66875.69 | 78925.97 |
| LOADING LOSSES (R = RATIO OF LRB TO ET) | (GAL) | 23778.82 | X12959.51 R | 20258.75 R | 10483.92 R | 13329.69 R | 12035.40 R | 14204.05 R |
| ENGINE BLEED (I = ICD DATA, A = ASSUMED) NOTE 2 | (GAL) | 38350.73 I | 51134.30 A | 51134.30 A | 51134.30 A | 51134.30 A | 51134.30 A | 51134.30 A |
| # OF ENGINES | | | 4 | 4 | 4 | 4 | 4 | 4 |
| BLEED PER ENGINE | (GAL) | 12783.58 | 12783.58 | 12783.58 | 12783.58 | 12783.58 | 12783.58 | 12783.58 |
| TOTAL OF LOADING LOSS PLUS ENGINE BLEED | (GAL) | 62129.55 | 64093.81 | 71393.06 | 61618.22 | 64463.99 | 63169.70 | 65338.35 |
| QTY REQ FOR ONE LRB NOTE 3 | (LB) | | 1289169.11 | 1742476.94 | 1135426.52 | 1312158.40 | 1231778.83 | 1366459.31 |
| | (GAL) | | 136104.39 | 183962.49 | 119872.97 | 138531.49 | 130045.39 | 144264.32 |
| QTY REQ FOR TWO LRBs | (LB) | | 2578338.22 | 3484953.87 | 2270853.05 | 2624316.81 | 2463557.65 | 2732918.62 |
| | (GAL) | | 272208.77 | 367924.97 | 239745.94 | 277062.98 | 260090.78 | 288528.64 |
| TOTAL LOX QUANTITY FOR TWO LRBs AND ET | (CF) | 17664.30 | 36918.46 | 47763.08 | 33240.44 | 37468.44 | 35545.50 | 38767.50 |
| | (LB) | 1251514.24 | 2615670.24 | 3384010.24 | 2355082.24 | 2654636.24 | 2518395.83 | 2746674.27 |
| | (GAL) | 132128.96 | 276150.11 | 357267.82 | 248638.46 | 280263.96 | 265880.34 | 289980.90 |
| TOTAL LOX QUANTITY REQUIRED FOR TWO LRBs AND ET | (LB) | 1840000.00 | 4418338.22 | 5324953.87 | 4110853.05 | 4464316.81 | 4303557.65 | 4572918.62 |
| | (GAL) | 194258.51 | 466467.29 | 562183.49 | 434004.45 | 471321.49 | 454349.30 | 482787.15 |
| STORAGE VESSEL USABLE QUANTITY NOTE 4 | (GAL) | 516000.00 | 516000.00 | 516000.00 | 516000.00 | 516000.00 | 516000.00 | 516000.00 |
| EXISTING STORAGE ABILITY TO LOAD LRB/SSV | | | SUFFICIENT | MORE STORAGE REQUIRED | SUFFICIENT | SUFFICIENT | SUFFICIENT | SUFFICIENT |

NOTES:
1. LOX @ 100 PSIA , 165 DEG R, 70.84992 LB/CF (PER NASA SP-3071)
2. ENGINE BLEED FOR 5.5 HOURS LOX @ 1100 LB/MIN, 166 DEG R, 50PSIA, 70.80022 LB/CF (PER NASA SP-3071)
3. LOX @ 100 PSIA, 165 DEG R, 70.84992 LB/CF (PER NASA SP-3071)
4. STORAGE VESSEL TOTAL LESS THE 330000 GAL MINIMUM RESIDUAL AND 6% ULLAGE

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Figure 11.2.1. Analysis of ET/LRB LOX Loading Requirement.

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### 11.2.2 Drain Analysis

Currently, when the ET is drained, approximately 5,000 gallons of LOX is lost to chilldown of the transfer line and boiloff. The LRB drain losses figure was obtained by interpolating the on-board ET quantity and drain losses and the on-board LRB quantities. Figure 11.2.2 shows the anticipated LRB drain losses for each LRB and the number of fills which can be accomplished. The LOX remaining in the existing storage vessel after a Vehicle drain will be insufficient to attempt a second vehicle loading operation if the 330,000 gallon requirement is maintained.

### 11.2.3 Scrub/Turnaround

As shown in Paragraph 11.2.2 insufficient LOX is present to drain and turnaround a LRB/SSV with the existing storage capacity. Figure 11.2.2 shows the number of loading capable from the existing storage vessel. Figure 11.2.3-1 shows for each LRB/SSV the number of tankers and days needed to fill the storage vessel to either the 846,000 gallon mark or the minimum to allow filling the LRB/SSV. Currently, 10 tankers are available that can offload 42,000 gallon of LOX in four hours using the existing five fill stations. Assuming the LOX plant in Mims, Florida, can turn around the tankers in four hours, LOX can be supplied to KSC at a rate of 126,000 gallons per day with a three shift operation. The best case is the GDSS LOX/LH2 LRB, which can fly 24 hours later. With a minimum in the LOX storage vessel the other LRBs would require a 32 hour turnaround minimum.

To fill the LOX storage vessel using 10 tankers, even with a three-shift operation it would require more than 42 hours. To achieve a 24-hour turnaround would require increasing the tanker fleet to 20 and KSC staffing to offload 252,000 gallons of LOX per 24 hour period.

To eliminate the need to replenish the LOX storage vessel after a scrub and vehicle drain, doubling the storage capacity is recommended. The number of scrub/turnarounds is shown in Figure 11.2.3-2. The refill times, if needed, are shown in Figure 11.2.3-3.

### 11.2.4 Acquisition

The liquid oxygen supplied to KSC arrives by over-the-road tankers from Mims, Florida. The cost of LOX is 28 cents per gallon (in 1988). The tanks deliver 4,200 gallons each and currently there

| | | ET ONLY | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/LH2 PUMP-FED | GDSS LOX/CH4 PUMP-FED | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED |
|---|---|---|---|---|---|---|---|---|
| DRAIN LOSSES (A = ASSUMED, R = RATIO OF LRB TO ET) | (GAL) | 5000.00 A | 2725.01 R | 4259.83 R | 2204.47 R | 2802.85 R | 2530.70 R | 2986.70 R |
| TOTAL LRB/SSV DRAIN LOSSES | (GAL) | 5000.00 | 10450.02 | 13519.66 | 9408.93 | 10605.70 | 10601.40 | 10973.40 |
| TOTAL LOX QUANTITY REQUIRED FOR TWO LRBs AND ET | (GAL) | 194258.51 | 466467.29 | 562183.49 | 434004.45 | 471321.49 | 454349.30 | 482787.15 |
| TOTAL OF LOADING LOSS PLUS ENGINE BLEED | (GAL) | 62129.55 | 190317.17 | 204915.66 | 185365.99 | 191057.53 | 188468.96 | 192806.25 |
| TANK MIN TO LOAD | (GAL) | 524258.51 | 796467.29 | 892183.49 | 764004.45 | 801321.49 | 784349.30 | 812787.15 |
| FULL TANK | (GAL) | 846000.00 | 846000.00 | 846000.00 | 846000.00 | 846000.00 | 846000.00 | 846000.00 |
| TANK AFTER 1ST F&D | (GAL) | 778870.45 | 645232.80 | INSUFFI-CIENT | 651225.08 | 644336.77 | 647469.65 | 642220.34 |
| TANK AFTER 2ND F&D | (GAL) | 711740.90 | | | | | | |
| TANK AFTER 3RD F&D | (GAL) | 644611.36 | | | | | | |
| TANK AFTER 4TH F&D | (GAL) | 577481.81 | | | | | | |
| TANK AFTER 5TH F&D | (GAL) | 510352.26 | | | | | | |
| SCRUB/TURNABOUT USING EXISTING VESSEL | | YES 4 FILLS | NO 1 FILL | NO | NO 1 FILL | NO 1 FILL | NO 1 FILL | NO 1 FILL |

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Figure 11.2.2. Analysis of LOX Drain Results After Loading.

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|  |  | ET | GDSS LOX/RP-1 PUMP | GDSS LOX/RP-1 PRESS | GDSS LOX/LH2 PUMP | GDSS LOX/CH4 PUMP | MMC LOX/RP-1 PUMP | MMC LOX/RP-1 PRESS |
|---|---|---|---|---|---|---|---|---|
| MIN IN STORAGE TO LOAD ET/LRB |  | 524258.51 | 796467.29 | 892183.49 | 764004.45 | 801321.49 | 784349.30 | 812787.15 |
| NUMBER OF FILLS ACCOMPLISHED |  | 5 | 1 | 0 | 1 | 1 | 1 | 1 |
| LEFT IN STORAGE AFTER LAST FILL OPERATION | (GAL) | 510352.26 | 645232.80 | 846000.00 | 651225.08 | 644336.77 | 647469.65 | 642220.34 |
| ADD MINIMUM TO LOAD LRB/ET | (GAL) | 13906.25 | 151234.48 |  | 112779.38 | 156984.71 | 136879.65 | 170566.81 |
| NUMBER OF TANKERS (@ 4200 GAL EACH) | (#) | 3.31 | 36.01 |  | 26.85 | 37.38 | 32.59 | 40.61 |
| QTY TO FILL STORAGE VESSEL | (GAL) | 335647.74 | 200767.20 |  | 194774.92 | 201663.23 | 198530.35 | 203779.66 |
| NUMBER OF TANKERS (@ 4200 GAL EACH) | (#) | 79.92 | 47.80 |  | 46.37 | 48.02 | 47.27 | 48.52 |
| EXISTING FLEET OF 10 TANKERS (10 TANKERS/DAY M-F) |  |  |  |  |  |  |  |  |
| MINIMUM TO LOAD DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) | (DAYS) | 0.33 | 3.60 |  | 2.69 | 3.74 | 3.26 | 4.06 |
| TOP STORAGE DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) | (DAYS) | 7.99 | 4.78 |  | 4.64 | 4.80 | 4.73 | 4.85 |
| DOUBLE FLEET AND PRODUCTION |  |  |  |  |  |  |  |  |
| MINIMUM TO LOAD DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) (20 TANKERS/DAY M-F) | (DAYS) | 0.17 | 1.80 |  | 1.34 | 1.87 | 1.63 | 2.03 |
| TOP STORAGE DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) (20 TANKERS/DAY M-F) | (DAYS) | 4.00 | 2.39 |  | 2.32 | 2.40 | 2.36 | 2.43 |

NOTE: THERE ARE PRESENTLY FIVE TANKER CONNECTIONS WHICH HAVE THE CAPABILITY OF OFF-LOADING 10 TANKERS IN FOUR HOURS. THEREFORE IT IS POSSIBLE TO OFF-LOAD 20 TANKERS IN A ONE-SHIFT OPERATION IF THEY WERE AVAILABLE.

Figure 11.2.3-1. LOX Storage Fill Using Existing Capacity Turnaround.

|  |  | ET ONLY | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/LH2 PUMP-FED | GDSS LOX/CH4 PUMP-FED | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED |
|---|---|---|---|---|---|---|---|---|
| TOTAL LOX VOL FOR TWO LRBs AND ET | (CF) | 17664.30 | 36918.46 | 47763.08 | 33240.44 | 37468.44 | 35545.50 | 38767.50 |
|  | (LB) | 1251514.24 | 2615670.24 | 3384010.24 | 2355082.24 | 2654636.24 | 2518395.83 | 2746674.27 |
|  | (GAL) | 132128.96 | 276150.11 | 357267.82 | 248638.46 | 280263.96 | 265880.34 | 289980.90 |
| TOTAL LOX QUANTITY REQUIRED FOR TWO LRBs AND ET | (LB) | 1840000.00 | 4418338.22 | 5324953.87 | 4110853.05 | 4464316.81 | 4303557.65 | 4572918.62 |
|  | (GAL) | 194258.51 | 466467.29 | 562183.49 | 434004.45 | 471321.49 | 454349.30 | 482787.15 |
| STORAGE VESSEL USABLE QUANTITY NOTE 1 | (GAL) | 1032000.00 | SUFFICIENT | SUFFICIENT | SUFFICIENT | SUFFICIENT | SUFFICIENT | SUFFICIENT |
| TOTAL OF LOADING LOSS PLUS ENGINE BLEED | (GAL) | 62129.55 | 64093.81 | 71393.06 | 61618.22 | 64463.99 | 63169.70 | 65338.35 |
| TOTAL LRB/SSV DRAIN LOSSES | (GAL) | 5000.00 | 10450.02 | 13519.66 | 9408.93 | 10605.70 | 10061.40 | 10973.40 |
| TANK MIN TO LOAD | (GAL) | 854258.51 | 1126467.29 | 1222183.49 | 1094004.45 | 1131321.49 | 1114349.30 | 1142787.15 |
| FULL TANK | (GAL) | 1692000.00 | 1692000.00 | 1692000.00 | 1692000.00 | 1692000.00 | 1692000.00 | 1692000.00 |
| TANK AFTER 1ST F&D | (GAL) | 1624870.45 | 1491232.80 | 1473564.67 | 1497225.06 | 1490336.77 | 1493469.65 | 1488220.34 |
| TANK AFTER 2ND F&D | (GAL) | 1557740.90 | 1290465.61 | 1255129.35 | 1302450.16 | 1288673.55 | 1294939.30 | 1284440..68 |
| TANK AFTER 3RD F&D | (GAL) | 1490611.36 | 1089698.41 | 1036694.02 | 1107675.23 | 1087010.32 | 1096408.95 | 1080661.02 |
| TANK AFTER 4TH F&D | (GAL) | 1423481.81 |  |  | 912900.31 |  |  |  |
| TANK AFTER 5TH F&D | (GAL) | 1356352.26 |  |  |  |  |  |  |
| TANK AFTER 6TH F&D | (GAL) | 1289222.71 |  |  |  |  |  |  |
| TANK AFTER 7TH F&D | (GAL) | 1222093.17 |  |  |  |  |  |  |
| TANK AFTER 8TH F&D | (GAL) | 1154963.62 |  |  |  |  |  |  |
| TANK AFTER 9TH F&D | (GAL) | 1087834.07 |  |  |  |  |  |  |
| TANK AFTER 10TH F&D | (GAL) | 1020704.52 |  |  |  |  |  |  |
| TANK AFTER 11TH F&D | (GAL) | 953574.98 |  |  |  |  |  |  |
| TANK AFTER 12TH F&D | (GAL) | 886445.43 |  |  |  |  |  |  |
| TANK AFTER 13TH F&D | (GAL) | 819315.88 |  |  |  |  |  |  |
| SCRUB/TURN AROUND |  | YES 13 FILLS | YES 3 FILLS | YES 3 FILLS | YES 4 FILLS | YES 3 FILLS | YES 3 FILLS | YES 3 FILLS |

NOTE: 1. STORAGE VESSEL TOTAL LESS THE 330000 GAL MINIMUM RESIDUAL & 6% ULLAGE

Figure 11.2.3-2. ET/LRB LOX Fill and Drain Results Doubling Storage Capacity.

| | | ET | GDSS LOX/RP-1 PUMP | GDSS LOX/RP-1 PRESS | GDSS LOX/LH2 PUMP | GDSS LOX/CH4 PUMP | MMC LOX/RP-1 PUMP | MMC LOX/RP-1 PRESS |
|---|---|---|---|---|---|---|---|---|
| MIN IN STORAGE TO LOAD ET/LRB | | 854258.51 | 1126467.29 | 1222183.49 | 1094004.45 | 1131321.49 | 1114349.30 | 1142787.15 |
| NUMBER OF FILLS ACCOMPLISHED | | 13 | 3 | 3 | 4 | 3 | 3 | 3 |
| LEFT IN STORAGE AFTER LAST FILL OPERATION | (GAL) | 819315.88 | 1089698.41 | 1036694.02 | 912900.31 | 1087010.32 | 1096408.95 | 1080661.02 |
| ADD MINIMUM TO LOAD LRB/ET | (GAL) | 34942.63 | 36768.87 | 185489.46 | 181104.14 | 44311.17 | 17940.35 | 62126.13 |
| NUMBER OF TANKERS (@ 4200 GAL EACH) | (#) | 8.32 | 8.75 | 44.16 | 43.12 | 10.55 | 4.27 | 14.79 |
| QTY TO FILL STORAGE VESSEL | (GAL) | 872684.12 | 602301.59 | 655305.98 | 779099.69 | 604989.68 | 595591.05 | 611338.98 |
| NUMBER OF TANKERS (@ 4200 GAL EACH) | (#) | 207.78 | 143.41 | 156.03 | 185.50 | 144.05 | 141.81 | 145.56 |
| EXISTING FLEET OF 10 TANKERS (10 TANKERS/DAY M-F) | | | | | | | | |
| MINIMUM TO LOAD DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) | (DAYS) | 0.83 | 0.83 | 4.42 | 4.31 | 1.06 | 0.43 | 1.48 |
| TOP STORAGE DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) | (DAYS) | 20.78 | 14.34 | 15.60 | 18.55 | 14.40 | 14.18 | 14.56 |
| DOUBLE FLEET | | | | | | | | |
| MINIMUM TO LOAD DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) (20 TANKERS/DAY M-F) | (DAYS) | 0.42 | 0.44 | 2.21 | 2.16 | 0.53 | 0.21 | 0.74 |
| TOP STORAGE DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) (20 TANKERS/DAY M-F) | (DAYS) | 10.39 | 7.17 | 7.80 | 9.27 | 7.20 | 7.09 | 7.28 |
| DOUBLE FLEET AND FILL STATIONS | | | | | | | | |
| MINIMUM TO LOAD DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) (20 TANKERS/DAY M-F) | (DAYS) | 0.21 | 0.22 | 1.10 | 1.08 | 0.26 | 0.11 | 0.37 |
| TOP STORAGE DAYS (ONE DAY = TWO EIGHT HOUR SHIFTS) (40 TANKERS/DAY M-F) | (DAYS) | 5.19 | 3.59 | 3.90 | 4.64 | 3.60 | 3.55 | 3.64 |
| DAYS (ONE DAY = THREE EIGHT HOUR SHIFTS) (80 TANKERS/DAY M-F) | (DAYS) | 1.15 | 0.80 | 0.87 | 1.03 | 0.80 | 0.79 | 0.81 |
| DAYS (ONE DAY = THREE EIGHT HOUR SHIFTS) (120 TANKERS/DAY M-F) | | 1.73 | 1.20 | 1.30 | 1.55 | 1.20 | 1.18 | 1.21 |

NOTE: THERE ARE PRESENTLY FIVE TANKER CONNECTIONS WHICH HAVE THE CAPABILITY OF OFF-LOADING 10 TANKERS IN FOUR HOURS.

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Figure 11.2.3-3. LOX Storage Fill of Double Capability Turnaround.

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are ten. Turnaround time for the tankers is eight hours, of which four hours are used to offload the LOX into the storage vessel on the Pad.

### 11.2.5 LRB LOX System Description

An analysis of the LRB LOX requirements resulted in three concepts being reviewed:

Concept 1:
Utilizes the existing 1000-gpm variable speed pump and 6-inch transfer line. The valve skids to load the LRBs would be connected upstream of the Main Propulsion System (MPS) LOX skid on the MLP. Figure 11.2.5-1 shows the loading times to fill the ET and LRB. The loading times are unacceptable for meeting existing ET interface requirements.

Concept 2:
Provides a new (as large as 3,000-gpm variable speed) pump and up to a 12-inch transfer line to meet the requirements of a fast fill time of 114 minutes and ET interface requirements. (See Figure 11.2.5-1) Since this system would abandon the existing MPS system, it is not considered cost-effective.

Concept 3:
Provides a new 5000-gpm variable pump and 8 inch transfer line for the LRB. (See Figure 11.2.5-1) This concept does not change any of the existing MPS operational procedures. The Transfer line and pump needed are smaller than the one required for Concept 2 and therefore will be less costly (Figure 11.2.5-2).

All concepts will require a second 900,000-gallon storage vessel to meet turnaround requirements without storage vessel refill. Also in the recommended design is the capability to offload ten tankers at a time instead of the present five.

### 11.2.6 Conclusion/Recommendations

The existing LOX Facility cannot meet program requirements for scrub/turnaround in 24 hours; therefore, doubling the facility size is required. Also included in the recommendation is the doubling of the tanker fleet so that number of shifts required to fill the storage vessel is reduced.

| | | ET ONLY | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/LH2 PUMP-FED | GDSS LOX/CH4 PUMP-FED | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED |
|---|---|---|---|---|---|---|---|---|
| SLOW FILL EACH | (GAL) | 2642.58 | 1440.21 | 2251.39 | 1165.09 | 1481.35 | 1337.51 | 1578.52 |
| SLOW FILL PAIR | (GAL) | | 2880.42 | 4502.78 | 2330.19 | 2962.70 | 2675.03 | 3157.04 |
| ON BOARD 0-2% | | | | | | | | |
| FAST FILL EACH | (GAL) | 126843.81 | 69130.15 | 108066.65 | 55924.56 | 71104.80 | 64200.66 | 75768.93 |
| FAST FILL PAIR | (GAL) | | 138260.30 | 216133.30 | 111849.12 | 142209.60 | 128401.32 | 151537.86 |
| ON BOARD 2-98% | | | | | | | | |
| TOPPING EACH | (GAL) | 2642.58 | 1440.21 | 2251.39 | 1165.09 | 1481.35 | 1337.51 | 1578.52 |
| TOPPING PAIR | (GAL) | | 2880.42 | 4502.78 | 2330.19 | 2962.70 | 2675.03 | 3127.04 |
| ON BOARD 96-100% | | | | | | | | |
| FAST FILL ET | | | | | | | | |
| FLOW RATE | (GPM) | 1300.00 | | | | | | |
| TIME | (MIN) | 114.00 | | | | | | |
| BOIL OFF FACTOR | | 1.17 | | | | | | |
| TOTAL FLOW QTY ET | (GAL) | 148200.00 | | | | | | |
| FAST FILL ET/LRB WORST | | | | | | | | |
| USING EXISTING SYSTEM | | | | | | | | |
| OPTION 1 | | | | | | | | |
| FLOW RATE LRB PAIR | (GPM) | | 4134.01 | 5730.22 | 3592.64 | 4214.96 | 3931.93 | 4406.17 |
| TIME | (MIN) | | 114.00 | 114.00 | 114.00 | 114.00 | 114.00 | 114.00 |
| TOTAL FLOW QTY LRB/SSV | (GAL) | | 471277.30 | 653245.64 | 409561.43 | 480505.74 | 448239.50 | 502303.39 |
| TOTAL FLOW ET/LRB | (GPM) | | 5434.01 | 7030.22 | 4892.64 | 5514.96 | 5231.93 | 5706.17 |
| TIME WITH 1300GPM | (MIN) | | 362.52 | 502.50 | 315.05 | 369.62 | 344.80 | 386.39 |
| USE EXISTING 1M PUMP | | | NO | NO | NO | NO | NO | NO |
| NEW LRB/ET SYSTEM | | | | | | | | |
| OPTION 2 | | | | | | | | |
| TIME OF FAST FILL 114 MIN | | | | | | | | |
| TOTAL FLOW ET/LRB | (GPM) | | 5434.01 | 7030.22 | 4892.64 | 5514.96 | 5231.93 | 5706.17 |
| NEW PUMP | | | 6M | 8M | 5M | 6M | 6M | 6M |
| NEW LINE | | | 10" | 12" | 8" | 10" | 10" | 10" |
| NEW LRB SYSTEM | | | | | | | | |
| OPTION 3 | | | | | | | | |
| TOTAL FLOW LRB | (GPM) | | 4134.01 | 5730.22 | 3592.64 | 4214.96 | 3931.93 | 4406.17 |
| PUMP | | | 4M | 6M | 4M | 5M | 4M | 5M |
| LINE | | | 8" | 10" | 8" | 8" | 8" | 8" |

Figure 11.2.5-1. LOX System Sizing Requirements.

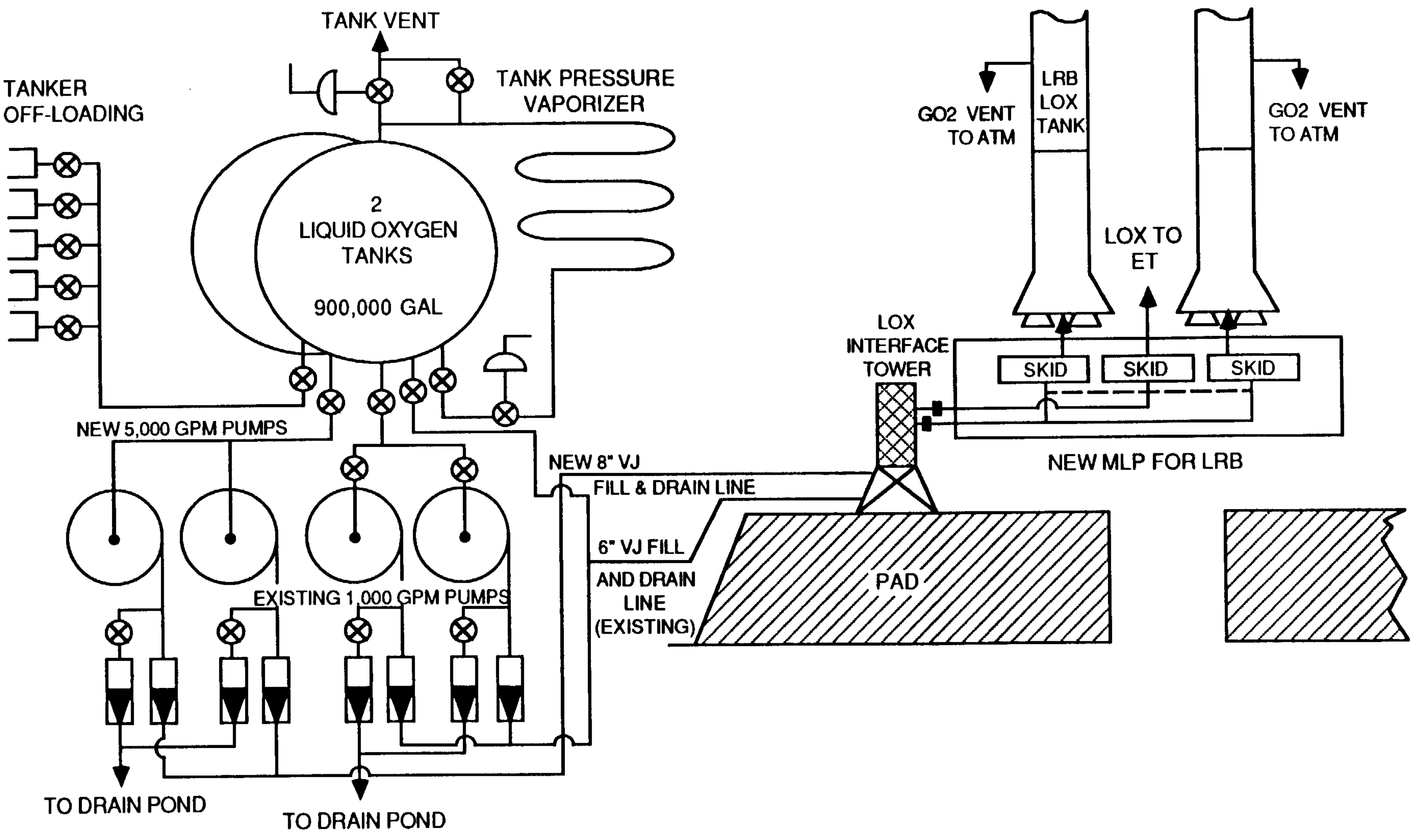

Figure 11.2.5-2. Liquid Oxygen Servicing System.

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### 11.2.7 Reference Documentation

MPS LOX Schematic - 79K06006
MPS LOX Operating Criteria - 79K05735
MPS LOX System Automatic Load and Drain - OMI 51003
LOX System Preps for Vehicle Loading - OMI B3151
LOX System Securing After - OMI B3153
LOX System Scrub/Turnaround - OMI B3155
Oxygen Properties - NASA SP 3071

## 11.3 LIQUID HYDROGEN

The analysis of the LRB LH2 requirements is based on data provided by General Dynamics, known ET/SSME processing operational data, and present SSV interface control requirements. The single LRB configuration was analyzed to define fill and drain requirements including anticipated boiloff results; define scrub/turnaround options; and LH2 storage and acquisition requirements,as well as to provide a description of a LRB LH2 facility and ground system.

The approach to determine the LH2 facility requirements to support the LRB configurations is accomplished by baselining the present ET loading system and interpolating the LRB requirement. Assumptions of the analysis include: the insulation quality of the ET and the LRB is the same, the transfer system insulation for ET and LRB are the same, and the engine bleed for each LRB engine and each SSME is the same. These assumptions allow a correlation of facility and loading requirement for the six LRB configurations based on the ET/SSME.

### 11.3.1 LRB Loading Requirements

Currently, the ET loading operation consumes approximately 300,000 pounds of LH2 (522,958 gallons). The ET will contain 356,911 gallons at launch, which means 166,047 gallons are lost to chilldown, boiloff, replenish, and high point engine bleed during loading. Figure 11.3.1-1 illustrates and breaks down the data in the "ET" column.

The GDSS data gives the on-board LH2 requirement in pounds. Figure 11.3.1-1 converts pounds to gallons at 50 psia and 40 °R.

|  |  | ET ONLY |  | EACH<br>GDSS LOX/LH2<br>PUMP-FED |
|---|---|---|---|---|
| TOTAL LOAD REQUIREMENT | (LB) | 300000.00 | I | 130310.62 |
| (I=ICD DATA, R=RATIO OF LRB TO ET) | (GAL) | 522957.46 |  | 227156.37 |
| NOTE 1 |  |  |  |  |
| VEHICLE VOL | (CF) | 53017.00 | X | 21367.05 |
| ULLAGE | (%) | 10.00 |  | 3.00 |
| ULLAGE VOLUME | (CF) | 5301.70 |  | 641.01 |
| FLIGHT LH2 QUANTITY (X=GIVEN DATA) | (CF) | 47715.30 |  | 20726.03 |
|  | (LB) | 204745.40 |  | 88935.00 |
|  | (GAL) | 356910.44 |  | 155030.74 |
| FILL LOSSES | (GAL) | 166047.02 |  | 72125.63 |
| HP BLEED @ | (GAL) | 8628.80 | I | 8628.80 |
| TOTAL LOSSES (FILL AND HP BLEED) | (GAL) | 174675.81 |  | 80754.43 |
| TOTAL LOSSES LRB/SSV LOADING | (GAL) | 174675.81 |  | 336184.67 |
| DRAIN LOSSES (A=ASSUMED) | (GAL) | 5100.00 | A | 2215.28 |
| TOTAL LOSSES LRB/SSV DRAIN | (GAL) | 5100.00 |  | 9530.56 |
| TOTAL TO LOAD | (GAL) | 522957.46 |  | 977270.20 |
| TANK MIN TO LOAD | (GAL) | 722957.46 |  | 1177270.20 |
| MIN TANK QTY | (GAL) | 200000.00 |  | 200000.00 |
| FULL TANK | (GAL) | 846000.00 |  | 846000.00 |
| TANK AFTER 1st F&D | (GAL) | 666224.19 |  | INSUFFICIENT<br>TO FILL |

NOTES: 1: TOTAL @ 50 PSIA, 40 deg R, 4.29098 LB/CF (PER NASA SP-3088)

2: 15 LB/MIN, 40 deg R, 50 PSIA, 4.29098 LB/CF FOR 5.5 HOURS (PER NASA SP-3088)

Figure 11.3.1-1 Analysis of ET/LRB LH2 Requirements.

The LH2 loading requirements (including loading losses) for each LRB were obtained by interpolating LRB tank quantity and ET tank quantity with the ET losses. The LH2 loading losses for each LRB are shown in Figure 11.3.1-1.

LRB high point engine bleed requiremes for each engine, as stated earlier, are assumed to be the same as for each SSME. This results in each LRB with four engines consuming 11,504 gallons for engine bleed. Figure 11.3.1-1 shows the total LH2 quantity needed to load and provide engine bleed for each LRB.

#### 11.3.1.1 Existing Storage Capability

The existing LH2 storage vessels at Launch Complex 39A and 39B have a 900,000-gallon capacity. With a 6% ullage, they each contain a maximum of 846,000 gallons of LH2. The minimum allowed quantity for these vessels is 200,000 gallons. The minimum was established during the Apollo program and is maintained in the STS program. The minimum requirement was established to prevent a thermal cycle on the vessel so as not to cause an extreme temperature gradient from top to bottom.

Figure 11.3.1-1 shows the minimum LH2 necessary to load the LRB/SSV (ET plus two LRBs). The results indicate that the present storage vessels contain insufficient LH2 to fill LRB/SSV once.

#### 11.3.1.2 Double Storage Capacity

Doubling the LH2 storage capacity by adding a second 900,000-gallon vessel would make loading the LRB/SSV possible. See Figure 11.3.1-2.

### 11.3.2 Drain Analysis

Currently, when the ET is drained, approximately 5,100 gallons of LH2 are lost to chilldown of the transfer line and boiloff. The LRB drain losses figure was obtained by interpolating the onboard ET quantity and drain losses and the on-board LRB quantities. Figures 11.3.1-1 and 11.3.1-2 show the anticipated LRB drain losses for the LRB.

|  |  | ET ONLY | EACH GDSS LOX/LH2 PUMP-FED |
|---|---|---|---|
| TOTAL LOAD REQUIREMENT | (LB) | 300000.00 I | 130310.62 |
| (I=ICD DATA, R=RATIO OF LRB TO ET) | (GAL) | 522957.46 | 227156.37 |
| NOTE 1 |  |  |  |
| VEHICLE VOL | (CF) | 53017.00 X | 21367.05 |
| ULLAGE | (%) | 10.00 | 3.00 |
| ULLAGE VOLUME | (CF) | 5301.70 | 641.01 |
| FLIGHT LH2 QUANTITY (X=GIVEN DATA) | (CF) | 47715.30 | 20726.03 |
|  | (LB) | 204745.40 | 88935.00 |
|  | (GAL) | 356910.44 | 155030.74 |
| FILL LOSSES | (GAL) | 166047.02 | 72125.63 |
| HP BLEED @ | (GAL) | 8628.80 I | 8628.80 |
| TOTAL LOSSES (FILL AND HP BLEED) | (GAL) | 174675.81 | 80754.43 |
| TOTAL LOSSES LRB/SSV LOADING | (GAL) | 174675.81 | 336184.67 |
| DRAIN LOSSES (A=ASSUMED) | (GAL) | 5100.00 A | 2215.28 |
| TOTAL LOSSES LRB/SSV DRAIN | (GAL) | 5100.00 | 9530.56 |
| TOTAL TO LOAD | (GAL) | 522957.46 | 977270.20 |
| TANK MIN TO LOAD | (GAL) | 722957.46 | 1177270.20 |
| MIN EACH TANK QTY | (GAL) | 200000.00 | 200000.00 |
| FULL TANK | (GAL) | 1692000.00 | 1692000.00 |
| TANK AFTER 1ST F&D | (GAL) | 1512224.19 | 1346284.76 |
| TANK AFTER 2ND F&D | (GAL) | 1332448.37 | 1000569.53 |
| TANK AFTER 3RD F&D | (GAL) | 1152672.56 |  |
| TANK AFTER 4TH F&D | (GAL) | 972896.75 |  |
| TANK AFTER 5TH F&D | (GAL) | 793120.93 |  |
| TANK AFTER 6TH F&D | (GAL) | 613345.12 |  |

NOTES: 1: TOTAL @ 50 PSIA, 40 deg R, 4.29098 LB/CF (PER NASA SP-3088)
2: 15 LB/MIN, 40 deg R, 50 PSIA, 4.29098 LB/CF FOR 5.5 HOURS (PER NASA SP-3088)

Figure 11.3.1-2 Analysis of LH2 Requirements Using Double Capacity.

### 11.3.3 Scrub/Turnaround

As shown in Paragraph 11.3.1, insufficient LH2 is present to fill a LRB/SSV with the existing storage capacity, and double storage capacity would be required. Figure 11.3.1-2 shows the number of loading capable from the two storage vessels. Figure 11.3.3 shows for each LRB/SSV the number of tankers and days needed to fill each of the storage vessels to either the 846,000 gallon mark or the minimum to allow filling the LRB/SSV. Currently, 10 tankers are available which can offload 100,000 gallon of LH2 in four hours using the existing five fill stations. Assuming the LH2 plant in Louisiana can turn around the tankers in 72 hours, LH2 can be supplied to KSC at a rate of 200,000 gallons per week (Monday and Friday only) with a three- shift operation. To achieve a 24-hour turnaround would require increasing the tanker fleet to 30.

### 11.3.4 Acquisition

The liquid hydrogen supplied to KSC arrives by over-the-road tankers from Louisiana. The cost of LH2 is $1 per gallon . The tanks deliver 10,000 gallons each, and currently there are ten. Turnaround of the tankers takes 72 hours, of which four hours are used to offload into the storage vessel on the Pad.

### 11.3.5 LRB LH2 System Description

The analysis of the LRB requirement resulted in the conclusion that the existing 10- inch vacuum jacket transfer line can provide the LH2 flow for LRB and ET. Figure 11.3.5 shows a general arrangement of equipment. The LRB valve skids can be connected to the LH2 transfer line on the MLP upstream of the MPS LH2 valve skid.

### 11.3.6 Conclusion/Recommendation

The existing LH2 Facility cannot meet program requirements for loading a LRB/SSV; therefore, doubling the facility size is required. Also included in the recommendation is the tripling of the tanker fleet so that the number of shifts required to fill the storage vessel would be reduced.

|  |  | ET | GDSS LOX / LH2 PUMP |
|---|---|---|---|
| EXISTING FLEET |  |  |  |
| ADD MIN TO LOAD VEHICLE | (GAL) | 109612.34 | 176700.67 |
| TANKER @ 10000 GAL (20 TANKERS / WEEK) | ( # ) | 9.96 | 16.06 |
| WEEKS (ONE WEEK = TWO 8-HOUR SHIFTS) | (WKS) | 0.50 | 0.80 |
| TURNAROUND (10 TANKERS / DAY M, F) | (DAYS) | 1 | 5 |
| QTY TO FILL TANK | (GAL) | 1078654.88 | 691430.47 |
| TANKER @ 10000 GAL (20 TANKERS / WEEK) | ( # ) | 98.06 | 62.86 |
| WEEKS (ONE WEEK = TWO 8-HOUR SHIFTS) | (WKS) | 4.90 | 3.14 |
| TURNAROUND (10 TANKERS / DAY M, F) | (DAYS) | 33 | 22 |
| DOUBLE FLEET |  |  |  |
| ADD MIN TO LOAD VEHICLE | (GAL) | 109612.34 | 176700.67 |
| TANKER @ 10000 GAL (40 TANKERS / WEEK) | ( # ) | 9.96 | 16.06 |
| WEEKS (ONE WEEK = FOUR 8-HOUR SHIFTS) | (WKS) | 0.25 | 0.80 |
| TURNAROUND (20 TANKERS / DAY M, F) | (DAYS) | 1 | 1 |
| QTY TO FILL TANK | (GAL) | 1078654.88 | 691430.47 |
| TANKER @ 10000 GAL (40 TANKERS / WEEK) | ( # ) | 98.06 | 62.86 |
| WEEKS (ONE WEEK = FOUR 8-HOUR SHIFTS) | (WKS) | 2.45 | 1.57 |
| TURNAROUND (20 TANKERS / DAY M, F) | (DAYS) | 15 | 12 |
| TRIPLE FLEET |  |  |  |
| MIN TO LOAD VEHICLE | (GAL) | 109612.34 | 176700.67 |
| TANKER @ 10000 GAL (60 TANKERS / WEEK) | ( # ) | 9.96 | 16.06 |
| WEEKS (ONE WEEK = SIX 8-HOUR SHIFTS) | (WKS) | 0.17 | 0.27 |
| TURNAROUND (30 TANKERS / DAY M, F) | (DAYS) | 1 | 1 |
| QTY TO FILL TANK | (GAL) | 1078654.88 | 691430.47 |
| TANKER @ 10000 GAL (60 TANKERS / WEEK) | ( # ) | 98.06 | 62.86 |
| WEEKS (ONE WEEK = SIX 8-HOUR SHIFTS) | (WKS) | 1.63 | 1.05 |
| TURNAROUND (30 TANKERS / DAY M, F) | (DAYS) | 12 | 8 |

1 DAY IS AN 8-HOUR NORMAL SHIFT
10 TANKS PRESENTLY AVAILABLE
72-HOUR TURNAROUND FROM LOUISIANA

Figure 11.3.3. LH2 Storage Fill (Turnaround) Requirement Using Double Capacity.

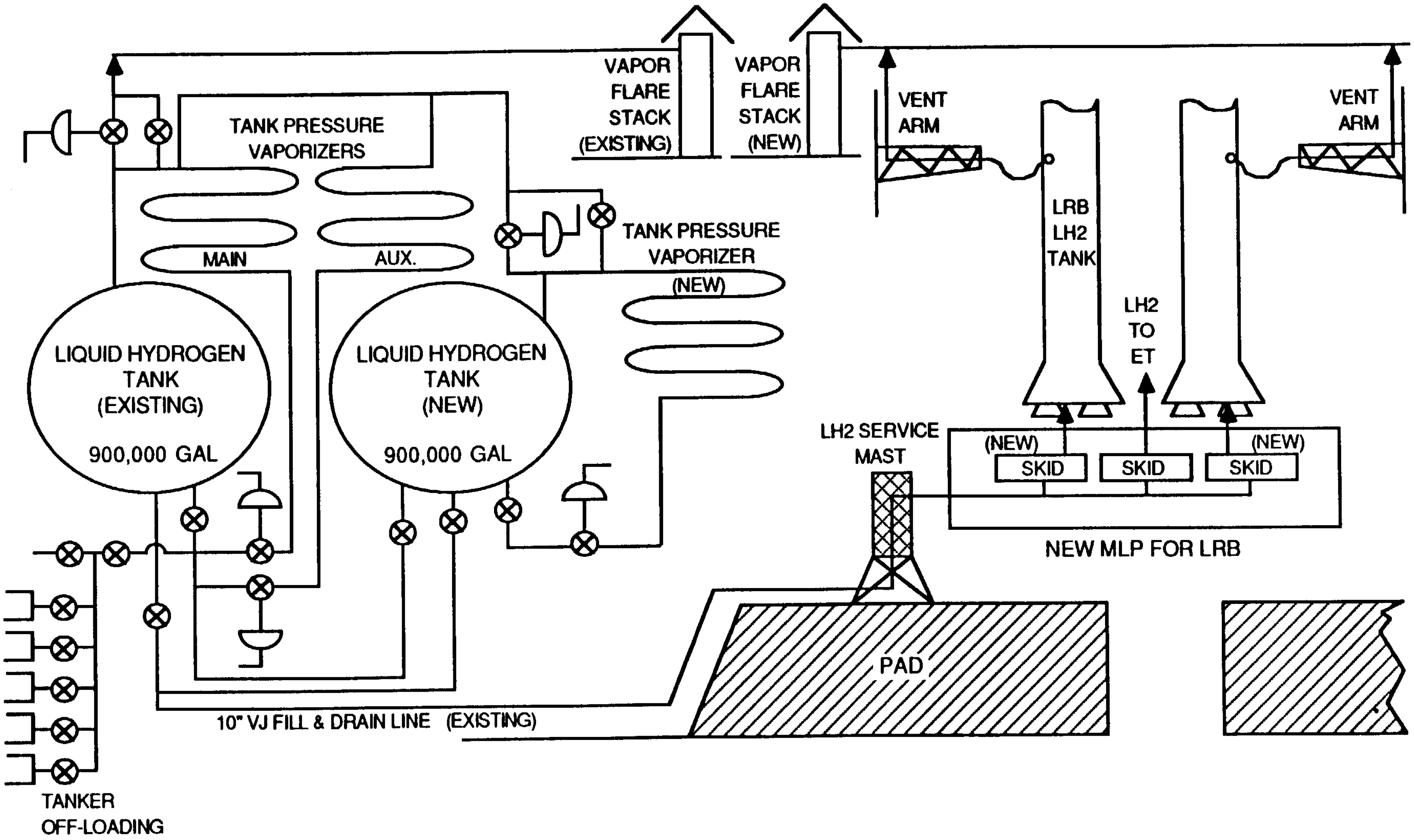

Figure 11.3.5. Liquid Hydrogen Servicing System.

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### 11.3.7 Reference Documentation

MPS LH2 Schematic - 79K06063
MPS LH2 Operating Criteria - 79K05896
MPS LH2 System Automatic Load and Drain - OMI 51004
LH2 System Preps for Vehicle Loading - G3251
LH2 System Securing After - G3254
LH2 System Scrub/Turnaround - G3255
Hydrogen Properties - NASA SP 3088

## 11.4 RP-1

The GDSS and MMC LOX/RP-1 data gives four configurations/options for the LOX/RP-1 system. These options involve the use of either pump- or pressure-fed liquid rocket boosters. Figure 11.4 shows the required quantities of RP-1 for each option. Assuming a 3% ullage, the GDSS pressure-fed mechanism requires the delivery of 115,297 gallons of RP-1. (See Figure 11.4) This option involves the largest quantity of RP-1, and for the purpose of clarity, unless otherwise indicated, this report will discuss this scenario. Also included in this study is an evaluation of the transfer method from storage to vehicle.

Due to the physical properties of RP-1, transfer and storage facilities would not involve a mass loss of RP-1 (such as boiloff). This quality simplifies a scrub/turnaround operation, and no additional storage space would be required above that necessary to support the vehicle and maintain a required mass storage capacity.

One of the advantages of RP-1/LOX is that it was used during the Apollo Program. A new baseline would be required, and a rebirth of the Apollo documentation should prove sufficient. There are still some existing installations involving RP-1, such as storage facilities on Pad A; however, these facilities have been abandoned in place and to assume their useability would be unrealistically optimistic. To presume the worst, an RP-1 system would require the installation of an entirely new storage and transfer mechanism.

| | | GDSS RP-1 PUMP-FED | GDSS RP-1 PRESS-FED | MMC RP-1 PUMP-FED | MMC RP-1 PRESS-FED |
|---|---|---|---|---|---|
| VEHICLE VOL EACH LRB (X=GIVEN DATA) | (CF) | 6163.16 | 7938.21 | 5969.88 | 6517.84 |
| ULLAGE | (%) | 3.00 | 3.00 | 3.00 | 3.00 |
| | (CF) | 184.89 | 231.21 | 173.88 | 189.84 |
| RP-1 VOL EACH LRB (X=GIVEN DATA) | (CF) | 5978.26 | 7707.00 X | 5796.00 X | 6328.00 X |
| | (LB) | 275000.00 X | 354522.00 | 266616.00 | 291088.00 |
| | (GAL) | 44717.29 | 57648.35 | 43354.08 | 47333.44 |
| RP-1 VOL TOTAL | (GAL) | 89434.78 | 115296.70 | 86708.16 | 94666.88 |
| LRB FILL LOSSES | | | | | |
| LOSSES EACH LRB | (GAL) | N/A | N/A | N/A | N/A |
| MIN. ALLOWABLE RP-1 IN STORAGE | (GAL) | 100000.00 | 100000.00 | 100000.00 | 100000.00 |
| STORAGE REQ MIN | (GAL) | 189434.78 | 215296.70 | 186708.16 | 194666.88 |
| STORAGE VESSEL CONTAINS LESS THE 10000 GAL MIN & 6% ULLAGE | (GAL) | SUFFICIENT | SUFFICIENT | SUFFICIENT | SUFFICIENT |
| RP-1 FAST FILL REQ'D | (%) | 96.00 | 96.00 | 96.00 | 96.00 |
| | (GAL) | 85857.39 | 110684.83 | 83239.83 | 90880.21 |
| RP-1 FAST FILL FLOW RATE (ASSUMED 114 MIN. FILL) | (GPM) | 753.13 | 970.92 | 730.18 | 797.19 |

Figure 11.4. Analysis of LRB RP-1 Loading Requirement.

### 11.4.1 Properties of RP-1

RP-1 is a semiodorless, colorless liquid under normal conditions. Actually, RP-1 is the commercial name given to a high grade of kerosene, which is a mixture of heavy organic hydrocarbons. As a mixture its properties can very; however, the assumption has been that RP-1 physical properties approach that of decane ($C10H22$), with a molecular weight of 142.28 lb/lb mole. RP-1 has a density of 45.6 lb/cu ft with melting and boiling points far beyond the scope of atmospheric conditions (Mp=-29.7 $^{o}C$, Bp=174 $^{o}C$).

As with organic fuel, RP-1 combusts readily with oxygen to produce $CO2$, $H20$, and heat. Like most of the heavier organic fuels, RP-1 requires vaporization to achieve its maximum burning efficiency; however, once an initial ignition source is present, the reaction is spontaneous.

### 11.4.2 Acquisition

The acquisition of RP-1 would require the use of rail cars, the method used in the Apollo program, and RP-1's high density (relative to LOX, LH2, and LCH4) and liquid state make delivery by any other means, such as pipeline, impractical. The transport of RP-1 by rail cars is governed by Department of Transportation regulations involving the shipping of hazardous commodities, and there are no current restrictions on such delivery.

RP-1 is available through several commercial distributors at a cost of approximately $3/gallon (1988 cost). This figure translates to a cost of $345,809 (1988 cost) per launch vehicle. Further study, exact quantities, offloading specifics, and lead-time would be required before the best distributor could be named.

### 11.4.3 Storage

The storage of RP-1 would be based on the Apollo concept of three 85,000-gal storage tanks. Environmental regulations will require that these tanks be bunkered or buried. Design considerations of these storage tanks would be strongly dependent on the type of transfer mechanism used, and it is appropriate to discuss each mechanism separately.

### 11.4.3.1 Storage of Hydraulic Transfer System

Storage of Hydraulic Transfer System would involve the use of three 85,000-gal tanks, as mentioned above. Tank construction would be a single-wall-type, constructed of stainless steel. Design pressure would be approximately 1,000 psig, with design temperature of approximately 60 °F. Tank design would include a pressurization line (GN2), burst disk, instrumentation, and vent capability. Estimated cost of such a facility would be $1.5 million (1988). The facility must also include a GN2 purge system to prevent a possible explosion.

### 11.4.3.2 Storage of Pump-Transfer System

Once again the facility would involve the use of three 85,000-gal tanks. Tank construction would be of stainless steel, single-wall type. Design pressure and temperature would be at or near atmospheric. Vent and burst disk requirements would not be needed. Estimated cost of such a facility: $800,000 (1988). The facility itself would not require a GN2 purge; however, the associated pumping system would.

### 11.4.4 RP-1 Handling and Transfer

Many of the concepts discussed in this section are based on the Apollo system. RP-1 handling procedures were well established during the Apollo program. Common sense precautions when handling an explosive fuel (such as during purges and with redundant systems), would prove adequate with RP-1 and LRBs.

### 11.4.4.1 RP-1 Transfer (Hydraulic Transfer)

The transfer of RP-1 by pressure would involve a 3-phase filling process:

- Slow fill to 2% (30-40 min)
- Fast-fill to 98% (1-1/2-2 hr)
- Topping to full load (30-40 min)

The filling process requires the delivery of 115,297 gallons of RP-1 to an elevation of approximately 200 feet. This elevation translates to a 64 psig pressure head. The pressure must be delivered through an approximate 1,600-ft line. To minimize line loss, an 8-inch insulated line was considered (Note: An existing 8-inch insulated line is currently available at both Pads; however, the condition of the line is unknown.) Assuming an average fast-fill time of 114 minutes, this translates to the delivery of 96% of RP-1 (110,685 gallons) at a flow rate of 970 gallons per minute. At this flow rate, line losses are estimated to be 25 psi. This loss, along with the required head at delivery (64 psig) translates to an 89 psig system minimum; however, this minimum pressure translates to a minimum flow. To achieve the desired flow rates and allow delivery regulating controls to operate within acceptable safety limits, a pressure of 1,000 psig would be required.

#### 11.4.4.2 RP-1 Transfer (Pump)

The transfer of RP-1 by pump would require a similar phase loading process. Pump peak loads would occur during the fast-fill period when a maximum flow rate of 970 gpm would again be expected. To avoid pump strain, a 2,000-gpm variable speed pump is recommended. Furthermore, to avoid the possible over-pressurization problems found in positive displacement pumps, a centrifugal-type pump would be necessary. A similar delivery length and elevation (1,600 feet; up 200 feet) would exist in both pressure- and pump-fed systems; however, line loss in a pump-driven system would not be so critical. A 6-inch insulated line would prove sufficient providing the existing 8-inch line is unusable. This line would lead to a pressure drop of approximately 80 psi, and this figure, along with the required delivery head of 64 psig (from the pressure-fed scenario) relates to a pump requirement of 144 psi head. It is recommended that a 2,000-gpm centrifugal pump capable of delivering 250 psig be used.

### 11.4.5 RP-1 System Design Concepts

#### 11.4.5.1 Design Concept for Hydraulic Transfer

The use of a pressure-fed RP-1 system also involves the installation of a new transfer (and probably storage) facility at KSC. Figure 11.4.5.1 shows an overview of the major components required in the new system. Three 85,000-gallons storage tanks with a burst disk venting system would hold the RP-1, while a new 1,000-psig GN2 source would provide the motive force. All other aspects of the pressure-fed system would be similar to those described in the pump-fed system.

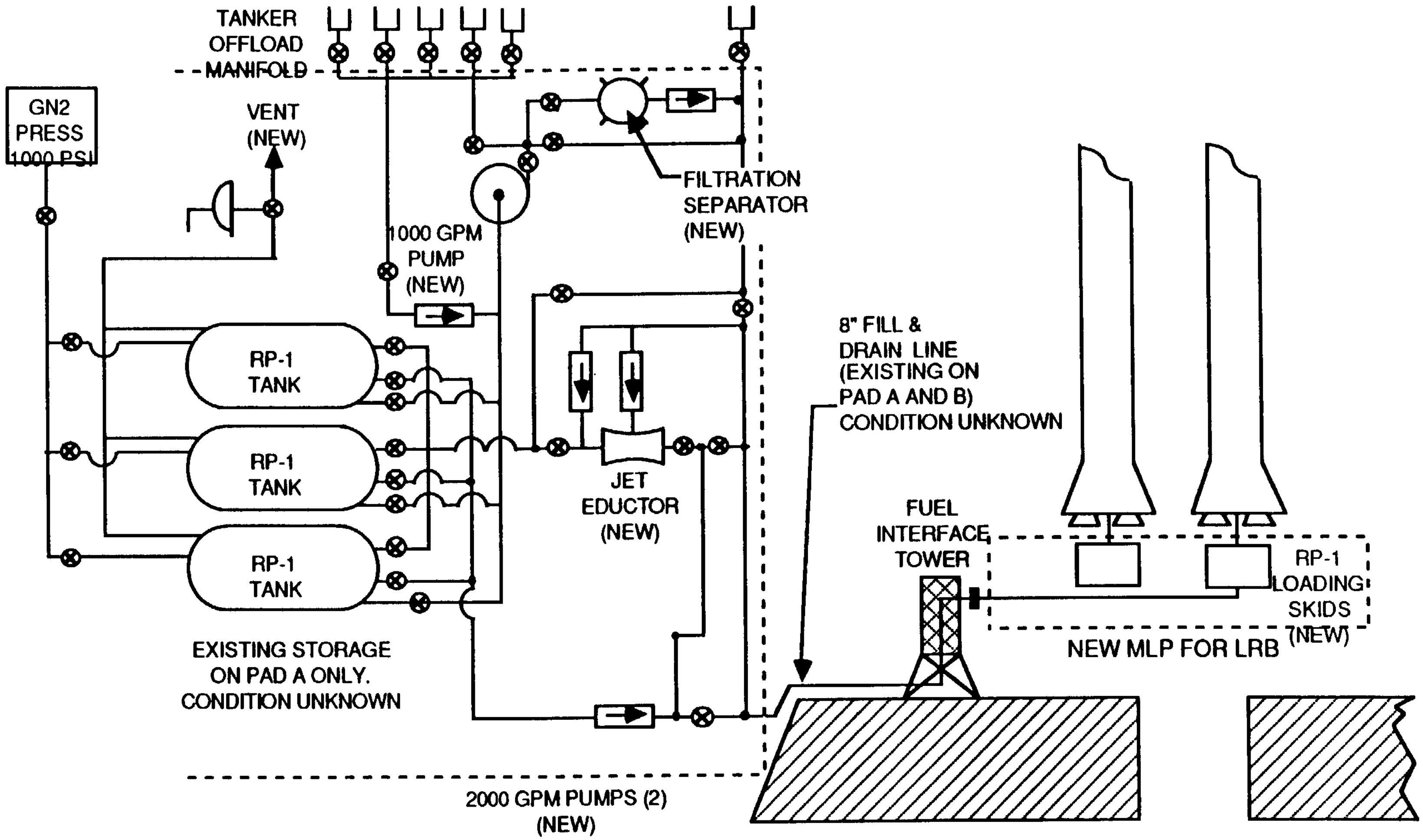

Figure 11.4.5.1. RP-1 Servicing System For LRB's (Hydraulic Transfer)

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### 11.4.5.2 Design Concept for Pump Transfer

The use of pump-fed RP-1 system involved the installation of a new transfer (and probably storage) facility at KSC. Figure 11.4.5.2 shows an overview of the major components required in the new system. Three 85,000-gallon storage tanks would hold the RP-1, while a redundant two-pump system would provide the motive force. A new eductor system would aid the hydraulic pressures in the event that a scrub turnaround was required. Finally, a secondary 1,000 gpm-pumping system would provide a purification capacity in the event it were required.

### 11.4.6 Reference Documentation

Chemical Engineers' Handbook, 5th Edit., Perry & Chilton,
Section 9, 1973

Tenneco Oil Co. Operators Handbook, Page 210, 1961

LC 39 RP-1 Mechanical System (SFD) 79K00083

LC 39 B/ML-1 RP-1 System Mechanical Specification for
SKYLAB Modifications 79K01001

RP-1 System Mechanical Specifications Complex 39A 75M05867

## 11.5 LIQUID METHANE

The GDSS LOX/LCH4 LRB data gives a tank volume of 8,014.8 cubic feet, with a 3% ullage, which requires a volume of methane per booster of 7,741.06 cubic feet. This equates to a liquid methane load of 57,903.16 gallons per booster or 115,806.32 gallons per LRB/SSV. (See Figure 11.5-1.)

It is assumed that the Liquid Methane (LCH4) boiloff, bleed, and chill-down losses would approximate that which currently is found in the LOX system. This assumption is based on the similar properties of cryogenic LOX and LCH4, although it is understood that this assumption will lead to some error. This error is small in comparison to the scope of the study. LCH4 loss per LRB is assumed to be 10,420 gallons per LRB, or 20,840 gallons per SSV loading. This figure, along with

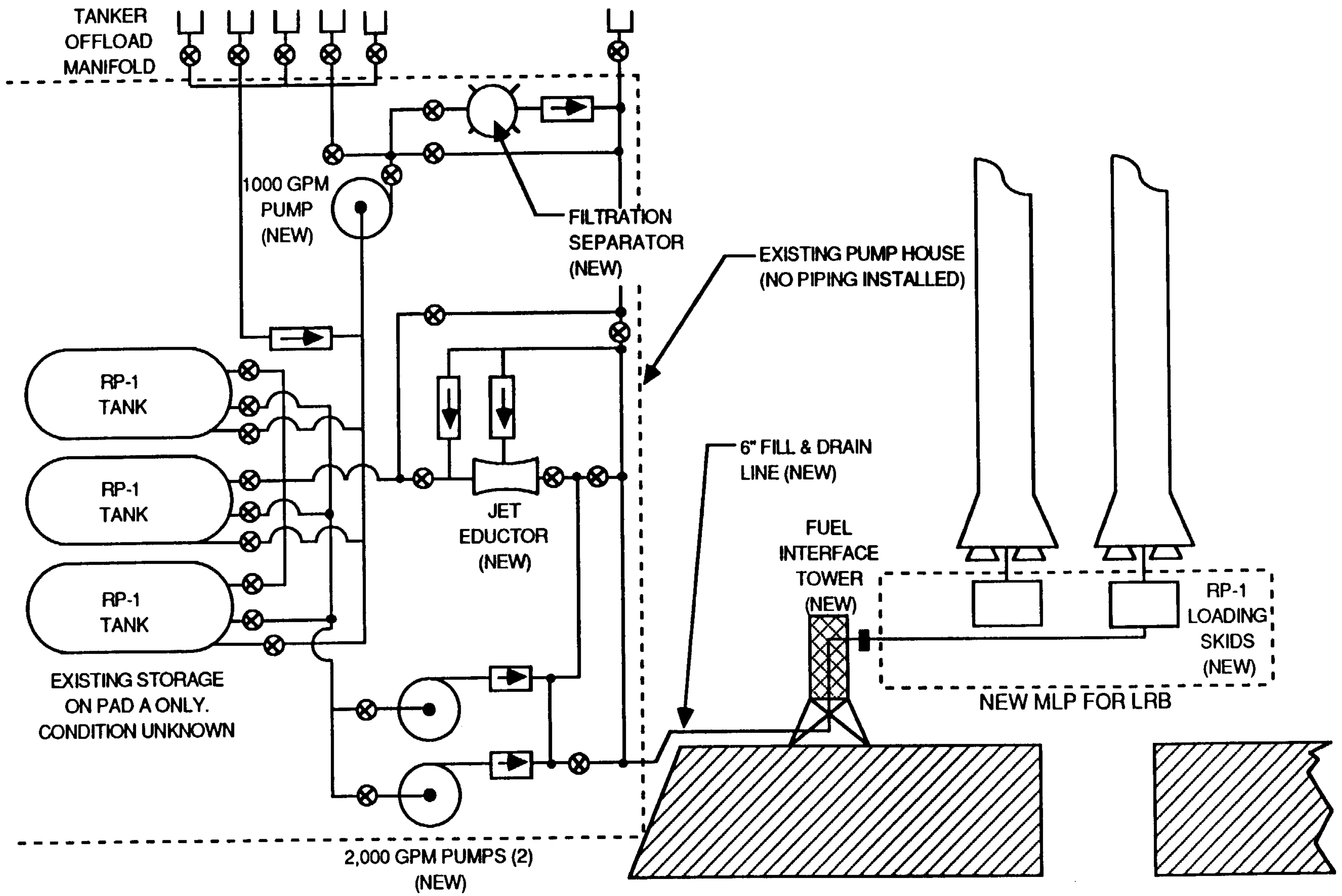

Figure 11.4.5.2. RP-1 Servicing System For LRB'S (Pump-Transfer).

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| | | GDSS LCH4 PUMP-FED |
|---|---|---|
| VEHICLE VOL EACH LRB (X=GIVEN DATA) | (CF) | 8014.80 |
| ULLAGE | (%) | 3.00 |
| | (CF) | 240.44 |
| LCH4 VOL EACH LRB (X=GIVEN DATA) | (CF) | 7741.06 |
| | (LB) | 204364.10 X |
| | (GAL) | 57903.16 |
| LRB FILL LOSSES (A=ASSUMED) | | |
| LOSSES EACH LRB (BASED ON LOX SYSTEM) | (GAL) | 10420.28 A |
| TOTAL FILL LOSS | | |
| TOTAL FILL LOSS EACH LRB | (GAL) | 10420.28 |
| QTY REQ FOR ONE LRB | (LB) | 241141.56 |
| | (GAL) | 68323.44 |
| QTY REQ FOR TWO LRBs | (LB) | 482283.13 |
| | (GAL) | 136646.89 |
| MIN. ALLOWABLE LCH4 IN STORAGE | (GAL) | 200000.00 |
| STORAGE REQ MIN | (GAL) | 336646.89 |
| STORAGE VESSEL CONTAINS<br>LESS THE 200,000 GAL. MIN.<br>AND 6% ULLAGE | (GAL) | SUFFICIENT |

Figure 11.5-1. Analysis of LRB LCH4 Loading Requirement.

the vehicle requirements, leads to a total consumed quantity of LCH4 to be 136,647 gallons per SSV loading.

In the event that a scrub/turnaround requires vehicle drain, drain losses are assumed, once again based on LOX system, to be 2,191 gallons per SSV drain. (See Figure 11.5-2.)

The largest challenge to the use of methane is the inherent unknowns involved in the establishment of any new system. A new baseline would be required, along with the installation of an entirely new storage and transfer system. Much of the data used in the estimation of these facilities was provided by Pittsburgh-Des Moines Corp.

### 11.5.1 Properties of Methane

Methane is an odorless, colorless gas under standard conditions. Its chemical formula is LCH4, and it has a molecular weight of 16 lb/lb mol. Methane has a density of 26.4 lb per cubic foot (3.5316/lb per gallon) at 14.7 psia at 110 °K (202 °R), which approximates storage conditions. At standard conditions, methane's density is 0.0448 lb per cubic ft, which is approximately half that of air (0.0808 lb per cubic ft) at similar conditions. The normal boiling point of methane is 111.7°K.

Methane is an organic fuel. It combusts readily in the presence of oxygen:

$$LCH_4 + 2O_2 = CO_2 + 2H_2O + (heat)$$

This reaction is spontaneous once an initial ignition source is present. Although no reaction is 100% complete, the burning of LCH4 in the presence of O2 approaches this 100% completion. The actual quantities of unburned LCH4 in the effluent gas stream would be strongly dependent upon reaction conditions, and to estimate residual LCH4 quantities in an LRB would be impractical at this time.

### 11.5.2 Methane Acquisition

Three options were considered for the acquisition of methane:

- Production Liquefaction/Purification Storage

| | | GDSS LCH4 PUMP-FED |
|---|---|---|
| LRB DRAIN LOSS (A=ASSUMED) | (GAL) | |
| EACH LRB DRAIN LOSSES (BASED ON LOX SYSTEM) | (GAL) | 2191.16 A |
| TOTAL TO LOAD STS | (GAL) | 136646.89 |
| TOTAL STS LOADING LOSSES | (GAL) | 20840.56 |
| TANK MIN TO LOAD | (GAL) | 466646.89 |
| FULL TANK | (GAL) | 704000.00 |
| TANK AFTER 1ST F&D | (GAL) | 678777.12 |
| SCRUB/TURNAROUND | | YES 9 FILLS |
| TANK AFTER 2ND F&D | (GAL) | 653554.23 |
| TANK AFTER 3RD F&D | (GAL) | 628331.35 |
| TANK AFTER 4TH F&D | (GAL) | 603108.47 |
| TANK AFTER 5TH F&D | (GAL) | 577885.58 |
| TANK AFTER 6TH F&D | (GAL) | 552662.70 |
| TANK AFTER 7TH F&D | (GAL) | 527439.82 |
| TANK AFTER 8TH F&D | (GAL) | 502216.93 |
| TANK AFTER 9TH F&D | (GAL) | 476994.05 |
| TANK AFTER 10TH F&D | (GAL) | 451771.17 |

Figure 11.5-2. Drain Analysis After Loading.

- Pipeline Liquefaction Storage
- Tanker Truck Storage

Option 1 was disregarded due to the excessive cost (above that required for storage) involved in the installation and maintenance of a liquefaction facility. Option 2 was also disregarded due to the environmental impacts involved in installing approximately 10 miles of liquid natural gas pipeline across the Florida/KSC wetlands.

Methane delivered by tanker truck is the most feasible method of methane acquisition; however, the proposed storage facilities could be upgraded to facilitate either option 1 or 2 if changes occur in the current Department of Transportation regulations involving the transport of hazardous commodities which mandate the stoppage of tanker truck deliveries.

Several companies provide liquid methane. Among these are Atlanta Gas, Atlanta, Georgia, and Alabama Gas, Birmingham, Alabama. An approximate cost figure for LCH4 of $0.35 per gal (1988) was provided by Alabama Gas. This figure translates to $48,000 per vehicle load, which does not include the cost of transportation. Alabama Gas currently uses Trans Gas (of Massachusetts) for the delivery of LCH4; however, no cost figure is available from Trans Gas because of the many unknowns (quantity, offloading specifics, and lead-time) involved in methane acquisition.

### 11.5.3 Storage

The storage of liquid natural gas (LNG) is fast becoming a commonplace technology. Several utility companies use stored LNG to reduce required plant size. Called peek saving facilities, these setups are used to supplement plant capacity during high load times. Pittsburgh-Des Moines Corp., Pittsburgh, Pa, has constructed several of this type facility and provided the following cost estimates and storage specifics. Based on a storage capacity of 750,000 gal, the cost of a storage tank, including insulation and foundation, would be $1.4 million (1988). The Pittsburgh-Des Moines Corporation can also provide/construct a complete turnkey storage facility, including truck unloading, boiloff compression, pumping system, controls, and instrumentation. The cost of a complete facility varies depending on specific project requirements. The storage tank would be a double-walled type, the inner tank would be constructed from aluminum or stainless steel, with an outer tank constructed from carbon steel of aluminum. Design pressure would be atmospheric with design temperature of 260 degrees F. Insulation would be primarily perlite, and vacuum jacketing of the storage tank would not be required.

A boil-off compression capacity would be required. Although a flare stack could be used during actual vehicle loading (and in the event of compressor downtime), continuous venting of LCH4 would not be allowed because of the damaging environmental impacts.

The final major aspect of a storage facility would be a storage fill capability. Five tanker connections with the capability to unload 10 tankers at 10,000 gallons each in four hours is planned. Figure 11.5.3 shows dthe time needed to refil the storage vessel after five fill and drains.

Figure ll.5.3 shows the required quantities of methane to support LRB loading. Based on these figures, a minimum storage capacity of 466,647 gallons would be required. This figure increases to an excess of 500,000 gal after only two fill and drain operations. Assuming a maximum of five fill and drain operations and sizing up to the nearest standard available tank size, a 750,000 gallon storage facility would be required. This storage quantity would allow for a maximum of nine fill and drain operations.

### 11.5.4 Methane Handling and Transfer

Many of the concepts discussed in these paragraph are based on the currently used LOX system and modified for methane.

#### 11.5.4.1 Handling

Handling of methane in both the storage facility and the LRBs involves methane in a saturated liquid state at or near atmospheric pressure. The temperature (-258° F) would be maintained by evaporation, with vent gases either recompressed to liquid during storage, or burned in a flare stack during loading. Recompression is favorable during storage due to the environmental impacts of continuously operating a flare stack; however, during loading, stringent limitations on methane's physical properties make the operation of a compressor an unnecessary variable. Once methane loading has been completed, a vent capture system (vent arm) would be required to prevent ice formation and possible Orbiter tile damage.

#### 11.5.4.2 Transfer

Methane transfer would involve the use of pumps and vacuum-jacketed lines. A pump-driven

| | | GDSS LCH4 PUMP-FED |
|---|---|---|
| MIN IN STORAGE TO LOAD ET/LRB | | 336646.89 |
| NUMBER OF FILLS ACCOMPLISHED | | 1.0 |
| LEFT IN STORAGE AFTER FIFTH F&D OPERATION | (GAL) | 577885.58 |
| QTY TO FILL STORAGE VESSEL | (GAL) | 126114.42 |
| NUMBER OF TANKERS (@ 10000 GAL EACH) | (#) | 12.61 |
| ASSUMING FLEET OF 10 TANKERS (10 TANKERS/DAY M-F) | | |
| TOP STORAGE<br>DAYS (ONE DAY = ONE EIGHT HOUR SHIFT) | (DAYS) | 1.26 |

NOTE: THERE WILL BE FIVE TANKER CONNECTION WHICH HAVE THE CAPABILITY OF OFF LOADING 10 TANKERS IN FOUR HOURS. THEREFORE IT IS POSSIBLE TO OFF LOAD 60 TANKERS IN A TWO SHIFT OPERATION.

Figure 11.5.3. LCH4 Storage Fill Using Proposed Capacity Turnaround.

system would be required due to the low hydraulic pressures found throughout the methane system. Loading would be accomplished in a four-stage process over a 3-hour period as follows:

1. Line chilldown (10-15 min)
2. Slow fill to 2% (30-40 min)
3. Fast fill to 98% (1-1/2 hr)
4. Topping to 99% (30-40 min)

Pump peak loads would occur during the 1-1/2-hr fast-fill period. Over this time span, 96% (111,174 gallons) of the total methane required to load (115,806 gallons) would be transferred. This figure leads to a maximum required flow rate of 1,235 gpm. To avoid pump strain and encompass the unknowns in methane transfer, a 2,000 gpm variable speed pump is recommended. Furthermore, to avoid potential cavitation and net positive suction head problems often found in low pressure centrifugal pumping scenarios, a positive displacement-type pump would be necessary. This pump would be required to deliver methane up an approximate 200-ft vertical climb. At this elevation a 36.7 psi pump head would be required.

This pressure must then be delivered through an approximate 1,600-ft line, and three line sizes were reviewed:

| Size | Velocity | Pressure |
|---|---|---|
| 6 inch | 14.08 ft/sec | 75.2 psia |
| 8 inch | 8.08 ft/sec | 19.2 psia |
| 10 inch | 5.08 ft/sec | 6.2 psia |

An 8 inch line would provide a satisfactory flow condition, while a 6 inch line showed excessive pressure losses. The cost of a 10 inch pipe could not be justified.

These line losses (19.2 psi), along with the required head of 36.7 psi, lead to a minimum delta P across the pump of 55.9 psi.

Therefore, it is recommended that a variable speed/positive displacement pump capable of delivering 100 psig at 2,000 gpm be used.

### 11.5.5 Methane System Design Concept

The use of methane as an LRB propellant involves the installation of a new system at KSC. Figure 11.5.5 shows an overview of the major components required in the new system. Although the facilities and associated GSE would be new, the current LOX facilities could provide a blue print as a starting point for a methane system, with the exception of the requirement for a boil-off compressor to prevent losses and environmental impacts.

The transfer system would be an 8-inch vacuum-jacketed line similar to that of the LOX system, which would be the transportation medium from storage to vehicle. Also included in the system would be an entirely new service mast, valve/control skid, and vent arm. The vent arm would include a capture and retract mechanism similar to the ET LH2 vent arm currently used. A new flare stack, capable of handling both LRB and storage vent-off rates, would also be required. Although methane is lighter than air and would disperse in the event of leakage, a leak detection system would be required to minimize the environmental and safety impacts of a leak. An additional study will be necessary. A GN2 purge on all systems, with the possible exception of the storage tank (due to contamination of boil-off compressor feed) would also be required to prevent the possible explosive impacts of a CH4/O2 mixture.

### 11.5.6 Methane - Other Considerations

The use of methane or natural gas as a power source, is a rapidly expanding practice. Sparked by natural gas's inherent efficiency and clean burning properties, natural gas is rapidly expanding into new markets. Undoubtedly, the addition of a natural gas utility here at KSC would cost millions; however, only recently are the potential uses of natural gas being explored. Methane LRBs are only one of the possible uses of natural gas. Other possible uses are:

- Government vehicle converted from gasoline to methane use
- Heating requirements from electric to methane:
- Food preparation
    - Building temperature control
    - Hot water

Though these cost-savings measures are beyond the scope of the LRB project, methane's potential and flexibility would mean cost-savings before, during, and after LRBs are replaced with the next generation of space travel. It should be clear that were methane's disadvantages (damage to the

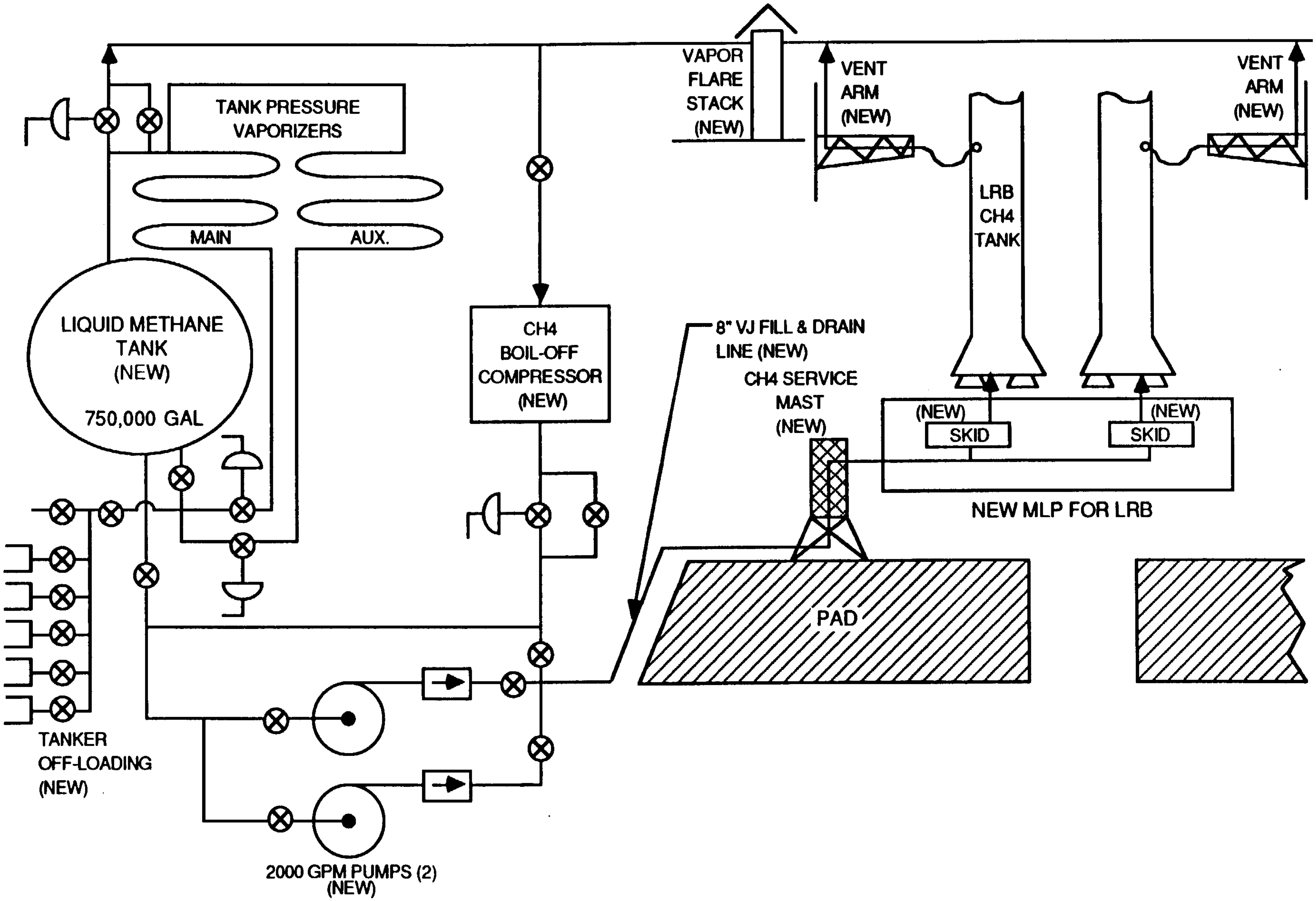

Figure 11.5.5. Liquid Methane Servicing System.

81019-03G

3-11 11/3 2:00p

environment and conversion cost) not far outweighted by its advantages (cost-savings, efficiency, clean burning, and flexibility), the science surrounding methane would not be expanding so rapidly.

### 11.5.7 Reference Documents

Matthews, C. S., and Hurd, C. O., Trans. Am. Inst.
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5th Edit, Section 3, (1973)

Klass, D. L., "Methane from An Aerobic Fermentation,
Science, March 1984, Vol. 223, #4640

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Thermodynamic Properties of Hydrocarbons and Related Compounds, Carnegie Press,
Pittsburgh (1953)

## 11.6 FINAL COMMENTS

The present operational philosophy at KSC is to outfit each MLP with the GSE necessary to launch a SSV. After reviewing this study, one conclusion stands out; the introduction of a mixed fleet with unique MLPs will mean duplicating existing equipment for installation on the MLPs. At the present time utilization of only two launch pads make installation of propellant systems on the Pad versus the MLP cost effective. As an example, currently, three MLPs carry equipment used only at the pad; yet we maintain three sets of equipment instead of two. As the idea of a mixed fleet expands, this will become a cost constraint.

In Section 3, the LRBs used as a baseline to study the KSC impacts was the LOX/RP-1 configurations from both contractors. This choice of configuration allowed the comparison of apples and apples and was not intended to advocate RP-1 as a fuel. The fuel choice for any future propulsion system is liquid hydrogen. Although the GDSS LOX/LH2 configuration have facility impacts which are more extensive than the four LOX/RP-1 configuration (See Section 3), from a propellant point of view the LH2 LRBs are preferred.

To compare LH2 with RP-1 system (Figure 11.6), a LH2 system would be more expensive to implement but the benefits out weigh the cost. The intangibles include environmental impacts (emissions-air quality, pollution-ground water quality), availability, engine requirements and system maintenance.

From a hazard point of view, LH2 vapor is more hazardous than RP-1 vapor but the safety system for H2 current exist and the environmental impacts are low.

All LRB configurations pose facility impacts (access, umbilical redesigns, flame deflector redesigns) which must be solved with engineering and operational changes. The taller LOX/LH2 LRB will interfere with the GOX vent arm (this problem exists with the LOX/RP-1 GDSS press fed configuration also). This impact to the GOX vent arm can be solved either with a configuration change to the vent arm or a design change to the ET.

Even with the facility impacts, the versatility of LH2 is far superior to RP-1 for launch vehicle programs of the future.

|  | RP-1 | LH2 |
|---|---|---|
| NON-RECURRING COST | ● LEAST @ $6.6M | ● MOST @ $25.9M |
| RECURRING COST INCLUDE | ● PUMP MAINTENANCE<br>● GROUND WATER MONITORING<br>● AIR QUALITY MONITORING<br>● NEW ENGINEERING STAFF | ● VJ EQUIP/VESSEL MAINTENANCE<br>● H2 MONITORING |
| TECHNOLOGY/SYSTEM | ● NEW INSTALLATION<br>● NEW SUPPORT/SAFETY SYSTEM | ● MODIFY EXISTING SYSTEM |
| COMMODITY COST/LAUNCH (SUCCESSFUL-NO SCRUB) | ● WORST LRB $348,000 (1)<br>● BEST LRB $ 261,000 (2) | ● $455,000 |
| ACQUISITION - COST | ● $3.00/GALLON | ● $1.00/GALLON |
| MADE FROM | ● PETROLEUM | ● NATURAL GAS, PETROLEUM |
| AVAILABILITY | ● LIMITED, |  |
| TRANSPORTATION | ● NEW FLEET | ● EXPANDING EXISTING FLEET |
| EXHAUST | ● ENVIRONMENTALLY DIRTY<br>● HOTTER THAN LOX/LH2 | ● ENVIRONMENTALLY CLEAN |
| ENGINE SERVICING | ● FLUSH/GUSH WITH WATER GLYCOL<br>● INSTALLATION OF PROPELLANT IGNITION CARTRIDGES |  |
| HAZARD | ● LOW VAPOR IGNITION HAZARD | ● HIGH IGNITION POINT HAZARD |
| LRB SITE - SKIRT DIAMETER | ● WORST 26.8' (1) | ● WORST 24.4' (1) |
|  | ● BEST 22.1' (2) | ● BEST 22.3' (3) |
| LENGTH | ● WORST 195.7' (1) | ● WORST 191.0' (3) |
|  | ● BEST 148.8' (5) | ● BEST 169.5' (4) |
| DIAMETER | ● WORST 16.2' (6) | ● WORST 17.7' (4) |

(1) GDSS PRESSURE
(2) MMC PUMP
(3) GDSS LOX/LH2
(4) GDSS FATBIRD
(5) GDSS PUMP
(6) MMC PRESSURE

Figure 11.6. Comparison of LH2 vs RP-1 LRB.

# VOLUME III

## SECTION 12

### RECOMMENDED CHANGES TO LRB DESIGN FOR OPERATIONAL EFFICIENCY

# SECTION 12

# RECOMMENDED CHANGES TO LRB DESIGN FOR OPERATIONAL EFFICIENCY

## 12.1 BACKGROUND

The introduction of a KSC requirements "check list" early in the study promoted indentification of LRB design features and launch site constraints which limit ground processing efficiency. (See Appendix 20 for the KSC requirements checklist.) These issues are not new to those familiar with KSC operations. Flight hardware booster designs have, in the past, not taken these efficiencies into account.

This study has promoted good exchange of design features which would enhance ground operational efficiency. The periodic technical working group meetings brought these ideas into focus and many of the launch site proposed ideas were incorporated into the preliminary booster designs.

## 12.2 LRB DESIGN RECOMMENDATIONS

A summary of recommended LRB design features and the supporting rationale is presented here by subsystem or processing area.

General LRB Design Goals:

- Limit LRB diameter to 18 feet and length to less than 170 feet. Diameter of 18 feet or less results in acceptable design clearance in VAB and GH2 vent arm areas. Lengths of less than 170 feet negate the need to redesign the existing ET GOX vent arm.

- Use expendable booster design to eliminate launch site retrieval, disassembly and refurbishment costs and risks.

- LRB design approach should minimize if not eliminate the need for Orbiter or ET modifications.

## Test/Checkout

- System design should facilitate both vertical and horizontal servicing and access. Horizontal stand alone checkout is planned; however no design feature should preclude vertical servicing if problems are encountered after MLP mate.

- All subsystems should employ new technology diagnostics and BITE design approach.

## Propulsion Systems

- Avoid toxic hyperbolic propellants and new propellants for which there is no experience base at KSC. RP-1 is favored and LH-2 is an established propellant for booster application.

- No hydrazine and no hydraulics for TVC or value activation. Currently hydraulic systems both on the Orbiter and booster provide one of the most time consuming and trouble prone of all ground/vehicle systems in our processing flow. Recommended electro-mechanical TVC actuators and similar actuation of propellant valves is a desired and proven best approach. With 4 engines per booster a simplified TVC design which slaves all the engines to a single pair of actuators is recommended.

- Avoid elephant trunks (traps) in propellant lines that require special attention. These design features force ground systems personnel into lengthly procedures for purging and evacuation of such areas.

- Eliminate or minimize extensive propellant and engine purges, bleeds and conditioning preparations. These lengthy procedures are manpower and timeline intensive during launch operations.

- Engine and aft skirt design should facilitate engine change out in both horizontal and vertical modes.

- Engine design should be modular in concept for ease of repair.

- Engine design and orientation on the booster should allow replacement of critical components (pumps, valves, regulators, controllers) without having to remove engine from the booster.

- Engine attachment to booster should incorporate design concept for ease of replacement.

- Utilize on board LOX vent systems which are designed to be non-icing and away from potentially endangering the Orbiter tile system. This approach also precludes the need for vent swing arms such as the existing ET beanie cap.

- Use liftoff umbilicals - no swing arms, LUT or TSMs. A set of simplified umbilicals in the aft area of the booster should be designed to mate interfacing ground side propellant fill and drain systems and ground electrical power connections situated inside the MLP flame holes. The ground side systems would be equipped with protective blast shields. Major fill and drain lines through the tail service mast for the ET - Orbiter fuel loading have presented significant problems in ground procedures and have required extensive set up and leak check procedures.

- Eliminate need for additional vent arms by routing fuel vent lines to liftoff umbilicals. GH2 vents can thus be routed through MLP to flare stacks without additional elevated swing arms.

## Avionics

- Locate avionic LRUs in aft skirt area for better accessibility. Intertank area is second choice. Forward skirt (nose cone area) is last choice. Although access can be provided in all areas the aft skirt area is most accessible.

- Consider external pods for avionics and batteries for ease of service. Establish as a goal modularized design for all LRU black boxes.

- Built In Test Equipment (BITE) should be designed in to the maximum extent possible for all systems.

- Use separate booster downlink (RF) and design LRB to be autonomous with minimum Orbiter interfaces.

- If possible, to accommodate the capacity required, the batteries should be one of the common types presently in use in the STS and maintained and serviced at KSC.

- Wherever possible all Avionics/Electronics should be "off-the-shelf" designs, not custom designed for LRB application.

# VOLUME III

## SECTION 13

A DETAILED USER'S MANUAL FOR GOCM
OPERATION

# VOLUME III SECTION 13

# KSC ENHANCED GROUND OPERATIONS COST MODEL USER'S MANUAL

## TABLE OF CONTENTS

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ALS | Advanced Launch System |
| BOC | Base Operations Contractor |
| CCAFS | Cape Canaveral Air Force Station |
| CER | Cost Estimating Relationships |
| CoF | Cost of Facilities |
| CORE | main element of a space vehicle |
| COREPF | CORE Processing Facility |
| CPF | Cost per Foot |
| CPF2 | Cost per Square Foot |
| CPF3 | Cost per Cubic Foot |
| CY | Calender Year |
| C/S | Contractor Support or Civil Service |
| DEQ | Direct Equivalent Head Count |
| DHC | Direct Head Count |
| DOS | Disk Operating System |
| ET | External Tank |
| ETR | Eastern Test Range |
| FR | Firing Room |
| FSS | Fixed Service Structure |
| FY | Fiscal Year |
| GOCM | Ground Operations Cost Model |
| LCC | Launch Control Center |
| LEO | Low Earth Orbit |
| LEOPF | Low Earth Orbit Processing Facility |
| LRB | Liquid Rocket Booster |
| LRBPF | Liquid Rocket Booster Processing Facility |
| LUT | Launcher Umbilical Tower |
| MEPF | Main Engine Processing Facility |
| MLP | Mobile Launch Platform |
| MP | (M/P) Manpower |
| MSFC | Marshal Space Flight Center |
| OMRF | Orbiter Maintenance Refurbishment Facility |
| OPF | Orbiter Processing Facility |
| O&M | Operations and Maintenance |
| PIF | Payload Integration Facility |
| PL | (P/L) Payload |
| PLPF | Payload Processing Facility |
| RSS | Rotating Service Structure |
| SPC | Shuttle Processing Contract(or) |
| SRB | Solid Rocket Booster |
| SRBPF | Solid Rocket Booster Processing Facility |
| SSME | Space Shuttle Main Engines |
| SRMRF | Solid Rocket Motor Refurbishment Facility |
| STS | Space Transportation System |
| VAB | Vehicle Assembly Building |
| VAFB | Vandenberg Air Force Base |
| VIB | Vertical Integration Building |
| VPF | Vertical Processing Facility |
| WTR | Western Test Range |

# VOLUME III SECTION 13

# KSC ENHANCED GROUND OPERATIONS COST MODEL USER'S MANUAL

## TABLE OF FIGURES

## SECTION 13

# KSC GROUND OPERATIONS COST MODEL USER'S MANUAL

**The Enhanced Ground Operations Cost Model is a series of menu-driven Symphony macro worksheets. The model will generate the costs associated with changing a space vehicle's configuration, support facilities or launch rate.**

Using this enhanced model requires only the most basic knowledge of Symphony. The menus, on-screen prompts and help screens make this model easy to use, even for those not familiar with microcomputers. However, you must have a working knowledge of KSC launch processing operations to make meaningful choices when the model prompts you for information.

You must install the KSC Ground Operations Cost Model with support software. Please refer to the Instructions Manual for computer requirements (Volume III Section 14.1) and installation (Volume III Section 14.2) before you start. The model begins with the Intro menu, as described below.

## 13.1 INTRO MENU

We designed the Intro menu to be as user friendly as humanly possible. A short graphics display presents the program name, and the program displays only two menu choices: Introduction and Main menu. The Intro part of the Ground Operations Cost Model (GOCM) is a super-friendly "front end" for inexperienced users. More experienced users will be able to bypass this portion of the model, and go directly to the Main menu. This approach is similar to Symphony itself, which allows you to call the program with either the front end "ACCESS" command, or directly with the "SYMPHONY" command.

### Introduction

This option presents a series of help screens that describe the purpose of GOCM and lists the various modules that comprise the total model. On-screen prompts guide the new user, and the help screens assume only the most limited knowledge of PC operations.

The brief description of the different modules, and what they do, will help orient new users to the structure and purpose of GOCM. The simplicity of the available menu responses (only the arrow

**and return keys) should keep any possible confusion to a minimum.**

**Main Menu**

**The Main menu selection retrieves a menu that displays all the modules that comprise the Ground Operations Cost Model and allows the user easy access to any portion of the model. In addition, the user may view an on-disk copy of the GOCM User's Manual text.**

## 13.2 MAIN MENU

The Main menu is the "control center" for accessing the different modules of the Cost Model. The Main menu presents eight selections: Operate, Variable, Process, Facility, Traffic, Learning, Manual, Exit.

### Operate

This selection brings the user to the main module, the Operations Model. This model retrieves information from each of the other modules, processes this information and generates a total cost report. The total cost report reflects the changes in cost caused by different options selected in the other modules. The job of the Operations Model is to integrate and process cost information generated by each of the other modules. The "Retrieve" command in the Operations Model allows the user to retrieve cost information generated by another module and saved to disk. By importing different costs generated by different vehicle configuration and vehicle processing assumptions, the user can generate "What if" analyses. The Operations Model features both hard copy output of various reports and full-color graphic representation of the total Summary Cost.

### Variable

This selection calls the Variable Module. The Operations Model bases its calculations on a number of basic assumptions. These assumptions include the location of the launch site, the average wage rate, the number of workdays per week and the number of shifts per day. This module allows you to select a standard choice from a menu, or, in some cases, enter your own value. The "Output" option in this menu allows you to save essential variable data to disk in the form of a small worksheet.

### Process

The Processing Module allows you to select a variety of vehicle configurations and evaluate the different processing costs for each. The "Output" option in this module allows you to save essential processing data to disk in the form of a small worksheet.

## Facility

The Facility Module allows you to choose the processing facilities required to prepare the type of vehicle you configured in the Processing module. The "Output" option in this module allows you to save essential facility data to disk in the form of a small worksheet.

## Traffic

The Traffic Module allows you to select different launch rates and payload capacities. The launch rates and payload capacities, in turn, affect operation cost. The "Output" option in this module allows you to save essential traffic data to disk in the form of a small worksheet.

## Learning

The Learning Curve Module allows you to create a variety of different learning curves. You import the factors that create these curves into the Operations Model. The factors change processing and cost data generated by the Operations Model.

## Manual

This selection allows you on-disk access to the text of this manual.

## Exit

Return to the Intro menu.

## 13.3 OPERATIONS MODULE

The following menu choices are diagramed in Figure 13.3.

Name

The program uses this input to name printed output and cost graphs.

Retrieve

This menu selection will allow you to retrieve (import data generated by a module) into the Operations Model. You can retrieve information from each module.

1. Variable

This option retrieves information from the Variable Module into the Operations Model.

2. Processing

This option retrieves information from the Processing Module into the Operations Model.

3. Traffic

This option retrieves information from the Traffic Module into the Operations Model.

4. Facility

This option retrieves information from the Facility Module into the Operations Model.

5. Learning Curve

This option retrieves information from the Learning Curve Module into the Operations Model.

6. Quit - Return to the Opening menu

Input/Review

1. Variable

This option allows you to review (and if you wish, change) the data previously imported from the Variable Module into the Operations Model via the "Retrieve" selection.

2. Processing

This option allows you to review (and if you wish, change) the data previously imported from the Processing Module into the Operations Model via the "Retrieve" selection.

3. Traffic

This option allows you to review (and if you wish, change) the data previously imported from the Traffic Module into the Operations Model via the "Retrieve" selection.

4. Facility

This option allows you to review (and if you wish, change) the data previously imported from the Facility Module into the Operations Model via the "Retrieve" selection.

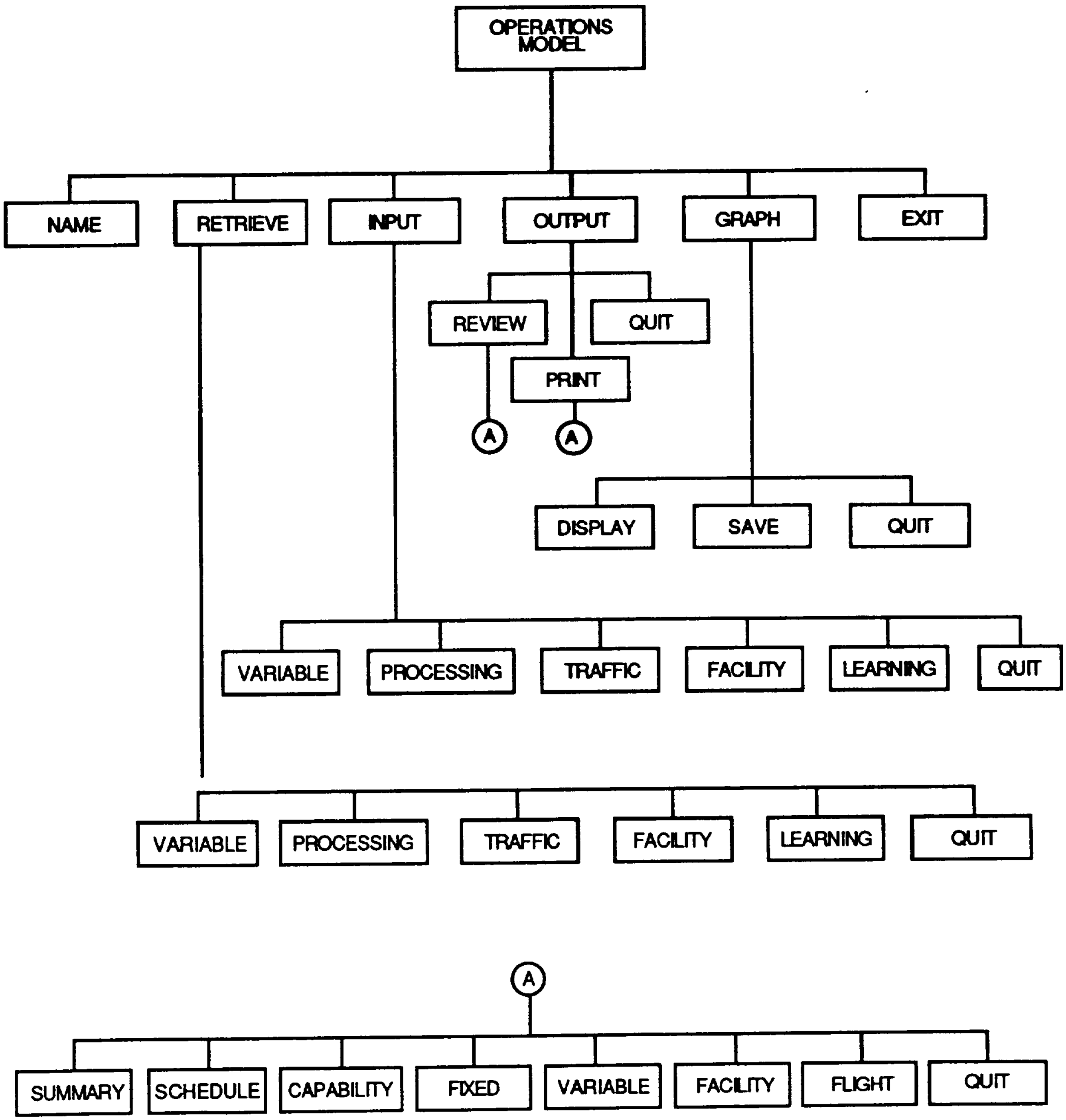

Figure 13.3. Operations Model.

**5. Learning Curve**

**This option allows you to review (and if you wish, change) the data previously imported from the Learning Curve Module into the Operations Model via the "Retrieve" selection.**

**6. Quit - Return to the Opening menu**

**Output - This selection allows you to generate hard copy of the following reports:**

**1. Summary**

**This option prints a summary of all fiscal year cost information. This information is also used to** generate the full-color graph available through the "Graph" option.

2. Schedule - This option prints the Processing Time Schedule Report.

3. Capability - This option prints the Facility Processing Capability Report.

4. Fixed - This option prints the Fixed Cost Report

5. Variable - This option prints the Variable Cost Report

6. **Facility - This option prints the Facility Requirements Report**

7. Flight - This option prints the Flight Hardware Report

8. Quit - Return to the Opening menu

Graph

1. Display

This option generates a full-color on-screen summary costs graph of the data in the Summary Costs Report.

2. Save

This option saves the summary costs graph to the disk. This will allow you to generate hard copy of the graph on a dot-matrix printer or plotter with the Symphony PrintGraph program.

3. Quit - Return to the Opening menu

Exit - Return to the Main menu

## 13.4 VARIABLE MODULE

**The Variable Module Opening menu contains eight menu options as diagramed in Figure 13.4: Name, Location, Manpower, Index, Schedule, Factors, Output and Exit. The Variable Module uses the input screen shown below. Changes are automatically made in the spreadsheet by the different menu choices.**

```
NAME:  MIXFLEET
===============================================================
Variable Rates and Factors
===============================================================
---------------------------------------------------------------
Location of Launch Site==>  ETR
Manpower Rate============>   $186   (Standard is $186 (1987$)
Index Year===============>   1988   (Standard is 1987)
Schedule Days/Week=======>      6   (Standard is 7)
         Shifts/Day======>      3   (Standard is 3)
         Holidays/Year===>     19   (Standard is 19)
Factors  Escalation Rate=>   0.0%   (Standard is 4.5   (NASA)
         Facility Utiliz=>  85.0%   (Standard is 85)
         Surge Factor====>  15.0%   (Standard is 0)    (NASA)
---------------------------------------------------------------
Start Year===========>       1996 (From Traffic Model)
Rate Factor==========>          1 (From escalation)
Nth Factor===========>          8 (Start_year less Index_year)
---------------------------------------------------------------
YEARS                  1996     1997     1998     1999
---------------------------------------------------------------
INDEX FACTOR           1.00     1.00     1.00     1.00
ESCALATION FACTOR      1.00     1.00     1.00     1.00
---------------------------------------------------------------
===============================================================
```

### Name

This option names the small spreadsheet that holds Variable Module data. The Operations Model can retrieve this information with the "Retrieve" selection. The name must be eight alphanumeric characters or less.

### Location

1. ETR. Eastern Test Range. This selection assigns a factor of 1 to a variety of inputs. ETR is defined as CCAFS/KSC.
2. WTR. Western Test Range. This selection assigns a factor of 1.25 to a variety of inputs.
3. Quit - Return to the Opening menu

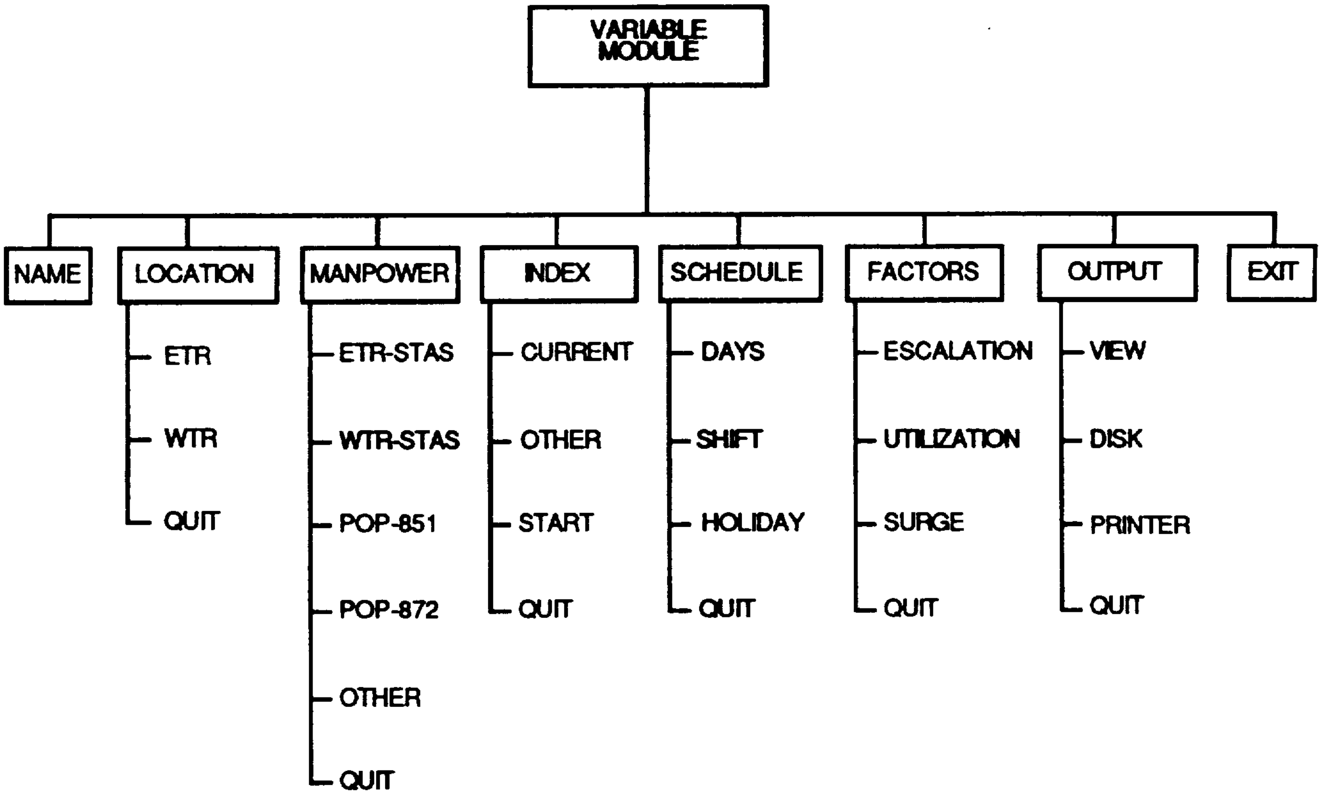

Figure 13.4 Variable Module

### Manpower

The manpower option refers to the "manpower rate," or the average dollars paid for one 8-hour shift. The Location menu allows you to select your launch location (ETR or WTR). WTR introduces a factor of 1.25 to compensate for higher costs of processing on the West coast.

1. ETR-STAS, Eastern Test Range-Space Transportation Architecture Study. This is a future, second-generation space transportation system (both manned and unmanned) for 1995 and beyond. The manpower rate is a given, $200. This cost model defines ETR as CCAFS/KSC.
2. WTR-STAS, Western Test Range-Space Transportation Architecture Study. This is a future, second-generation space transportation system (both manned and unmanned) for 1995 and beyond. The manpower rate is a given, $240.
3. POP-851, Program Operation Plan, 1985. The manpower rate is a given, $185.
4. POP-872, Program Operation, 1987. The manpower rate is a given, $186.
5. Other. This option allows you to enter your own manpower rate for sensitivity analysis
6. Quit - Return to the Opening menu

### Index

This menu establishes an index table used to express expenditures in a base year dollars. In this menu you select the year used as the base. You apply the escalation rate, selected in the Factors menu, to this base. The escalation rate automatically adjusts current dollars to determine the base year rate. As a result, this section allows you to apply an escalation rate of, say, 5%, to a base of, say, 1979 dollars. The Index menu provides the following options:

1. Current. This option automatically selects the current year as your base.
2. Other. This option allows you to specify any year as your base.
3. Start. This option allows you to select the starting year for the index table. Although the table may start with (for example) 1988, your selection of the base year determines the base year factor assigned to 1988. The escalation rate, multiplied by the base year factor, yields the factor used for calculations.
4. Quit - Return to the Opening menu

### Schedule

1. Days. This option lets you to enter the number of days in the work week, usually 6 or 7.
2. Shift. This option allows you to enter the number of shifts per day, usually 2 or 3.
3. Holidays. This lets you enter the number of holidays per year, usually 19.
4. Quit - Return to the Opening menu

Factors

This option allows you to enter percentage values (as whole numbers) used by the Operations Model.

1. Escalation

The escalation rate provides an inflation effect for future expenditures. It also provides a discount rate if you input a negative number. The standard rate is 4.5%.

2. Utilization

The utilization rate refers to facility utilization. You cannot use a productive facility 100% of the time. Required maintenance, breakdowns and repairs all detract from normal productive time. The standard rate is 85%.

3. Surge

The surge rate is the capability of the shuttle ground systems and associated flight hardware to increase "short term" the annual launch capacity. We have reserved this rate for contingency purposes. The standard rate is 0.

4. Quit - Return to the Opening menu.

Output

1. View

This selection allows you to view the data you will send to the printer or write to disk.

2. Disk

This selection will take output data required by the Operations Model and write it to disk as a separate worksheet file. When in the Operations Model, you will be able to import this data. You should use a name associated with to the configuration/study you're saving to disk.

3. Print

This selection will send the output data to the printer for hard copy backup.

4. Quit - Return to the Opening menu

Exit - Exit to the Return to the Main menu

## 13.5 PROCESSING MODULE

**The Processing Module Opening menu contains seven menu options as diagramed in Figure 13.5-1 and Figure 13.5-2: Name, Vehicle, Technology, Turnaround, Configure, Output and Exit. The main Processing input screen is shown below:**

```
=======================================================
Processing Factors
=======================================================
Vehicle===============>    STS
Technology============>    BASELINE
Turnaround============>    REVISED

=======================================================
Vehicle Configuration
=======================================================
Module |Number  Element Locate   Fuel    Recovery
-------------------------------------------------------
SRB    |     2        4 SIDE     CURRENT WATER PARACH
LRB    |     0 N/A      N/A      N/A     N/A
CORE   |     1        0 SIDE     LH2     EXPEND
LEO    |     1        3 SIDE     LH2     MANNED GLIDE
PAYLOAD|     2       25 INTERNAL LIQUID  EXPEND
-------------------------------------------------------
=======================================================
```

### Name

This option names the small spreadsheet that holds Processing Module data. The Operations Model can retrieve this information with the "Retrieve" option. The name must be 8 alphanumeric characters or less.

### Vehicle

At present, this menu provides information only. It does not influence any values in the Operations Model. Future enhancements will make the Operations Module sensitive to different vehicles.

1. STS - Space Transportation System
2. ALS - Advanced Launch System
3. Shuttle II - Shuttle II
4. Shuttle C - Shuttle C
5. Derivatives - Future space vehicle configurations
6. Quit - Return to the Opening menu

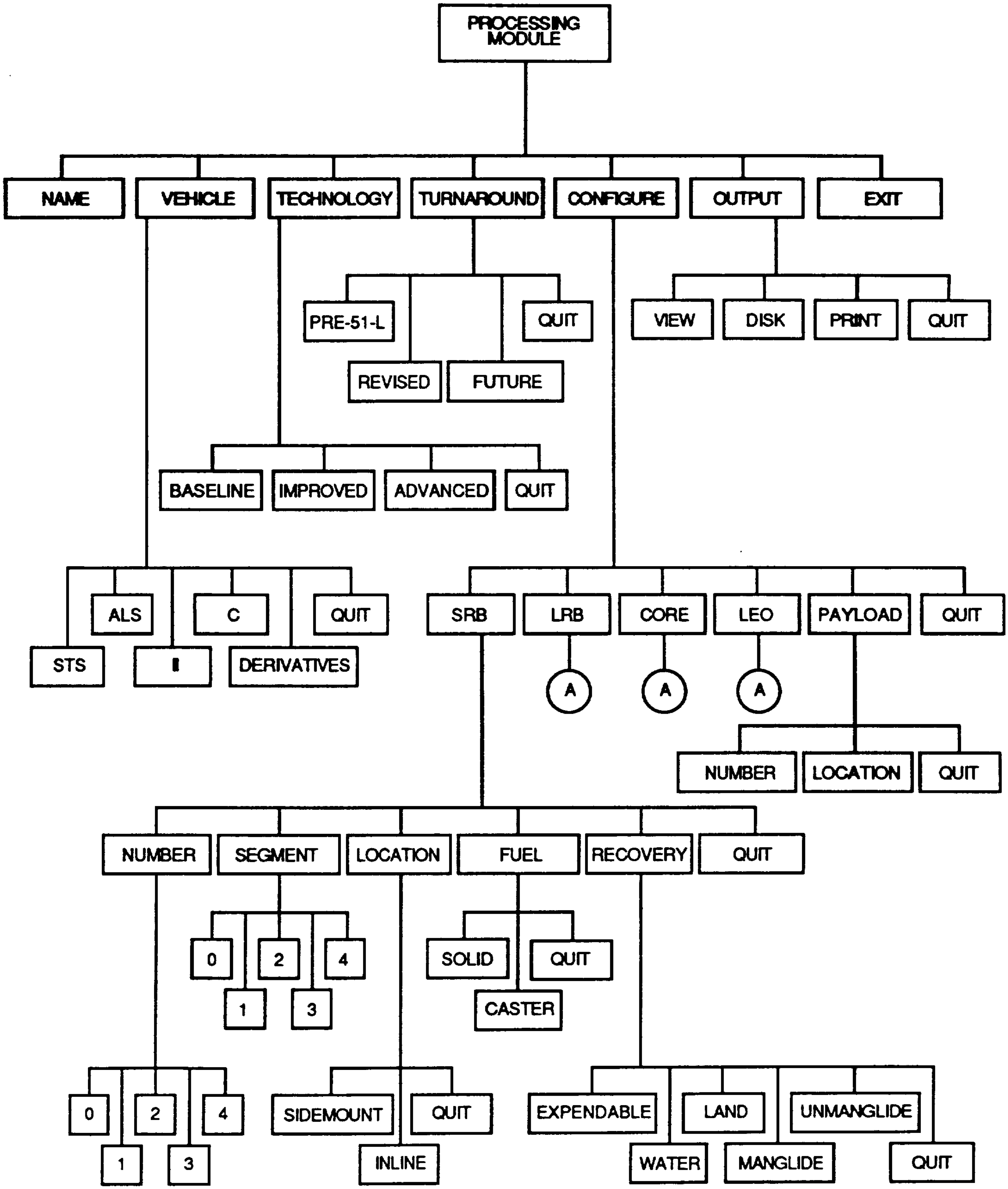

Figure 13.5-1. Processing Module.

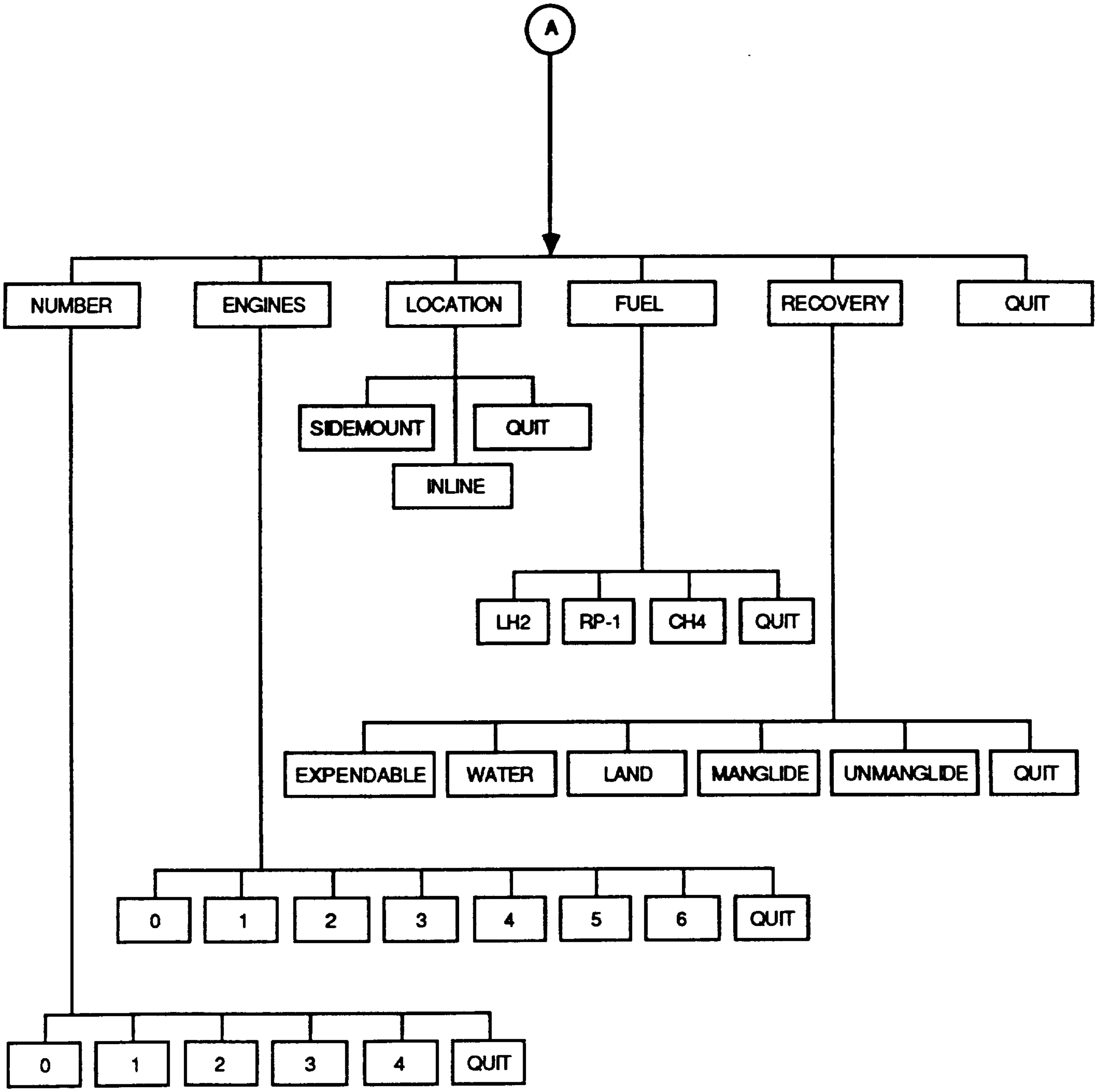

Figure 13.5-2. Processing Module.

Technology

The technology level, combined with the turnaround rate, is the basis for the calculations that determine the number of shifts required by different operations. Increased technology affects different operations to different degrees. A small database assures that the program applies the proper factors to the appropriate areas.

1. Baseline.
2. Improved
3. Advanced
4. Quit - Return to the Opening menu

Turnaround

The turnaround level, combined with the technology rate, is the basis for an important calculation: the number of shifts different operations require. Increased technology affects different operations to different degrees. A small database assures that the proper factors are applied to the appropriate areas.

1. Revised
2. Pre-51L
3. Experimental
4. Quit - Return to the Opening menu

Configure

1. SRB
    - a) Number

      This segment option refers to the number of SRBs attached to the vehicle. At present, the STS is launched with two SRBs. However, future vehicle configurations may differ.
    - b) Segment

      The segment option refers to different components in different systems. Here, it refers to the SRB segments fitted together with field joints.
    - c) Location
        - 1) Inline
        - 2) Sidemount
        - 3) Quit - Return to Configure menu

   - d) Fuel
      - 1) Solid - This option refers to the currently used solid rocket propellant.
      - 2) Caster - This option refers to a solid rocket propellant to be used at a future date.
      - 3) Quit - Return to the Configure menu
   - e) Recovery
      - 1) Expendable - not recovered
      - 2) Water - parachute to a water splashdown
      - 3) Land - paraglide to landing
      - 4) Manglide - manned glideback landing
      - 5) Unmanglide - unmanned glideback landing
      - 6) Quit - Return to the SRB menu
   - f) Quit - Return to the Configure menu

2. LRB
   - a) Number - This option refers to the number of boosters per vehicle
   - b) Engines - This option refers to the number of LRB engines per booster
   - c) Location
      - 1) Inline
      - 2) Sidemount
      - 3) Quit - Return to the LRB menu
   - d) Fuel
      - 1) LH2 - Liquid oxygen and liquid hydrogen
      - 2) RP-1 - Liquid oxygen and RP-1
      - 3) CH4 - Liquid oxygen and methane
      - 4) Quit - Return to the LRB menu
   - e) Recovery
      - 1) Expendable - not recovered
      - 2) Water - parachute to a water splashdown
      - 3) Land - paraglide to landing
      - 4) Manglide - manned glideback landing
      - 5) Unmanglide - unmanned glideback landing
      - 6) Quit - Return to the LRB menu
   - f) Quit - Return to the Configure menu

3. CORE
   - a) Number - This option refers to the number of CORE elements per vehicle. At present there is only one, the STS External Tank. Future configurations may contain more.

- b) Engines - This option refers to the number of engines per CORE vehicle. The STS CORE is the External Tank (ET). The ET contains fuel only, and has no engines. However, future configurations may include CORE elements with engines.
- c) Location
  - 1) Inline
  - 2) Sidemount
  - 3) Quit - Return to Configure menu
- d) Fuel
  - 1) LH2 - Liquid oxygen and liquid hydrogen
  - 2) RP-1 - Liquid oxygen and RP-1
  - 3) CH4 - Liquid oxygen and methane
  - 4) Quit - Return to the CORE menu
- e) Recovery
  - 1) Expendable - not recovered
  - 2) Water - parachute to a water splashdown
  - 3) Land - paraglide to landing
  - 4) Manglide - manned glideback landing
  - 5) Unmanglide - unmanned glideback landing
  - 6) Quit - Return to the CORE menu
- f) Quit - Return to the Configure menu

4. <u>LEO</u>
   - a) Number

     This option refers to the number of LEO elements per vehicle. Although this option may at first seem far fetched, future space vehicle configurations might include more that one orbital element.
   - b) Engines

     This option refers to the number of engines contained in the LEO element. In the STS, there are 3 Space Shuttle Main Engines (SSME). Future configurations may be different.
   - c) Location
     - 1) Inline
     - 2) Sidemount
     - 3) Quit - Return to the LEO menu
   - d) Fuel
     - 1) LH2 - Liquid oxygen and liquid hydrogen

        2) RP-1 - Liquid oxygen and RP-1
        3) CH4 - Liquid oxygen and methane
        4) Quit - Return to the LEO menu
    e) Recovery
        1) Expendable - not recovered
        2) Water - parachute to a water splashdown
        3) Land - paraglide to landing
        4) Manglide - manned glideback landing
        5) Unmanglide - unmanned glideback landing
        6) Quit - Return to the LEO menu
    f) Quit - Return to the Configure menu

5. Payload
    a) Number - This option refers to the number of payloads launched into orbit.
    b) Location
        1) Internal
        2) External
        3) Quit - Return to the Payload menu
    c) Quit - Return to Configure menu
6. Quit - Return to Opening menu

Print

1. View

This selection allows you to view the data you will send to the printer or write to disk.

2. Disk

This selection will take output data required by the Operations Model and write it to disk as a separate worksheet file. The program will use the name you chose under the "NAME" option. When in the Operations Model, you will be able to import this data file.

3. Printer

This selection will send the output data to the printer for hard copy backup.

4. Quit - Return to the Opening menu

Exit - Exit to the Main menu

## 13.6 TRAFFIC MODULE

**The Traffic Module allows the user to input schedule and flight data used by the Operations Model. The Traffic Module presents six menu options: Name, Year, SRB vehicle, LRB vehicle, Output and Quit (see Figure 13.6).**

```
==========================================================
Traffic Rates and Factors
==========================================================
START YEAR=====>  1996
SRB VEHICLE====>LRB STUDY       LRB VEHICLE===> POP-87
MAX WEIGHT=====>    65 K-LBS    MAX WEIGHT====>   75 K-LBS
PAYLOAD UTIL% =>   100%         PAYLOAD UTIL%=>   100%
----------------------------------------------------------
FLIGHTS: LRB STUDY        3        6         9        12
FLIGHTS: POP-87          14       14        14        14
WEIGHT (CUM) K-LBS      195      390       585       780
----------------------------------------------------------
SCHEDULE                1996     1997      1998      1999
----------------------------------------------------------
POP 85                    20       20        20        20
POP 87                    14       14        14        14
POP 88                     1        7        10        10
MANIFEST                   1        5        10        10
LRB STUDY                  3        6         9        12
GENERIC                   14       14        16        16
CUSTOM                     1        1         1         1
-----------------------------------------------------------
===========================================================
```

Name

This option names the small spreadsheet that holds Traffic Module data. The Operations Model can retrieve this information with the "Retrieve" selection. The name must be eight alphanumeric characters or less.

Year

This option prompts the user to enter the starting year for flight operations. The Traffic Module examines a 16 year period starting with the year you specify here.

SRB Vehicle

1. Schedule

This option allows the user to choose from a small database of different launch schedules. In addition, the user may select the "Customize" option, and enter an entirely new schedule. The pro-

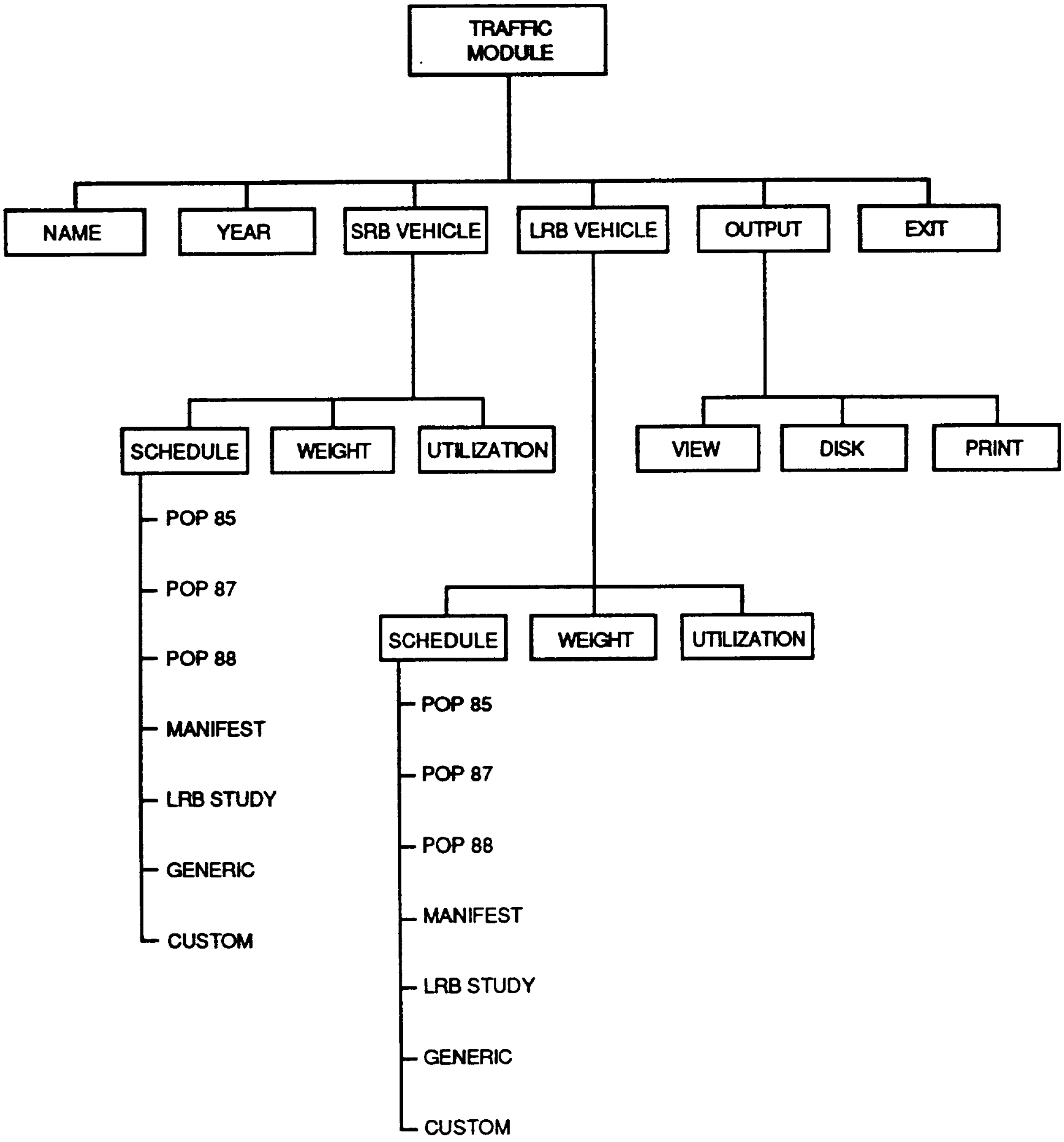

Figure 13.6. Traffic Module.

gram saves the new schedule for future use. The menu choices at this level are:

a) POP 85
b) POP 87
c) POP 88
d) MANIFEST
e) LRB STUDY
f) GENERIC
g) CUSTOM
h)Quit - Return to the SRB Vehicle menu

2. Weight

This option prompts the user to enter the maximum payload weight in kilopounds

3. Utilization

This option prompts the user to enter the payload utilization efficiency. The standard value is 85%. You enter the percentage value as a whole number.

4. Quit - Return to the Opening menu

LRB Vehicle

1. Schedule

This option allows the user to choose from a small database of different launch schedules. In addition, the user may select the "Customize" option, and enter a new schedule. The program saves the new schedule for future use. The menu choices at this level are:

a) POP 85
b) POP 87
c) POP 88
d) MANIFEST
e) LRB STUDY
f) GENERIC
g) CUSTOM
h) Quit - Return to the LRB Vehicle menu

2. Weight

This option prompts the user to enter the maximum payload weight in kilopounds.

3. Utilization

This option prompts you to enter the payload utilization efficiency. The standard value is 85%. You enter the desired value as a whole number.

4. Quit - Return to the Opening menu

**Output**

1. **View**

**This selection allows you to view the data you will send to the printer or write to disk.**

2. **Disk**

**This selection will take output data required by the Operations Model and write it to disk as a separate** worksheet file. The program will use the name you chose under the "NAME" option. **When** in the Operation Model, you will be able to import this data file. You should use a name associated with the configuration/ study you're saving to disk.

3. Printer

This selection will print the output data to the printer for hard copy backup.

4. Quit - Return to Opening menu

Exit - Exit to the Main menu

## 13.7 FACILITY MODULE

The Facility Module allows you to select a "portfolio" of assets used in the ground operations. The Facility Module consists of six options as diagramed in Figure 13.7: Name, Input, Modify, Variables, Output and Exit.

### Name

This option names the small spreadsheet that holds Facility Module data. The Operations Model can retrieve this information with the "Retrieve" option. The name must be eight alphanumeric characters or less.

### Input

This option puts the user in the Symphony Form environment. The program presents a "database edit form", shown on the following page. You can view all facilities in the model. However, you are able to change only five values in this Form window: Number, Shared, Element length, Element width and Element height.

The "Number" value allows you to change the number of facilities in use (0 removes the facility from consideration). "Shared" requires a "Y" or "N" input. This input determines whether the vehicle you configured in the Processing Module can use (or share) existing STS facilities. If your new vehicle configurations can't use existing facilities, the model will create new facilities as needed. The Element length, width and height inputs are the dimensions of the vehicle element the facility will process. The Form window examines these inputs, accesses a standard offset database, and then automatically creates and displays the Facility length, width and height. The Cost of Facilities ("COF"), cost of equipment for the facility ("Equip") and cost for supporting facilities ("Supt") are also automatically generated and displayed in the window.

A full description of the formulas used in the Form window (and the location/contents of the databases the Form window uses) is given the GOCM Instruction Manual. The Processing Module makes use of a variety of Symphony database features and several different databases. As a result, modifications to this module that may be required by future cost data and new facilities should be performed only by experienced users.

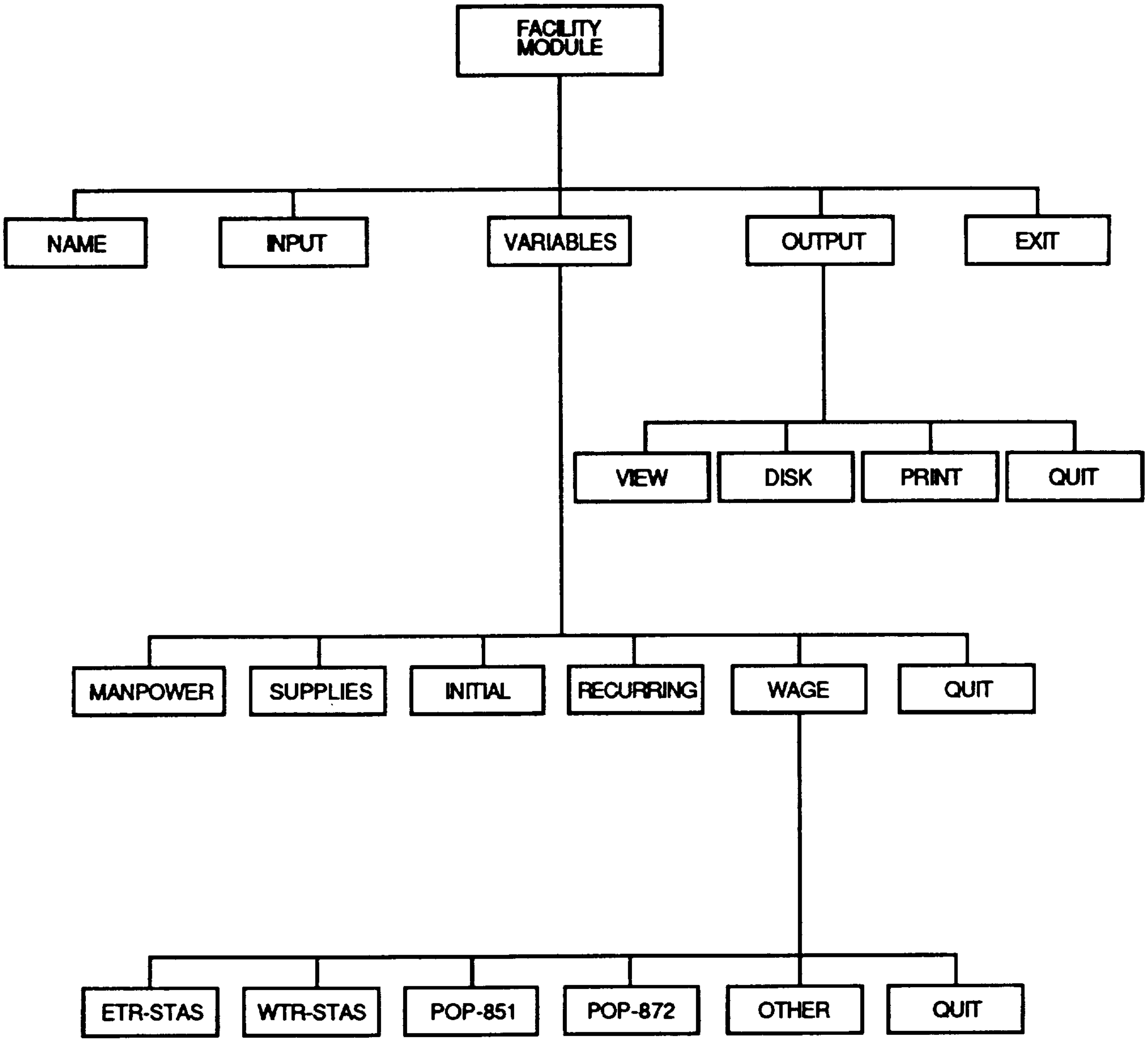

Figure 13.7. Facility Module.

```
+-------------------------------------------+
|GENERIC OMRF_____                          |
|CER 16                                     |
|NUMBER 0                                   |
|SHARED Y                                   |
|ELEMENT LENGTH 122______                   |
|ELEMENT WIDTH 78_______                    |
|ELEMENT HEIGHT 57_______                   |
|FACILITY LENGTH 197.0____                  |
|FACILITY WIDTH 150.0____                   |
|FACILITY HEIGHT 95.0_____                  |
|COF 140.1____                              |
|EQUIP 281.5____                            |
|SUPT 18.6_____                             |
+-----------------------------------INPUT--+
```

Variables

1. Manpower

This option allows you to input the O&M manpower factor. The standard value is 18.5%. You must enter this input value in decimal form (.185).

2. Supplies

This option allows you to input the O&M supplies rate. The standard value is 1%. You must enter this input value in decimal form (.01).

3. Initial

This option allows you to input the initial spares rate. The standard value here is 6.5% of the facility equipment value. You must enter this input value decimal form (.065).

4. Recurring

This option allows you to input the recurring spares rate. The standard value is 1.17% of facility equipment. You must enter this input value in decimal form (.0117).

5. Wage

This option allows you to input the manpower wage rate per shift. This value is the average wage paid to an employee for an entire 8-hour shift. The manpower wage rate you select in this menu is used only for internal calculations in the Facility Module. The Facility Module wage rate is used to generate O&M costs. These O&M costs are imported into the Operations Model. However, the main Operations Model only uses the manpower wage rate selected in the Variables Module.

a) ETR-STAS ($200)
b) WTR-STAS ($240)
c) POP-851 ($185)
d) POP-872 ($186)
e) Other - value entered directly by the user

f) Quit - Return to the Variables menu

6. Quit - Return to the Opening menu

Output

1. View

This selection allows you to view the data you will send to the printer or write to disk.

2. Disk

This selection will take output data required by the Operations Model and write it to disk as a separate worksheet file. The program will use the name you chose under the "NAME" option. When in the Operations Model, you will be able to import this data file. You should use a name associated with the configuration/ study you're saving to disk.

3. Printer

This selection will print the output data to the printer for hard copy backup.

4. Quit - Return to the Opening menu

Exit - Exit to the Main menu

## 13.8 LEARNING CURVE MODULE

The theory of learning curves quantifies with algebraic formulas a common sense notion: the more you do something the better you get at it. This is as true for manufacturing widgets as it is for processing space shuttles. The learning curve tries to predict when you will get better, and how much better you will get. We based this module on the "Aircraft Learning Curve" by Dr. T. P. Wright. The Learning Curve Module presents eight menu choices as diagramed in Figure 13.8: Name, Vehicle, Retrieve, Manpower, Processing, Flight, Output and Exit.

### Name

This option names the small spreadsheet that holds Learning Curve Module data. The Operations Model can retrieve this information with the "Retrieve" selection. The name must be eight alphanumeric characters or less.

### Vehicle

This selection allows you to choose the type of space vehicle you will evaluate. This might be a vehicle from the existing shuttle program, a shuttle-derivative program, or a totally new program. This choice will determine the variables used to calculate the learning curve factors.

### Retrieve

This selection imports data from the Traffic Module. The learning curve factors, to be accurate, must use the same data as the Traffic Module. This selection assures that the same data is used in both models.

### Manpower

This selection enters the learning experience curve percentage to be applied to the manpower head count. The valid learning factor range is between 50% and 100%. A commonly accepted number.

### Processing

This selection enters the learning experience curve percentage to be applied to the space vehicle processing timeline. The valid learning factor range is between 50% and 100%. A commonly accepted learning factor in the STS program is 85%. You enter the percentage as a whole number.

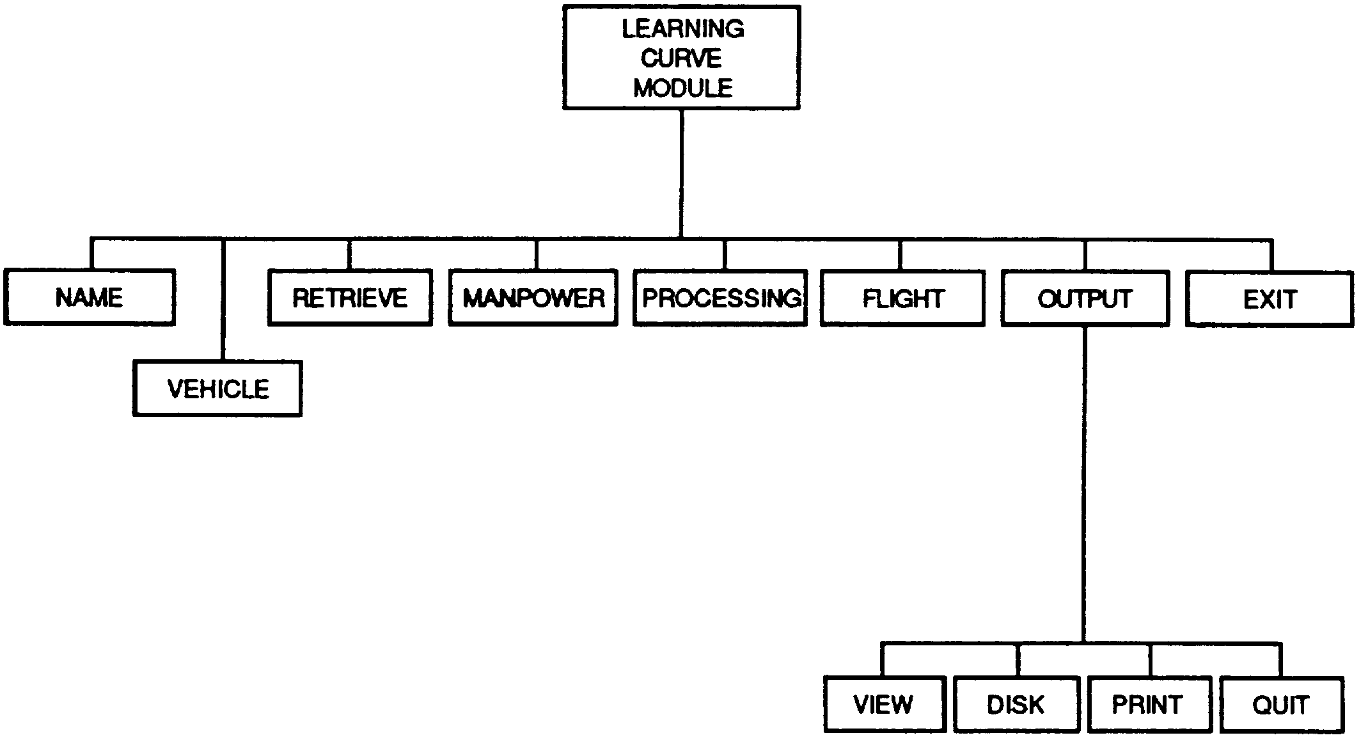

Figure 13.8. Learning Curve Module.

Flight

This option enters the flight number that will be the basis of the learning curve percentage. It's actually an adjustment factor that places you at a particular point on the learning curve.

Output

1. View

This option allows you to view the data you will sent to the printer or write to the disk.

2. Disk

This selection will take output data required by the Operations Model and write it to disk as a separate worksheet file. The program will use the name you chose under the "NAME" option. When in the Operation Model, you will be able to import this data file. You should use a name associated with the configuration/ study you're saving to disk.

3. Print

This selection will print the output data to the printer for hard copy backup.

4. Quit - Return to the Opening menu

Exit - Exit to the Main menu

# VOLUME III

## SECTION 14

### INSTRUCTIONS FOR UPDATING/MODIFYING THE GOCM PROGRAM

# VOLUME III - SECTION 14
# KSC GROUND OPERATIONS COST MODEL INSTRUCTIONS

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## LIST OF FIGURES

# ACRONYMS & ABBREVIATIONS

| | |
|---|---|
| ALS | Advanced Launch System |
| BOC | Base Operations Contractor |
| CCAFS | Cape Canaveral Air Force Station |
| CER | Cost Estimating Relationships |
| CoF | Cost of Facilities |
| COREPF | Core Processing Facility |
| CPF | Cost per Foot |
| CPF2 | Cost per Square Foot |
| CPF3 | Cost per Cubic Foot |
| CY | Calender Year |
| C/S | Civil Service |
| DEQ | Direct Equivalent Head Count |
| DHC | Direct Head Count |
| DOS | Disk Operating System |
| ETR | Eastern Test Range |
| FR | Firing Room |
| FSS | Fixed Service Structure |
| FY | Fiscal Year |
| GOCM | Ground Operations Cost model |
| HB | High Bay |
| LCC | Launch Control Center |
| LEO | Low Earth Orbit |
| LEOPF | Low Earth Orbiter Processing Facility |
| LRB | Liquid Rocket Booster |
| LRBPF | Liquid Rocket Booster Processing Facility |
| LRBRF | Liquid Rocket Booster Refurbishment Facility |
| LUT | Launcher Umbilical Tower |
| MEPF | Main Engine Processing Facility |
| MLP | Mobile Launch Platform |
| MP | (M/P) Manpower |
| MSFC | Marshal Space Flight Center |
| OMRF | Orbiter Maintenance Refurbishment Facility |

| | |
|---|---|
| OPF | Orbiter Processing Facility |
| O&M | Operations and Maintenance |
| PIF | Payload Integration Facility |
| PL | (P/L) Payload |
| P/LPF | P/L Processing Facility |
| RPSF | Rotation Processing and Surge Facility |
| RSS | Rotating Service Structure |
| SDV | Shuttle Derivative Vehicle |
| SPC | Shuttle Processing Contract |
| SRB | Solid Rocket Booster |
| SRBPF | Solid Rocket Booster Processing Facility |
| SRBRF | Solid Rocket Booster Refurbishment Facility |
| SSME | Space Shuttle Main Engines |
| STS | Space Transportation System |
| VAB | Vehicle Assembly Building |
| VAFB | Vandenberg Air Force Base |
| VIB | Vertical Integration Building |
| VPF | Vertical Processing Facility |
| WTR | Western Test Range |

# SECTION 14

# KSC GROUND OPERATIONS COST MODEL INSTRUCTIONS

## INTRODUCTION

The enhanced Kennedy Space Center Ground Operations Cost Model (GOCM) is a parametric cost model used to estimate the cost of ground operations for various vehicle configurations. Parametric cost models provide quick and moderately accurate cost estimates. This is an advantage over the other types of cost models which results from the use of physical parameter inputs as the independent variables in the cost estimating relationships (CERs). For instance, the cost of a facility may be expressed as $75.00 per cubic foot: cubic feet being the parametric input to the model. With minimum input, the parametric data can be used to derive useful cost estimates long before actual designs are generated.

Parametric models are never complete, since their input is general in nature and often incomplete. The usual intent of a parametric model is to identify the major cost drivers, estimate the cost of major sensitive elements, and to provide consistent results in "what-if" scenarios. Therefore, high resolution inputs are nether employed nor desirable and usually not available.

The KSC GOCM was originally developed by Planning Research Corporation as a facility model for estimating the cost of new ground operations support facilities utilizing actual historical data. This facility model was turned over to NASA in October, 1987. NASA expanded the facility model to include processing factors and time lines to estimate the total cost of launch operations at either the Eastern Test Range or Western Test Range. In March, 1988, Lockheed Space Operations Company was contracted to perform a Liquid Rocket Booster Integration (LRBI) Study and to evaluate, enhance and expand GOCM under contract NAS10-11475. LSOC was also to provide Instructions for modifying GOCM software, a Users Manual for model operation, and turn over the revised software to NASA when completed in December, 1988.

Contract NAS10-11475 was a KSC study that complemented a MSFC phase A study of alternate Liquid Rocket Boosters (LRB) as a potential replacement for the current STS Solid Rocket Boosters (SRB). The KSC study addressed launch site operations, KSC facilities and GSE/LSE impact requirements. Another LRBI study task was to perform an evaluation and provide enhancements to the KSC GOCM. GOCM was designed for the performance of early configuration cost generation used primarily to support trade studies. The purpose of the GOCM study was to expand and enhance the utility and relevance of the GOCM to the STS KSC programs through the incorporation of lessens learned from the LRBI study and to develop a detailed User's Manual for the operation of the model as well as instructions on its future modification.

GOCM CERs were evaluated and compared to actual data and alternate estimates with respect to LRBI study configurations and support scenarios. Additional LRBI study CERs where incorporated into GOCM as a module for significant and or sensitive cost drivers that were identified during the study. GOCM was used in the LRB costing and was evaluated for its relevancy and utility. Consideration was given and documented in the deliverable "Recommendations" to the approach, resources and utility of evolving GOCM from its present configuration as a macro estimating tool to a future configuration as a detailed design estimating tool. The mix of cost generation techniques typically employed on a program varies with program maturity. Initially during phase "A" (conceptual evaluation/study) an all up parametric technique is employed which provides only moderate confidence in accuracy. This is the point where GOCM is believed to have utility and was tested for relevancy, accuracy and ease of use on the LRB program. Soon to follow as the program advances from phase "A" and transitions into phase "B", certain cost drivers and/or cost elements sensitive to design/planning decisions will require greater confidence in their accuracy. This is especially true with respect to facility modifications required to support new flight hardware configurations. These elements will require examination in greater detail and the employment of engineering estimates (analogy). Select cost elements which are deemed very sensitive and significant may transition early to direct engineering and detail estimates. Such elements may be crucial to budget planning and/or trade studies. These type of estimates should be conducted outside the GOCM and should be evaluated for incorporation into GOCM as a module. Such modules, however, may no longer be parametric in nature. Careful consideration must be given to the technique for incorporation. The traditional approach to generating CERs (for incorporation into GOCM) is to draw from a large database (actual data) various cost element values and apply regression analysis to the data for CERs derivation. However, for the LRBI study there are few actuals to draw from. Data point that came from the LRBI study and expressions estimates were based on scaling effects, complexity and similarity to other relationships and data. In this way best engineering judgments and LRB experience was incorporated into the GOCM evaluation and LRB module generation.

GOCM has had three configurations since 1987:

1. Facility Model: This was provided by PRC to NASA in 1987 and estimated the cost of new facilities and support to these facilities.

2. Baseline GOCM: NASA developed a Processing Module and Operations Model to estimate total launch operation costs. This was provided in 1988 by NASA to LSOC under the LRBI Study.

3. Enhanced GOCM: User friendly/expanded software using the baseline methodology and CERs with additional modules for expansion, graphics, mixed booster fleet analysis and additional facilities.

## 14.1 REQUIREMENTS

This section describes the minimum hardware and software requirements necessary to operate the KSC GOCM. Also, the optional equipment is listed to take full advantage of the features available to the user of the cost model.

### 14.1.1 Hardware:

- An IBM Personal Computer or compatible type, with at least 640 KB of available main memory (RAM).

- One 5 1/4" floppy disk drive (360 KB or 1.2 MB) and one hard disk drive (5 MB available storage). A hard disk drive with one floppy is necessary to prevent numerous disk exchanges during model operations.

- Standard keyboard with typewriter keys, pointer movement keys and special [Alt] and [F1] through [F10] function keys.

- A monochrome monitor with a graphics adaptor. A color monitor is preferable with a color graphics adapter.

o A printer is required to produce hard copies of model results. A dot-matrix printer is desirable for graphics capability. The printer should accept 11" or 14" width paper.

### 14.1.2 Software:

- PC or MS Disk Operating System (DOS), version 2.0 or higher.
- Lotus Symphony, version 1.2 or higher.
- KSC Ground Operations Cost Model, version 1988.

## 14.2 INSTALLATION

All hardware, as described in Section 14.1, Requirements, must be setup and operational. Refer to individual hardware item owner manuals for installation and configuration of the integrated system. The DOS must be the first software package installed on the hard disk. This is necessary since Symphony must utilize DOS to communicate with the computer. Refer to DOS users manual for software installation and operation.

Lotus Symphony can be installed after DOS is installed and operational. Create a directory on the hard disk for the Symphony program. Use the DOS command "MD C:\SYMPHONY" and copy the symphony program to the newly created directory. Refer to the "Getting Started" book that comes with the Symphony software package. Installation of Symphony is dependent on the type of hardware being used. Therefore, an install program is included with the Symphony software that will allow the user to select the type of hardware being used for display of graphs and printed hard copies of model results.

Once Symphony is installed and operational, the KSC GOCM should be installed in a new sub-directory called "C:\SYMPHONY\COST". Use the DOS command "MD C:\SYMPHONY\COST". After the new sub-directory is created, copy the KSC GOCM from the program disk to the sub-directory by inserting the GOCM disk A (refer to Section 15) into the floppy disk drive and typing "copy A:*.* C:\SYMPHONY\COST". This will copy disk A to the hard disk drive. Follow the previous procedure to copy the GOCM disk B onto the hard disk drive. The GOCM can be accessed through Symphony as a regular spread sheet work file by using the file retrieve commands to access the file "INTRO.WR1." Or access Symphony by typing

"C:\SYMPHONY\ACCESS", select Symphony from the menu and press the [RETURN] key, press the [F9] key, select File and press [RETURN], select Retrieve and press [RETURN], type "INTRO" and press [RETURN]. The GOCM introduction will be displayed. To skip the GOCM introduction and access the GOCM main menu directly, type "AUTO" instead of "INTRO" and press [RETURN].

## 14.3 OPERATION

Operation of the KSC GOCM, requires the user to be somewhat knowledgeable with basic DOS commands, spreadsheet software programs, and have an understanding of the general operations and processing functions at KSC. There are currently software programs on the market that will tutor the user in basic DOS commands and operation. Also, the Technical Learning Center in room 2145 of the KSC Headquarters Building has self paced tutorial material that will familiarize the user with DOS operation. Lotus Symphony has a good tutorial included with the programs that will teach users spreadsheet and word processing skills necessary to operate and modify the KSC GOCM work files and setting sheets. It is recommended that the user go through the Symphony tutorial before an attempt is made to modify or update any of the GOCM work files. Once the GOCM is installed on the computer, and functioning properly (refer to Section 14.2), the user will be able to utilize the GOCM with on line help screens and reference to the KSC GOCM Users Manual (Volume III, Section 13).

## 14.4 REVISIONS AND MODIFICATIONS - GOCM

### 14.4.1 Access to Spreadsheet Labels and Formulas

Access to the worksheet labels and formulas may be obtained from the initial INTRO screen after any of the Modules or the Operations Model is loaded into RAM and visible on the screen. Press the [Esc] key to clear any menus that may appear on the screen. Press [F9], select Window, press [Return], select Use, press [Return], type "main", press [Return] and [Home]. This will place you at the beginning of the file and allow free access to the entire worksheet with the use of the [Pg Up], [Pg Dn], and arrow keys.

Caution must be exercised when inserting or deleting rows or columns. Window settings and/or range names should be checked for alignment and position. If an error is made or spreadsheet data lost, press [F7] twice, exit the module through the use of the menu and do not save the file.

Original configuration will be restored when the module is reloaded. If pressing [F7] twice does not bring the main menu up, then use the following procedure: Press [Esc], [F9], select Exit, and select Yes. This procedure will ignore any changes and/or errors made to the file and allow you to reaccess the module in its original configuration. If the procedures listed above do not work or the program starts to act erratic then press [Ctrl] [Alt] and [Break] simultaneously. This will exit the file and Symphony and reboot the computer. If the file has been corrupted or configuration lost, the file can be reloaded from the original disk.

### 14.4.2 Automatic Access To GOCM Main Menu from Symphony

To skip over the introduction at the beginning of GOCM and access the Main GOCM Menu automatically after Symphony is loaded, follow the following procedure: Access GOCM in the normal manner. After the GOCM Introduction is displayed, press the [F9] key to access the Symphony Services Menu. Select Configuration, Select Auto, press [Esc] key, type Auto.WR1 and press the [Return] key. To save this change select Update and press [Return], press [Esc] twice.

When Symphony is started again from the DOS prompt, it will automatically load the Main GOCM Menu first instead of the Introduction. This Menu can then access all of the Modules and the Operations Model.

### 14.4.3 Print Setting Sheets for Paper Output

The GOCM, Operations Model and five Modules, have been equipped with two print setting sheets for 11" wide x 8 1/2" long paper and for 14" wide x 11" long paper. To select the print setting sheets for your printer, use the following sequence of commands for the Operations Model or any of the five Modules: access the Model/Modules from the GOCM Main Menu as described under Section 14.4.1. Press the [ESC] key to clear any menus that may appear at the top of the screen. Press the [F9] key, press P for Print, press S for Settings, press N for Name, press U for Use and select either 11" x 8.5" or 14" x 11" and press the [RETURN] key. The Print Setting Sheet will now be set for the paper you are using. Press the [ESC] key three times to exit the Services Menu. Save this Model/Module configuration to retain this information by selecting "YES" when exiting from any of the GOCM menus.

## 14.5 REVISIONS AND MODIFICATIONS - OPERATIONS MODEL

This selection brings the user to the main module, the Operations Model. This model retrieves information from each of the other modules, processes this information and generates a variety of cost reports. The Summary Cost Report reflects the changes in cost caused by different options and variables selected from the five different modules. The function of the Operations Model is to integrate and process all the selected cost information generated by each of the other modules and produce reports with the use of macros. The output reports, together with their range names and location within the model are summarized below in Figure 14.5.1. Macros are located in the model starting at cell A662.

The following is a discussion of the Reports that are generated and information that is contained within the Operations Model.

| Range | Cell | Description |
|---|---|---|
| NAME | B240 | Operations Model identification name |
| PRINT1) | A621..U658 | Summary Cost Report |
| PRINT2) | A261..J315 | Processing Time Schedule |
| PRINT3) | A321..J342 | Facility Processing Capability |
| PRINT4) | A361..H382 | Fixed Cost Report |
| PRINT5) | A401..U437 | Variable Cost Report |
| PRINT6) | A441..U536 | Facility Analysis Report |
| PRINT7) | A541..U568 | Facility Requirement Report |
| PRINT8) | A581..U609 | Flight Hardware Report |

Figure 14.5.1 Operation Model Output Range Names

### 14.5.1 Processing Time Schedule

The Processing Time Schedule takes shifts and manpower data from the Processing Module, and schedule data from the Variables Module, to determine the variable head count to process and recover a vehicle for launch. Manpower and shift modification should be made in the Processing Module to maintain configuration (see Section 14.7.3, Modification of Processing Module CERs). Scheduled work days per week and shifts worked per day are taken from Variables Module and applied to all of the station set flow processes. If unique work day or shift schedules are desirable for any of the station sets, the reference to range D10 for shifts/day and range D9 for days/week must be removed and new values placed in the cells. This procedure will override the automatic reference to Variables Module if the Operation Model is saved at the end of the session. The cells for processing shifts per day are located in the range E269 through E302 and days per week are located in the range G269 through G302 in the Operations Model.

The Processing Time Schedule also determines the minimum variable manpower required to be maintained on site. This minimum manpower is calculated in cell D312 for an SRB type vehicle and cell D313 for an LRB vehicle. The formula used to calculate minimum manpower is shifts per day times (booster, core, LEO-VEH and P/L Processing) men per shift.

### 14.5.2 Facility Processing Capability

The Facility Processing Capability takes the days per flow and calendar weeks required to process the various vehicle elements from the Processing Time Schedule, and determines the number of flows that can be processed through each facility at 100% facility utilization. These flights per year for each facility are then adjusted by the facility utilization factor from the Variable Module (cell D13). The Facility Processing Capability is also dependent on the number of weeks that are available in each facility. The calculation for available weeks can be found in cell C314 for all facilities except the OPF and is given as 365 days per year minus the number of holidays per year, as input from the Variable Module, divided by seven days per week. Available weeks in the OPF can be found in cell C315 and subtracts the time required to conduct structural inspections on the LEO-VEHs as shown in the Processing Time Schedule (cell D310).

Also listed under Facility Processing capability is the LEO-VEH capability that calculates the maximum number of flights that can be obtained from one LEO-VEH in a year. If the LEO-VEH being modeled is an Orbiter, than place "Orbiter" in cell C342 to account for downtime during structural inspections. If the LEO-VEH is not an orbiter than place "other" or any other name into cell C342.

The number of shifts required for one structural inspection is located in cell D310 and is currently set at 81 if the LEO-VEH is set to "Glideback" in cell G60 and turnaround is set to "Revised" in cell D50. To change shifts per structural inspection, access cell D310 and change 81 to the revised value. Save the Operations Model when exiting to retain any changes you have made.

### 14.5.3 Fixed Costs

Fixed costs in the Operations Model can be found within the range A361 to H382. These costs are actually user defined fixed costs that are required for base operations, independent of vehicle processing and operations and maintenance. The summation of fixed costs are shown in cell H381 and the summation of fixed manpower is shown in cell H382. Both summations are adjusted by the "Manned Factor" given in cell H379. Currently, the Manned Factor states that 100% of the Fixed Costs and manpower are used if the vehicle being modeled is manned and 50% of the Fixed Costs and Manpower are used if the vehicle is unmanned. This formula uses the input given in the Processing Module to determine if the vehicle is manned or unmanned from cell F60 in the model. Any updates or modifications to fixed costs should consider the above referenced cells before changes are made.

### 14.5.4 Variable Costs

Variable costs are brought together and illustrated in the model within the cell range A401 through U437. The flight schedule is received from the Traffic Module to determine the number and type of booster vehicles that are launched per year. Variable manpower required to process the vehicle(s) are taken from the Processing Time Schedule. A comparison is made between cells E428.T428 to determine the minimum manpower required for each booster type vehicle and uses the largest minimum requirement. Another comparison is made between cells E411 through S411 to determine whether the minimum manpower or required manpower should be used (the larger value is chosen). The required variable manpower is adjusted (smoothed) between cells A422 through S425 to bring half of the additional people required for processing on board one year in advance, if required manpower is increasing.

Variable costs per flight are the sum of direct cost and direct support cost shown in cell D435 for a solid booster vehicle and cell G435 for a liquid booster vehicle. Direct support costs are calculated as a percent of direct costs in cells D434 and G434. Currently, the direct support values are set to 0% as received in the original model configuration. After a model calibration exercise is conducted, these values may be adjusted to reflect actual conditions. Simply access cells D434 and G434, type in the revised percent of direct costs, for direct support costs, and save the model configuration when completed.

Variable costs per flight are further adjusted in cells E415 through T415 for a solid booster vehicle and cells E416 through T415 for a liquid booster vehicle to account for learning or process experience from the Learning Curve Module. Manpower improvement factors are located in cells E193 through T193 in the Operations Model.

### 14.5.5 Facility Requirements

Facility requirements takes the summary results from facility analysis (See Section 14.5.7) and displays the output in an easy to read format. The number of existing facilities are listed together with the new facility requirements and the date required to support the launch rate as specified from the Traffic Module. Also listed, is the number of existing reusable Orbiters and number of additional Orbiters required to support the launch rate as defined under Section 14.5.6, Flight Hardware.

### 14.5.6 Flight Hardware

Flight Hardware is analyzed in the Operation Model in the range of cells between A581 through U609. This area of the model calculates costs and manpower for structural inspections if the LEO-VEH is a reusable Orbiter. The number of existing Orbiters in the fleet is placed in cell D608. Currently, four existing Orbiters are assumed for future studies. The flight per year capability of an orbiter is taken from the Facility Processing Capability, see Section 14.5.2. This capability is then compared to the required flights per year per Orbiter and new Orbiters added as required to meet the launch rate. Manshifts for one structural inspection is shown in cell E600. This value is received from the Processing Time Schedule (see Section 14.5.1). Manpower is transferred to cost in cell E601 and then multiplied by the number of Orbiters in the fleet in each year. The cost for structural inspections is rolled up in cells E590 through S590 and required manpower rolled up in cells E591 through S591.

### 14.5.7 Facility Analysis

Facility analysis in the Operations Model is used to compare existing facilities with the required facilities to support the launch schedule. If a sufficient number of facilities are not available, then new facilities and associated costs are added, as required. Existing and new facilities are then man loaded to determine O&M costs together with recurring spares to support the facilities. The facility analysis section utilizes a major portion in the model and is located in the cell range between A441 through U536.

Each facility required to support the launch schedule, as defined by the Traffic Module, is listed. These listed facilities, as defined by the Facility Module, are analyzed by capability, required number, available number, new facilities that should be added, cost of initial investment and recurring support O&M manpower and spares cost. O&M costs and manpower is factored and rolled-up in ranges E452.T452 and E459.T459, respectively. Total O&M costs are subtotaled from each of the facilities in cells E455 through S455 plus 40% for "other" O&M costs. To modify or revise this 40% factor, access cells E454 through T454 and replace the value (.4) with the new factor as a decimal percentage. Save the module configuration when exiting to retain the revised O&M factor.

The Facility investment cost is increased when the launch site is located at the Western Test Range (WTR) by a factor of 1.25 or 125% of the ETR baseline. This factor is located in cell C439. To change this factor, access cell C439, insert the new factor and save the model when exiting.

### 14.5.8 Summary Costs

The summary cost section of the GOCM is located in the Operations Model in the cell range A621 through U658. This section takes the summary costs and manpower from Variable Processing, Facility O&M, Flight Hardware, Fixed and Facility Requirements and roll these values up for a total cost per fiscal year in cells E632 through S632. Total Recurring Costs are total costs per fiscal year excluding the KSC Facility Investment Costs and are located in cells E635 through U635. Total recurring costs per year are then divided by the number of flights per year and the payload weight to orbit as received from the Traffic Module to calculate the cost per flight (cells E638.S638) and cost per pound of P/L (cells E639.S639). Summary costs and their subtotals are also used to make-up the Summary Cost Graph that is an available option from the Main Operations Model Menu.

## 14.6 REVISIONS AND MODIFICATIONS - VARIABLES MODULE

The Operations module basis its calculations on a number of basic assumptions. These assumptions include the location of the launch site, the average wage rate, the number of workdays per week and the number of shifts per day. This module allows you to select a standard choice from a menu, or enter your own values.

### 14.6.1 Input Variables

The Variables Module is basically a storage file for variables used throughout the Operations Model. It is menu driven by the use of macros and range names. The macro menus can be seen in the Variables Module starting at cell A52. Range names for the input variables are listed in Figure 14.6.1 together with their cell location within the worksheet and a brief description.

| Range | Cell | Description |
|---|---|---|
| DAYS | D32 | Work schedule in days per week |
| ESCAL% | D35 | Escalation rate in percent |
| HOLIDAYS | D34 | Holidays in days per week |
| INDEX_YEAR | D31 | Year to express dollar value |
| LOC_SITE | D29 | Launch site location |
| MAN_RATE | D30 | Manpower wage rate in dollars per man shift |
| NAME | B27 | Variables Module identification name |
| NTH | D41 | Factor calculated, equals start year minus index year |
| SHIFTS | D33 | Work schedule in shifts per day |
| START_YEAR | D39 | Start year (Use same year as Traffic Module) |
| SURGE% | D37 | Flight hardware surge capacity in percent |
| UTIL% | D36 | Facility utilization capability in percent |

Figure 14.6.1 Variable Module Input Range Names

### 14.6.2 Elimination of Introduction at Beginning of Variables Module

To skip over the introduction at the beginning of the Variables Module, follow the following procedure: Access the Variables Module from the Main GOCM Menu. The introduction window to the Variable Module will be displayed. Press the [F9] key which will access the Symphony Services Menu. Select Settings, select Auto-execute, select Set, type \7, press the [Return] key, press [Esc] twice. this procedure will now execute the Macro \7 at the beginning of the next session. to save this modification, save the current file configuration by pressing [F9], select File, select Save, press [Return] select Yes.

## 14.7 REVISIONS AND MODIFICATIONS - PROCESSING MODULE

The Processing module allows you to select one type of vehicle with either a solid or liquid booster configuration and evaluate the different processing costs for each. If a mixed booster fleet is being analyzed, then select the input variables for both a solid and a liquid booster.

### 14.7.1 Input Variables

The Processing Module determines the vehicle configuration for a SRB and/or LRB type vehicle with the use of input variables. These vehicle configuration input variables are used to calculate the number of processing manpower and shifts required to process flight hardware prior to launch and deservice after landing (if required). This Module is also menu driven by the use of macros and range names. The macro menus can be seen in the Processing Module starting at cell A182. Range names for the input variables are listed in Figure 14.7.1 together with their cell location within the worksheet and a brief description.

| Range | Cell | Description |
|---|---|---|
| CORE_ENG | D37 | Number of engines to place on CORE module |
| CORE_LOC | D39 | Location of CORE on integrated vehicle |
| CORE_NUM | D38 | Number of COREs per integrated vehicle |
| CORE_PRO | D40 | Type of CORE propellant (fuel) being used |
| CORE_REC | D41 | Recovery Method used for CORE disc. #1 |
| CORE_REC1 | E41 | Recovery Method used for CORE disc. #2 |
| LEO_ENG | D42 | Number of engines to place on Low Earth Orbiter |
| LEO_LOC | D44 | Location of LEO on integrated vehicle |
| LEO_NUM | D43 | Number of LEOs per integrated vehicle |
| LEO_PRO | D45 | Type of LEO propellant (fuel) being used |
| LEO_REC | D46 | Recovery Method used for LEO disc. #1 |
| LEO_REC1 | E46 | Recovery Method used for LEO disc. #2 |
| LRB_ENG | D32 | Number of engines to place on Liquid Rocket Booster |
| LRB_LOC | D34 | Location of LRB on integrated vehicle |
| LRB_NUM | D33 | Number of LRBs per integrated vehicle |
| LRB_PRO | D35 | Type of LRB propellant (fuel) being used |
| LRB_REC | D36 | Recovery Method used for LRB disc. #1 |
| LRB_REC1 | E36 | Recovery Method used for LRB disc. #2 |
| NAME | B62 | Processing Module identification name |
| PAY_LOC | D48 | Location of integrated vehicle payload |
| PAY_NUM | D47 | Average number of payloads to process per flight |
| SRB_LOC | D29 | Location of SRB on integrated vehicle |
| SRB_NUM | D28 | Number of SRBs per integrated vehicle |
| SRB_PRO | D30 | Type of SRB propellant (fuel) being used |
| SRB_REC | D31 | Recovery Method used for SRB disc. #1 |
| SRB_REC1 | E31 | Recovery Method used for SRB disc. #2 |
| SRB_SEG | D27 | Number of segments for Solid Rocket Booster |
| TECH | D25 | Technology level being modeled |
| TURN | D26 | Processing turnaround timeframe |
| VEH | D24 | Type of Vehicle being modeled |

Figure 14.7.1 Processing Module Input Range Names

### 14.7.2 Elimination of Introduction at Beginning of Processing Module

To skip over the introduction at the beginning of the Processing Module: Access the Processing Module from the Main GOCM Menu. The introduction window to the Processing Module will be displayed. Press the [F9] key which will access the Symphony Services Menu. Select Settings, select Auto-execute, select Set, type \7, press the [Return] key, press [Esc] twice. this procedure will now execute the Macro \7 at the beginning of the next session. to save this modification, save the current file configuration by pressing [F9], select File, select Save, press [Return] select Yes.

### 14.7.3 Modification of Processing Module CERs

The processing CERs consist of two groups within the module. The first group contains the processing shifts required to process the vehicle configuration chosen from the input variables. Shift CERs are located in the module starting at cell A134 and ending at cell M158. The second group of CERs contain the manpower required to process the vehicle elements that are configured from the input variables. Manpower CERs are located in the module starting at cell A160 and ending at cell M180. Use the following method to access the processing module CERs: Access the processing module from the main GOCM menu. The introduction window to the processing module will be displayed, if it has not been over ridden as described in section 14.7.2. If the introduction window has been removed then press the [Esc] key to clear the opening menu. Press the [F9] key, which will access the symphony services menu. Select window, select use, type "main" and press the [Return] key. This will allow you access to the entire spreadsheet. Press the [F5] key and type "A134" and press [Return]. This will place you at the beginning of the processing module CERs. See section 14.7.3.1 to update shift CERs and section 14.7.3.2 to update manpower CERs. Save any modification or revisions that are made to the module by processing [F7] twice, select exit and select Yes to "Save this module with all changes".

#### 14.7.3.1 Processing Shift CERs

Processing shift CERs are described between cells A138 through A156 of the spread sheet. These descriptions may be modified without jeopardizing the integrity of the calculation results. The shifts required to process the basic flight elements are located in three areas: 1. Pre 51-L processing shifts are located in cells I138 through I156. 2. Post 51-L processing shifts are located in cells H138 through H156. 3. Future processing shifts are located in cells J138 through J156. Currently, future processing shifts are identical to pre 51-L shifts due to lack of sufficient planning data.

However, these CERs have been provided as an expansion ready feature and can be modified as data becomes available. To insert a new value for the shifts required to process the elements as described under column A in the spread sheet, use the arrow keys to highlight the cell you would like to change. Type in a new CER valve and press [Return].

Technology CERs are percentage values applied to processing shifts. Basically, the higher the technology applied or in place, a lower number of shifts will be required to process flight elements. The technology levels that can be chosen from the module menu are within "Baseline", "Improved" or "Advanced". These CERs are located in cells K138 - K156, L138 - L156 and M138 - M156, respectively. Currently, baseline technology is existing and no reduction to the number of shifts is implied (0%). Improved technology assumes that all existing technology has been implemented and that a reduction in the number of shifts can be realized. This reduction (0-85%) is dependent on the flight hardware being processed and the associated available technology. To insert a new technology percentage for either "Baseline" or "Improved", use the arrow keys to highlight the cell you would like to change. Type in a new decimal percent and press the [Return] key. Advanced technology is calculated from the improved technology level by the equation:

$$y = 2x - x^2$$

where: $y$ = advanced technology factor
$x$ = improved technology factor

This equation can be replaced by either a modified expression or actual decimal value as described above for baseline and improved.

### 14.7.3.2 Processing Manpower CERs

Processing manpower CERs are described between cells A164 through A179 of the spreadsheet. These descriptions may be modified without jeopardizing the integrity of the calculation results. The manpower required to process the basis flight elements are located in three areas: 1. Pre 51-L processing manpower are located in cells I164 through I179. 2. Post 51-L processing manpower are located in cells H164 through H179. 3. Future processing manpower are located in cells J164 through J179. Currently, Post 51-L and future processing manpower are identical to Pre 51-L manpower levels.

To insert a new value for the manpower required to process the elements as described under column A, use the arrow keys to highlight the cell you would like to change. Type in a new CER value and press [Return].

Technology CERs are percentage values applied to processing manpower requirements. Basically, the higher the technology applied or in place, a lower number of manpower will be required to process flight elements. The technology levels that can be chosen from the module menu are within "baseline", "improved" or "advanced". These CERs are located in cells K164..L179, L164..L179 and M164..M179, respectively. Currently, baseline technology is existing and no reduction to the number of manpower is implied (0%). Improved technology assumes that all existing technology has been implemented and that a reduction in the number of manpower can be realized. This reduction (0 - 50%) is dependent on the flight hardware being processed and the associated available technology. To insert a new technology percentage for either "baseline" or "improved", use the arrow keys to highlight the cell you would like to change. Type in a new decimal percent and press the [Return] key. Advanced technology is calculated from the improved technology level by the equation:

$$y = 2x - x^2$$

where: $y$ = advanced technology factor
$x$ = improved technology factor

This equation can be replaced by either a modified expression or actual decimal value as described above for baseline and improved.

## 14.8 REVISIONS AND MODIFICATIONS - TRAFFIC MODULE

The Traffic model allows you to select different launch rates and payload capacities. The launch rates and payload capacities, in turn, affect operation cost.

### 14.8.1 Input Variables

The Traffic Module is basically a mission model file for the start year of assessment, flight schedule for solid and/or liquid rocket booster configuration(s) and respective payload weight to low earth orbit. These traffic variables are used throughout the Operations Model for calculations regarding flight rates and payload weights. It is menu driven by the use of macros and range names. The macro menus can be seen in the Traffic Module starting at cell A54. Range names for the input variables are listed in Figure 14.8.1 together with their cell location within the worksheet and a brief description.

| Range | Cell | Description |
|---|---|---|
| NAME | B27 | Traffic Module identification name |
| PAY_UTIL | C32 | Payload utilization efficiency for SRB vehicle(%) |
| PAY_UTIL2 | G32 | Payload utilization efficiency for LRB vehicle(%) |
| PAY_WEIGHT | C31 | Average payload capability of SRB vehicle (K-lbs) |
| PAY_WEIGHT2 | G31 | Average payload capability of LRB vehicle (K-lbs) |
| PAY_YEAR | C29 | Start year (Use same year as Traffic Module) |
| SCHEDULE | C30 | Schedule name of SRB vehicle from list in table |
| SCHEDULE2 | G30 | Schedule name of LRB vehicle from list in table |

Figure 14.8.1 Traffic Module Input Range Names

### 14.8.2 Elimination of Introduction at Beginning of Traffic Module

To skip over the introduction at the beginning of the Traffic Module, follow the following procedure: Access the Traffic Module from the Main GOCM Menu. The introduction window to the Traffic Module will be displayed. Press the [F9] key which will access the Symphony Services Menu. Select Settings, select Auto-execute, select Set, type \7, press the [Return] key, press [Esc] twice. This procedure will now execute the Macro \7 at the beginning of the next session. To save this modification, save the current file configuration by pressing [F9], select File, select Save, press [Return] and select Yes.

### 14.8.3 Modification of Vehicle Schedule Database

The Traffic Module comes with six pre-defined vehicle schedules and one schedule that can be defined by the user through the use of menus and on line instructions. The pre-defined schedules include POP 85, POP 87, POP 88, MANIFEST, LRB STUDY and GENERIC. The user defined schedule is referred to as CUSTOM. All seven of these schedule names and flight rates may be modified by the user by following these instructions: Access the Traffic Module in the normal manner. After the INTRO window is displayed, press the [F9] key to access the Symphony Services Menu. Select Window, Select Use, type "Main" and press the [Return] key. This will allow you access to the entire spread sheet. Press the [F5] key and type "A42" and press [Return]. This places you in the vehicle schedule database. Go to the cell that is to be modified by the use of the arrow keys and type a new name for a vehicle schedule or replace a number for a new flight rate.

When the above procedure is completed, and the database has been modified, the Traffic Module should be saved to retain the new modifications. Press [F7] twice, Select Exit, Select Yes to "Save Module with all changes". When the Traffic Module is accessed again, the new flight schedule database will be displayed. The new Vehicle flight schedules names will automatically appear in the menu after the Schedule is selected.

## 14.9 REVISIONS AND MODIFICATIONS - FACILITY MODULE

The Facility module allows you to choose the processing facilities required to prepare the type of vehicle you configured in the Processing module.

### 14.9.1 Input Variables

The Facility Module makes full use of the Symphony database functions and the Form window. The form window shown below, takes data from an input database, performs calculations, and then returns the data to the database. The calculations are executed in cells E54 to E66. You are "locked out" of the GENERIC, CER, FACILITY LENGTH, FACILITY WIDTH, FACILITY HEIGHT, CoF, EQUIP and SUPT fields in the Input Form window. The window only allows you to change NUMBER, SHARED, and ELEMENT LENGTH, ELEMENT WIDTH, and ELEMENT HEIGHT. The Facility Module Input Variable Window is shown in Figure 14.9.1-1.

The GENERIC name and CER number are taken directly from the CER database, and cannot be changed by the user from the input window. The NUMBER, SHARED, ELEMENT LENGTH, ELEMENT WIDTH, and ELEMENT HEIGHT are input variables that are user defined.

The Facility Module is menu driven by the use of Macros that drive the windows and range names. The Macro menus can be found in the module starting at cell A196. Range names for the input variables are listed in Figure 14.9.1-2 together with their cell location and a brief description.

```
+--------------------------------------------+
|GENERIC SRMPF____                           |
|CER 16                                      |
|NUMBER 0                                    |
|SHARED Y                                    |
|ELEMENT LENGTH 13__                         |
|ELEMENT WIDTH 13__                          |
|ELEMENT HEIGHT 49__                         |
|FACILITY LENGTH 197.0____                   |
|FACILITY WIDTH 150.0____                    |
|FACILITY HEIGHT 95.0____                    |
|COF 140.1____                               |
|EQUIP 281.5____                             |
|SUPT 18.6____                               |
+-------------------------------------INPUT--+
```

Figure 14.9.1-1 Facility Module Input Variables

| NAME | RANGE | DESCRIPTION |
|---|---|---|
| INIT_SPARES | D133 | Initial Spares Rate |
| INPUT_CR | A71.M72 | Input database criteria |
| INPUT_DB | A78.R94 | Input database |
| INPUT_DF | A54.H66 | Input database definition |
| INPUT_EN | A36.A48 | Input database entry |
| MAN_RATE | D135 | Manpower wage rate |
| NAME | B108 | Facility Module Identification name |
| O&M_MAN_FACTOR | D130 | O&M manpower factor |
| O&M_MAN_RATE | D131 | O&M manpower rate |
| O&M_SUPP_RATE | D132 | O&M supplies rate |
| RECUR_SPARES | D134 | Recurring spares rate |

Figure 14.9.1-2 Facility Module Input Range Names

### 14.9.2 Elimination of Introduction at Beginning of Facility Module

To skip over the introduction at the beginning of the Facility Module, follow the following procedure: Access the Facility Module from the Main GOCM Menu. The introduction window to the Facility Module will be displayed. Press the [F9] key which will access the Symphony Services Menu. Select Settings, select Auto-execute, select Set, type \7, press the [Return] key, press [Esc] twice. This procedure will now execute the Macro \7 at the beginning of the next session. To save this modification, save the current file configuration by pressing [F9], select File, select Save, press [Return] and select Yes.

### 14.9.3 Modification of Facility Module Variable CERs

The Facility Module Variable CERs can be accessed through the initial menu by choosing "Variables". These input variable CERs and their range names are shown if Figure 14.9.1-2 and include: O&M Manpower Factor, O&M Supplies Rate, Initial Spares Rate, Recurring Spares Rate and Manpower Wage Rate. The O&M Manpower Rate is an equation that is calculated by multiplying 3 (which represents 3 shifts per day) times the Manpower wage rate divided by the O&M manpower Factor. This equation can be found in cell D131 and modified by accessing the module spreadsheet (press the [Esc] key, press the [F5] key, type "D131" and press the [Return] key. After you have modify the equation, press the [F7] key twice which will return you to the opening menu and be sure to save any change made.

### 14.9.4 Modification of Facility Module CERs

The Facility Module CERs are listed values calculated from the source database and the user inputs. The formulas, which may appear complicated at first, are actually very simple in concept. The formula for F_LENGTH is located in cell E61 and listed as follows:

F_LENGTH = +B58+@vlookup(B55,A145..N160,5)

The value +B58 is the element length. The value @vlookup(B55,A145..N160,5) is a reference to the D_LENGTH column in the Lookup Table range (A145..N160). The D_LENGTH column itself is calculated from the Source Database range (A166..N180). D_LENGTH is the difference between the Source Database value for the element length and the facility length. As you can see, all that the formula for facility length does is take the user input element length and add a standard offset for that element. The facility F_WIDTH and F_HEIGHT are calculated using similar formulas and are located in cells E62 and E63, respectively.

The previous paragraph referred to the "Source Database." The Source Database is located between cells A163 and N181 and contains the original facility data as provided by NASA. This database cannot be accessed by the macro program. You can only reach this information by addressing the spreadsheet itself as described under Section 14.4.1. This data should only be changed after a revised Cost Estimating Relationship (CER) has been verified. The Lookup Table Range supplies data to the Form window and is derived from data in the Source Database which is located between cells A142 through N160.

The Cost of Facility (CoF) formula calculates the cost of the building, or structure itself. This value is located in cell E64 and is calculated by the following formula:

CoF = [@vlookup(B55,A145..N160,1)*(B61*B62*B63)]/1000000

This is also a complicated looking formula that is really simpler than it looks. The @vlookup(B55,A145..N160,1) part of the formula is a reference to the cost per cubic foot (CPF3) column in the Lookup Table Range. B61, B62 and B63 are the cells that hold the facility length, width and height calculations. So the formula takes the per-determined cost per cubic foot of a facility, multiplies it by the volume of the facility, and divides the product by one million to get the total estimated cost of the facility in millions of dollars.

The Cost per Cubic Foot (CPF3), for each of the facilities, are located in the Source Database between cells N166 and N181 and are original CERs based on 1987$. Two additional CERs have been added to the Facility Module as a result of the LRBI Study. One is for a Liquid Rocket Booster Processing Facility and the other is for a Liquid Rocket Booster Refurbishment Facility.

The EQUIP input refers to the cost of GSE/LSE and capital equipment contained within the facility and is located in cell E65. This value is calculated using the formula:

EQUIP = [@vlookup(B55,A145..N160,3)/@vlookup(B55,A145..N160,2)]*E64

The @vlookup(B55,A145..N160,3) part of the formula refers to the Equip column in the Source Database. The @vlookup(B55,A145..N160,2) part of the formula refers to the CoF column in the Source Database. The quotient of these two numbers gives you a percentage. This percentage is multiplied by cell E64, the CoF calculated in the Form window. So this formula takes the percentage of EQUIPment/CoF in the original, unchanging Source Database and multiplies it by the new CoF calculated in the Form window. The result is the equipment cost for the facility as defined by the user in the Form window.

The SUPT CER refers to the Support Facilities, or peripheral facilities required by the main facility and is located in cell E65. An example would be the LH2, LO2 and Hypergol support facilities at the launch pad. This value is calculated using the formula:

SUPT = [@vlookup(B55,A145..N160,4)/@vlookup(B55,A145..N160,2)]*E64

The @vlookup(B55,A145..N160,4) part of the formula refers to the SUPT column in the Source Database. The @vlookup(B55,A145..N160,2) part of the formula refers to the CoF column in the Source Database. The quotient of these two numbers gives you a percentage. This percentage is multiplied by cell E64, the CoF calculated in the Form window. So this formula takes the percentage of SUPT/CoF in the original, unchanging Source Database and multiplies it by the new CoF calculated in the Form window. The result is the SUPT equipment cost for the facility as defined by the user in the Form window.

## 14.10 REVISIONS AND MODIFICATIONS - LEARNING CURVE MODULE

The Learning module allows you to create a variety of different learning curves. You import the factors that create these curves into the Operations module. The factors change processing and cost data generated by the Operations module.

### 14.10.1 Input Variables

The Learning Curve Module can reduce the number of shifts required to process flight hardware and the number of people that are required per shift if desired. The Learning Module uses a cumulative average relationship developed by Dr. T.P. Wright. The variables required for the Wright equation are the cumulative flight number, the learning percentage, and Traffic Module data to determine when the cumulative flight number occurs and whether the vehicle is a shuttle type vehicle which has already experienced leaning in the past. These variables are used to calculate a percentage reduction table that is used by the Operations Model. The Leaning Curve Module is also menu driven by the use of macros and range names. The macros menus can be seen in the Leaning Curve Module starting at cell A119. Range names for the input variables are listed in Figure 14.10.1 together with their cell location within the worksheet and a brief description.

| Range | Cell | Description |
|---|---|---|
| FLIGHT | B33 | Cumulative number of flights required to achieve estimated learning percent. |
| LEARN | B31 | Manpower learning curve percent. |
| LEARN_P | B32 | Processing time learning curve percent. |
| NAME | B28 | Learning Module identification name. |
| RTRVE_TRAFFIC | A99 | Traffic Module input data location. |
| VEHICLE | B30 | Type of vehicle being modeled. |

Figure 14.10.1 Learning Curve Module Input Range Names

### 14.10.2 Elimination of Introduction at Beginning of Learning Curve Module

To skip over the introduction at the beginning of the Learning Curve Module, follow the following procedure: Access the Learning Curve Module from the Main GOCM Menu. The introduction window to the Learning Module will be displayed. Press the [F9] key which will access the Symphony Services Menu. Select settings, select auto - execute, select set, type \ 17, press the [Return] key, press [ESC] twice. This procedure will now execute the Macro \ 7 at the beginning of the next session. To save this modification, save the current file configuration by pressing [F9], select File, select Save, press [Return] and select yes.

### 14.10.3 Previous Launch Experience

The Learning Curve Module compensates for previous experience gained on the existing shuttle program by use of the vehicle name used in the input variables. If a vehicle beginning with "STS" (Shuttle Transportation System) or "SDV" (Shuttle Derivative Vehicle) is typed from the vehicle input menu, then experience gained from the STS program is taken into consideration when future calculations are made. Currently, the prior shuttle launches are calculated in cell C45 which assumes the following factors if a STS or SDV preceding vehicle name is chosen.

- Learning starts with STS - 26R as the first launch.
- Nine launches are assumed to occur prior to FY 1990.
- A launch rate of 14 flights per year is assumed to occur during and after FY 1990.

To change the previous assumptions, access cell C45 and revise the equation. Save the file configuration when exiting the Learning module to maintain the new configuration. If a vehicle is chosen that does not begin with STS or SDV, then no previous learning is assumed and the curve will start on the first launch and first year specified by the Traffic Module input data that is retrieved from the Learning Curve Module.

## APPENDIX A) GROUND RULES

The following ground rules and assumptions were used in the preparation of the KSC Ground Operations Cost Model.

1. Baseline costs were converted to 1987 dollars and factored for previous and future years.
2. Original configuration was maintained, when possible, and revised only to enhance and expand the GOCM.
3. No CER's where modified or changed, only new CER's added to expand the GOCM.

## APPENDIX B) REFERENCE DOCUMENTS

1. Learning Curves Theory and Application Ravinder Nada and George l. Alder, 1982

2. Space Transportation System and Associated Payloads: Glossary, Acronyms, and Abbreviations NASA Reference Publication 1059 Revised, 1985

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   Release 2.0, 1987

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   NSTS Engineering Integration Office
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7. Baseline Manifest, KSC Assessment
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   Draft Final Report
   Boeing Aerospace Operations
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October 1, 1986

# VOLUME III

## SECTION 15

ALL SOFTWARE DEVELOPED

## VOLUME III - SECTION 15
## KSC GROUND OPERATIONS COST MODEL SOFTWARE

This section fulfills Part I, Section C, Paragraph 3.0 Study Products of the contract requirement under "All software developed". The enhanced KSC Ground Operation Cost Model (GOCM) is stored on two 360K double sided, double density, flexible disks. Both disks are attachments to the Final report. These disks contain all of the work files necessary to operate GOCM assuming that a Disk Operating System and a Symphony software package are already installed on the computer (See VOLUME III, Section 14 Instructions). Also, contained on the two disks, are the Users Manual (VOLUME III, Section 13), Instructions (VOLUME III, Section 14), Modules and sample data files. The following is a tabulation of the files located on the two flexible disk:

### 15.1 Disk A

| | |
|---|---|
| Ground Operations Cost Model | Operate.WR1 |
| Users Manual | Manual.WR1 |
| Instructions | Instruct.WR1 |

### 15.2 Disk B

| | |
|---|---|
| Variables Module | Variable.WR1 |
| Processing Module | Process.WR1 |
| Traffic Module | Traffic.WR1 |
| Facility Module | Facility.WR1 |
| Learning Curve Module | Learn.WR1 |
| Variables Module Data | Baseline.VAR |
| Processing Module Data | Baseline.PRO |
| Traffic Module Data | Baseline.TRF |
| Facility Module Data | Baseline.FAC |
| Learning Curve Module Data | Baseline.LRN |

# VOLUME III

## SECTION 16

### RECOMMENDATIONS FOR FOLLOW-ON STUDY ACTIVITY

# VOLUME III SECTION 16

# RECOMMENDATIONS FOR FOLLOW-ON STUDY ACTIVITY

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# RECOMMENDATIONS FOR FOLLOW-ON STUDY ACTIVITIES

The individual recommendations for continued study fall into three groups. The first of the three recommendations enhance the modeling tools to more effectively deal with multi-mission transition planning and costs. The fourth through the sixth recommendation reflects the application of LRB to alternate launch vehicles. The last recommendation proposes the development of a model of launch site requirements and specifications to be incorporated into contracts effecting the launch and launch processing. During the performance of the first phase of the LRB Integration Study the study team developed analysis techniques and launch site models which are universally applicable for the evaluation of any new element integration activity.

The LRB Phase-A contractors for MSFC have moved into the definition of alternate LRB applications in their current contract extensions. In order to continue the integration of launch site aspects in the planning for these new LRB configurations, LSOC proposes to apply these newly developed requirements, scenarios, impacts and cost for alternate applications of LRB.

Communicating the launch processing requirements and recommendations can most effectively be accomplished by incorporating in the study, engineering and development contracts, the appropriate requirements and specifications. This could be accommodated by developing and maintaining a model of these parameters.

## 16.1 ENHANCED PROCESSING FLOW MODEL

The SRB/STS Ground Processing Flow Model is an Artemis network based planning tool. It provides timeline visibility for facility planning and utilization at the launch site in a multi-mission single fleet environment. The model is based upon a generic set of groundrules and assumptions which are incorporated as the network database. The LRBI Study Team has utilized this model to generate a SRB/STS ground processing baseline which was manually compared with multiple LRB scenarios and used in impact analysis.

As a result of the Phase 1 LRBI Study lessons learned, it is believed this model currently is limited in flexibility by its network structure and format. It will not, in its present state, accommodate automated multi-mission mixed fleet evaluations. Timely execution of "what-if" routines for various vehicle scenarios is therefore limited.

An enhanced STS Ground Processing Flow Model has the potential to be a useful tool for Advanced Programs schedule and resource analysis. It can be tailored for multi-mission, mixed fleet evaluation and standardized impact analysis for alternate program options.

A. Restructure the Artemis net work database to provide capability for:
  - Automated multi-mission fleet evaluation
  - Quick response analysis of discreet scenario alternatives

B. Reformat the Artemis software to a menu oriented package for simple data entry and analysis.

C. Exercise the enhanced STS Ground Processing Flow Model with a mixed fleet of SRB/STS, LRB/STS and alternate vehicles flight hardware scenarios.

D. Optional-study the interface between Artemis and GOCM.

### 16.1.2 Products

All software developed; sample products will be generated including graphics and reports for a STS multi-mission mixed fleet providing schedule visibility.

## 16.2 MODIFY/UPDATE GOCM

### 16.2.1 Purpose

Post 51-L ground processing environment must be incorporated into GOCM as derived from KSC ground processing operations. Simultaneously, GOCM needs to be redeveloped using a more capable software system in order to achieve greater user friendliness and application. Another proposed modification is to incorporate a mixed fleet capability into GOCM.

The KSC Ground Operations Cost Model (GOCM) is now capable of analyzing costs of both Solid and Liquid Booster configurations launching concurrently during the same fiscal year. This mixed fleet capability, for one STS type vehicle with different boosters, provides more flexibility in the model to analyze alternative scenarios. It is recommended that this enhancement be further developed to include mixed fleet capability for two alternative Shuttle type vehicles such as in the Shuttle II and Shuttle C studies. Results from these studies should be incorporated into the GOCM database.

This enhancement to GOCM would increase the utility of the cost model and allow greater flexibility in the analysis of alternate vehicle configurations at KSC. A mixed fleet analysis is essential to evaluate the phase-in of new programs while existing programs are in place or are being phased-out.

### 16.2.2 Tasks

A. Update GOCM Ground Processing CERs - develop data collection system.
B. Investigate software for GOCM - implement Mixed Fleet, multi-mission capability into GOCM.

### 16.2.3 Products

A. Software
B. Update User Manual
C. Revised Instructions

## 16.3 DEVELOP GOCM II

### 16.3.1 Purpose

Design and implement a Ground Processing Cost and Schedule Assessment System which will serve KSCs future program planning.

### 16.3.2 Requirements

The ability to tailor a GOCM type modeling system to the application and its phase of study requires the concept of modularity to be employed. Many GOCM features today would just as easily handle parameters developed elsewhere from accounting techniques, besides those currently developed parametrically. Therefore, with further refinement, GOCM could span the vast needs for costing over a wide range of study phases. There would be the quick broad response obtained from parametric CERs to the focused, detailed accounting cost techniques, available in various mixes for each application.

### 16.3.3 Approach

A. Expand GOCM to provide more options and expand its applicability.

B. Develop the requirements for the establishments of a fulltime custodial, development and user organization, referred to here after as the Cost Projection Organization (CPO).

C. Develop a CPO plan and budget request to accomplish the following tasks:

1. Participate and/or review all studies conducted relating to the launch/ground processing activities to:

    a. Expand the CPO database
    b. Perform Cost evaluations

2. Establish cost and effectiveness projection for NASA, and its customers.

3. Develop costing and measures of merit capability.

4. Participate in NASA/Contractor working group meetings.
    a. Cost assessments
    b. R&M
    c. Advanced technology
    d. Another

5. Assist budget generation and reviews

6. Develop a supplementary data collection system which would supply the necessary feedback data to maintain the GOCM CERs currency and relevancy. This data system would also be used to create and maintain CERs of greater resolution for Phase A-D

Studies (budget and trade studies). Typical data elements would include:

   a. By station set and facility: Shifts, manpower, elapsed time per flow. Associated flight/ground hardware R&M. Logistics data: Spares, other cost elements.

   b. Indirect support: BOC, Civil Service, Support contractors.

7. Study alternate computer hardware and software programs that are currently in the market, to further enhance the utility of the GOCM. Enhancements can include standalone capability, enlarged database memory, user friendly menus and pop-up help screens.

8. Integrate an enhanced mixed fleet capability into GOCM which could evaluate combined concurrent Shuttle II, Shuttle C, ALS and other possible vehicle configurations.

9. Study expansion of the model to include mixed site capability to include concurrent launches from the Eastern Test Range (KSC and CCAFS) and Western Test Range.

10. Evaluate optimization capability to include both mixed fleet and mixed site launch operations. This option would allow the user to optimize costs of placing various types of payloads into orbit based on space, weight and configuration constraints.

11. Consider combining a schedule module to GOCM that would generate automatic mission model schedules and resource requirements. A trade study should be conducted to determine if GOCM could be integrated with the LSOC mission model that is artificial intelligent based to produce integrated costs and schedules.

12. Evaluate the utilization of Database Management Systems (DMS) incorporating global commands.

### 16.3.4 Products

A. Model/data system configuration control
   1. Software
   2. Maintained database

    3. Documentation
    4. User manual

B. Model/data system assessment report
    1. Integration
    2. Accuracy
    3. Utility

C. Subject application

## 16.4 CANDIDATE SCENARIOS FOR STUDY

Establish candidate launch site scenarios for efficient ground operations concepts in the following operations:

A. Payload Canister/Shroud Flow
B. Core Vehicle Flow
C. Booster Options/Processing Approaches
D. Vehicle Integration/Launch Processing

### 16.4.1 Products

A selected "best fit" launch site scenario (including these four major areas) for each of the two LRB alternate vehicle configurations. Selection criteria and rationale will be specified.

## 16.5 LAUNCH SITE REQUIREMENTS DEFINITION FOR ALTERNATE CONFIGURATIONS

Expand the dialogue with flight hardware design teams and begin merging launch site integration planning with alternate vehicle system design. This will achieve control of life cycle cost elements and will assure the satisfaction of anticipated requirements in the area of:

1. Processing/Maintainability
2. Launch Operations
3. Recovery Operations

### 16.5.1 Product

Itemized list of launch site requirements (in these three areas) for each of two LRB alternate vehicle configurations.

## 16.6 FACILITIES INTEGRATION STUDY

Additional evaluations of alternate new and modified launch station set facilities will be accomplished. The analysis would accommodate alternate processing scenarios and program integration at the launch site. A facility model would be established to provide a trade study tool. This would encompass cost schedule and transition parameters for both existing and new station set facilities.

Additional evaluations of current and future technology should be accomplished to generate new concepts for facilities, launch support equipment and GSE. These concepts should reflect an alternate processing approach. This approach should accommodate, in the original design, the goals of reduced life cycle costs.

### 16.6.1 Products

A generic plan will be developed for effective management to integrate new and modified station set facilities and ground systems. This plan would include engineering, procurement, and contractor management during activation. In addition, it will include management of interfaces with existing configurations and on-going operations.

## 16.7 LAUNCH PROCESSING SOW AND SPECIFICATION MODEL

### 16.7.1 Purpose

In today's launch environment it is becoming increasingly difficult to accelerate the yearly launch rate, yet this is precisely what is envisioned to occur prior to the LRB introduction and is planned to endure during the phase-in of LRB phase-out of SRB. In order to achieve the sustained launch rate goals effectively and maintain schedule, the SRB/LRB transition will have to occur smoothly.

This will require assurance that the early and subsequent delivered boosters are ground processing friendly and reliable.

### 16.7.2 Approach

LSOC recommends the generation of the KSC portion of a model LRB system SOW and model system specification. The Model LRB SOW/Spec would give the ground processing hardware and planning status equal to that given to flight hardware. Quantitative requirements would be identified, for the LRB, GSE/LSE and the ground processing plan. Ground processing as a capability demonstration would be a program milestone.

### 16.7.3 Products

A. Model System KSC Statement of Work
B. Model KSC System Specification Requirements
C. Review of NASA NHB 5300.4 as it applies to LRB and the Model SOW/Specification.

# VOLUME III

## SECTION 17

## VLS ASSESSMENT

# VOLUME III SECTION 17

# LRB INTEGRATION AT VLS ASSESSMENT

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# SECTION 17

# VANDENBERG LAUNCH SITE (VLS) ASSESSMENT

The following presentation figures assess the integration of LRB at VLS. This independent cursory assessment, which is a requirement of Contract NAS 10-11475, page 04, Section 2.1.1, Launch Site Operations, was prepared by the SPC VLS Engineering Directorate at Vandenberg Air Force Base, California.

The VLS Processing Scenarios was assumed to be similar to that planned at KSC. This includes the use of a new LRB Horizontal Processing/Storage Facility, common and mod-common GSE/LSE and new Propellant Storage. The major difference between VLS and KSC is vehicle integration. At VLS integration is performed at the Pad.

The assessment indicates modifications required to adapt VLS for LRB launches can be accomplished in parallel with reactivation from "Mothball" status. In addition, other than the Launch Mount modification, the required changes would be accomplished similar to the concepts being considered for the KSC launch facilities. Even in the case of the Launch Mount, the booster holddown system, TSMs and the booster exhaust entrance size and shape can duplicate the KSC concepts.

The recommendations offered are independent of the LRB Integration at VLS Assessment. VLS Engineering believes that implementing either or both of these recommendations would be cost effective, and reduce risk to the overall Shuttle program.

## 17.1 GROUND RULES AND ASSUMPTIONS

The ground rules and assumptions established conform to the "cursory" level of assessment requested.

Use of the KSC equipment design whenever possible reduced the technical and fiscal impact. Assessment of the acoustic and overpressure impacts as well as the effect of the additional quantity of combustible propellants to be stored at SLC-6 were beyond the scope of this assessment. Current plans for utilization of the VLS Solid Rocket Booster processing facility and its unsuitability for Liquid Rocket Booster processing resulted in ground ruling a new LRB Horizontal Processing Facility. Establishment of the ground rule "only Shuttle vehicles with LRBs will be processed at VLS " is based on guidance received from LSOC/KSC. Eliminating the need to process both SRB and LRB boosted vehicles at VLS, resulted in simplifying the assessment and markedly reduced the technical impact. Maintaining the Orbiter and external tank vertical location control was critical in minimizing the SLC-6 facility interface impact.

The exact siting of the LRB Horizontal Processing Facility requires considerable analysis which was beyond the scope of this assessment. The assumption of locating the facility along the existing tow route eliminates any technical impact for construction of new tow capacity roadways.

Re-activation of the LCC with the equipment upgrade being proposed at KSC will allow for incorporation of the necessary LRB processing consoles and equipment.

## 17.2 FLOW PROCESSING SUMMARY

Delivery by barge of a completely assembled LRB to the existing VLS docking facility simplified the VLS flow processing from the current tail delivery of SRB propellant segments and air delivery of its other components.

Land transportation from the docking facility to the new LRB Horizontal Processing Facility will be by transporter two, identical to the KSC concept; see Figure 17.2 All LRB stand-alone checkout and testing will be conducted in this facility. Each LRB will then be towed on its transporter to the SLC-6 launch pad where it will be erected by the existing MST and SAB cranes. The MST crane will then lift and translate each LRB in a vertical attitude to its respective holddown post.

The balance of the VLS Shuttle vehicle integration will remain unchanged.

Incorporation of extensive launch mount modifications or replacement by a new launch fixture will provide the necessary holddown modifications and enlarged booster duct entrance area. This arrangement will provide control and guidance of the exhaust plume into the existing VLS closed ducts to preclude a potentially hazardous overpressure.

Vehicle launch processing will be modified to provide for expanded LOX and LH2 capacity and loading (or instead of LH2 the addition of RP-1 fuel capability, if it is selected).

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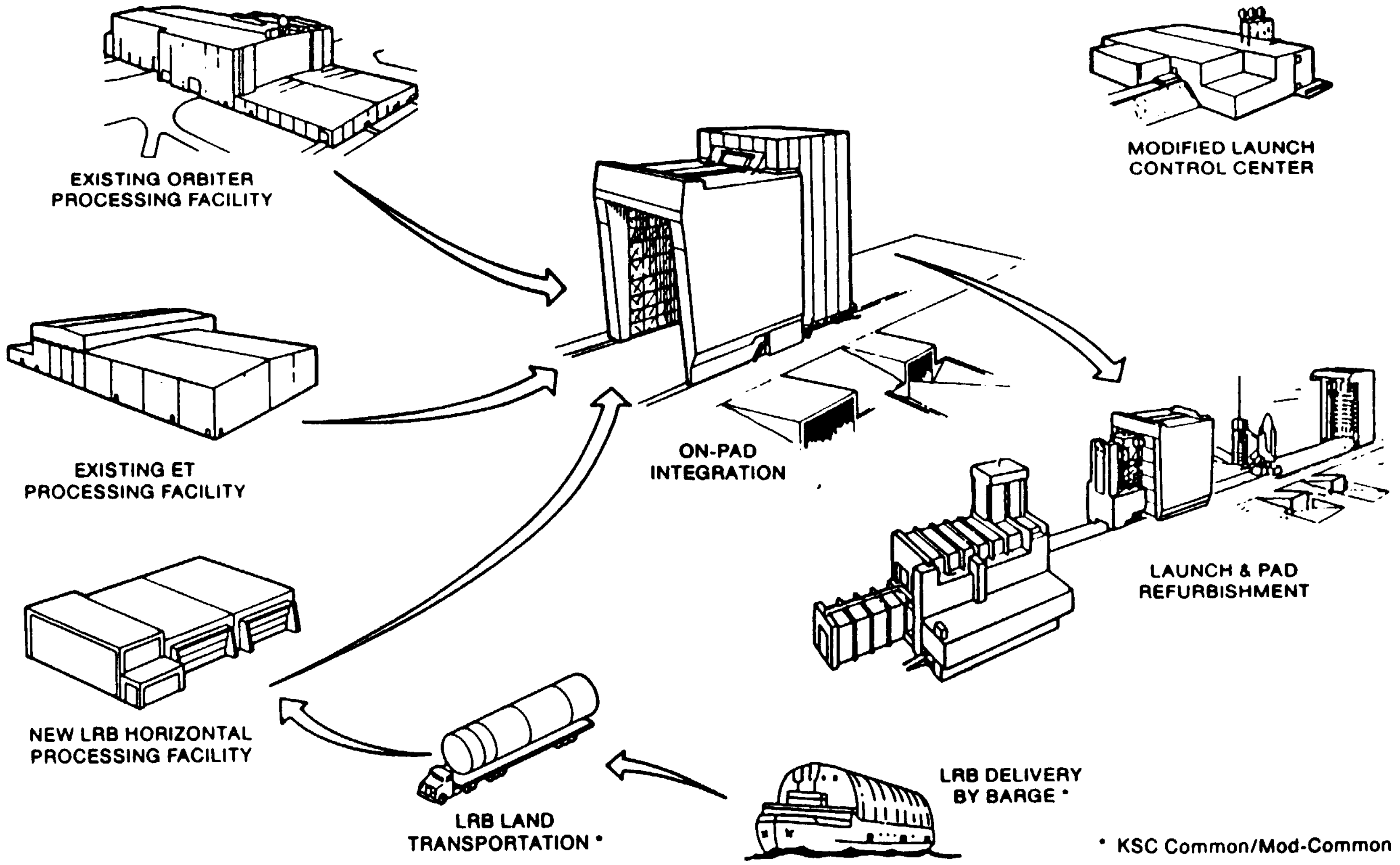

81019-01D

Figure 17.2. Flow Processing Summary.

3-17 10/17 8:00 a

Additionally, the Launch Control Center will incorporate the new LRB consoles and ground software, similar to KSC.

## 17.3 IMPACTS TO INCORPORATE LRB AT VLS

The launch pad configuration and Shuttle vehicle integration is considerably different at VLS than KSC. At VLS the boosters, external tank and the Orbiter are integrated on the launch pad rather than on a mobile launch platform in a vertical assembly building with subsequent transportation to the launch pad. This difference precludes incorporating a MLP clone at VLS. Therefore, VLS will either make modifications to the existing launch mount or replace the launch mount with a new launch fixture.

As a result of the VLS hydrogen disposal system analysis and testing, a steam inerting system has been designed for the SSME closed duct.

This system was demonstrated to inert the potential hydrogen/air detonation hazard in the VLS SSME closed duct. VLS proposes to incorporate a similar steam inerting system in the closed booster ducts if detailed analysis indicates a hazard potential exists. If the selected LRB engines are LOX/Hydrogen, the risk will be considerably higher than if LOX/RP-1 are the selected propellants. However, either combination will require analysis of the time phasing and quantity of propellant flows and the resultant detonation hazard in order to conclude if inerting will be required.

The holddown concept for VLS will be identical to that selected for KSC. The VLS vehicle holddown system stiffness will match as closely as possible that obtained on the new KSC MLP. The new VLS launch fixture concept being considered allows detail construction, in the area around the booster exhaust holes, to be common to the new KSC MLP. This type of construction would contribute to the stiffness matching capability.

VLS will add a new LRB horizontal processing facility. The facility will be similar to the KSC concept except there will not be an ET section. The existing VLS ET processing facility will be satisfactory.

Modification to the VLS MST servicing platforms will be similar to those planned for the KSC VAB, except simplified as accommodation for SRBs will not be required. Removal of approximately 30 feet from the bottom of the MST east wall will be required for clearance with either a modified launch mount or new launch fixture. This removal will not effect any major structural elements of the MST. The existing MST 200 ton crane will be used to erect and position the LRBs. Vehicle lengths up to 196 feet will not require crane/MST modification.

VLS will utilize the same LRB barge and land transporters as planned for KSC. The existing docking and two roads will be satisfactory for LRB handling.

The power systems available for SLC-6 will be adequate to accommodate the LRB requirements. Minor modifications will be required to process the power to the GSE and LRBs for checkout and processing.

Incorporation of the LPS upgrade, currently being proposed for KSC, into the VLS LCC will provide additional space and computer capacity allowing incorporation of the additional requirements for the LRB.

An additional liquid oxygen dewar will be required at VLS to provide the capacity to fill both the external tank and the two booster tanks. The modifications to the propellant loading equipment will be similar to that being considered for KSC. Maintaining the existing propellant loading time line will require VLS to add pumping capacity and a new cross country line. However, if an increased loading time will be acceptable, the existing systems will require only minor modification.

Fuel system requirements at VLS will depend on the final selection of the LRB fuel propellant, liquid hydrogen or RP-1. Whichever is selected, the additional/new fuel will be stored and loaded into the LRBs at VLS in a manner similar to the concepts being considered for KSC. Final design analysis may show that the existing VLS H2 flare stacks may be adequate to burn-off vented hydrogen without the need for an additional stack. If RP-1 is selected, VLS will require a completely new storage and loading facility to support the LRBs.

The modified launch mount or new launch fixture will incorporate the required vacuum jacketed lines to interface with the new LRB TSMs. Modification to the VLS ET GOX nd H2 vent umbilicals will be similar to those planned for KSC. LRB TSMs identical to those planned for KSC will be installed onto the modified launch mount or new launch fixture.

### 17.3.1 Existing VLS Launch Mount

Figure 17.3.1 shows the current VLS launch mount. Nearly all of the structure is steel above level 100, the basic pad surface. A small section of concrete exists in the center between the two booster mounting locations.

### 17.3.2 Launch Mount Modifications

The demolition zone indicated by the "cross hatching" on the launch mount matches the size and location required for the starboard LRB exhaust entrance, Figure 17.3.2. The required demolition encroaches into the east SE room walls and launch mount major structural members located in the east wall of the SSME exhaust duct. Therefore, relocation of the SSME east wall and major modifications to its enclosed structure are required as well as relocation of some of the equipment located in the SE rooms. The launch mount to the west of the indicated demolition zone will remain as is. The area to the east will be reconstructed to provide for LRB holddown, exhaust plume guidance and control, engine servicing and changeout, etc.

The extent of these launch mount modifications requires further study and analysis to determine if it would be more cost effective to remove the total launch mount to the pad deck, level 100, and use a newly constructed launch fixture somewhat like the KSC MLP.

### 17.3.3 New Launch Fixture

The new launch fixture concept, shown in Figure 17.3.3 if proven cost effective, will incorporate construction details common to the new KSC MLP in the area of the booster holddown system and the zone between the SSME and booster exhaust entrances. The existing SSME duct west wall as well as the SSME servicing and changeout equipment and procedures will be preserved.

MLP method and its electrical and fluid interface connection concept will be adapted. A LRB engine servicing and changeout platform will be incorporated into the east end of the launch fixture. A preliminary examination of access from below through the booster exhaust ducts appears impractical. The engine servicing and changeout platform will be capable of moving into position when required.

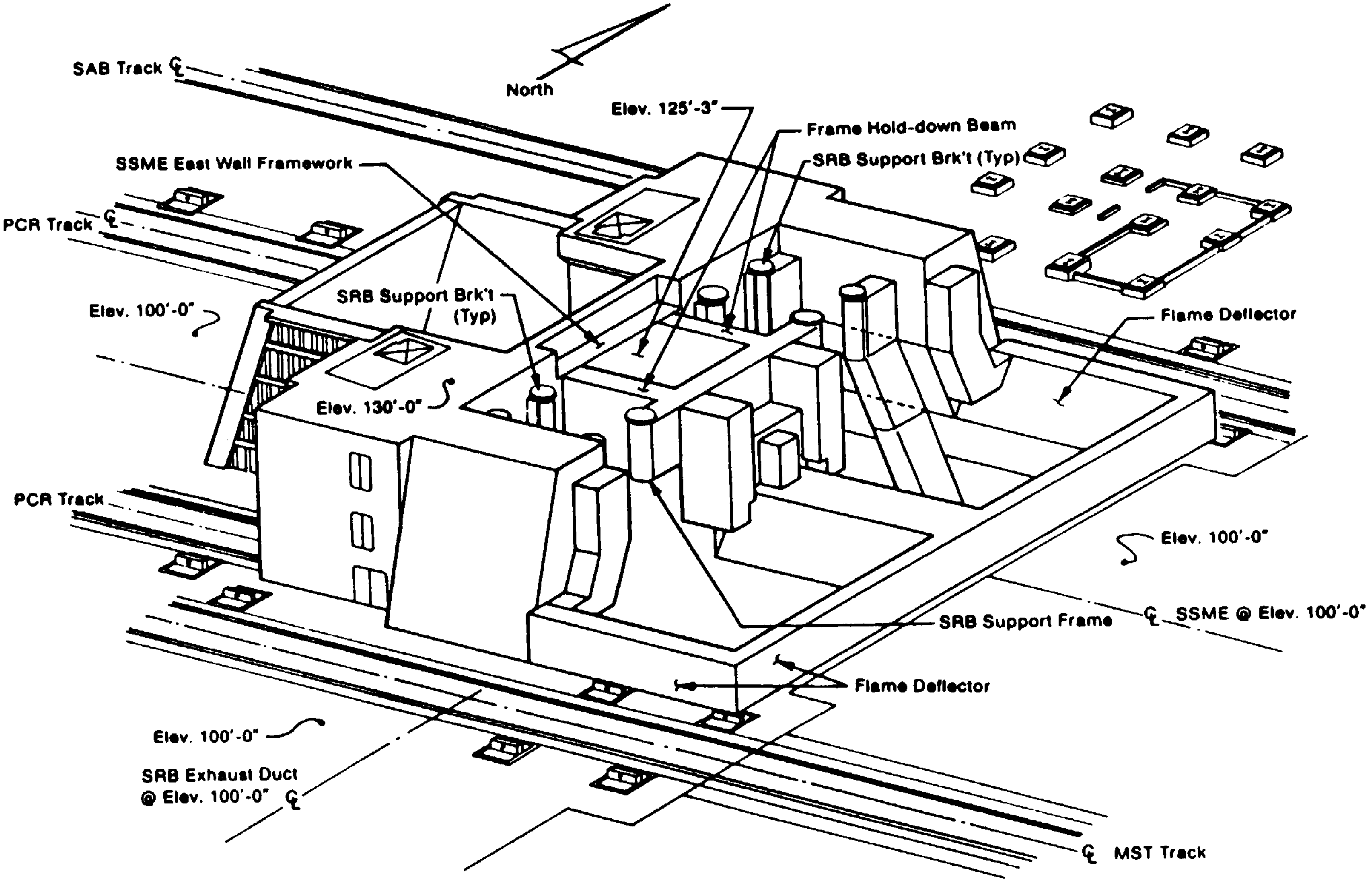

Figure 17. 3.1. Existing VLS Launch Mount.

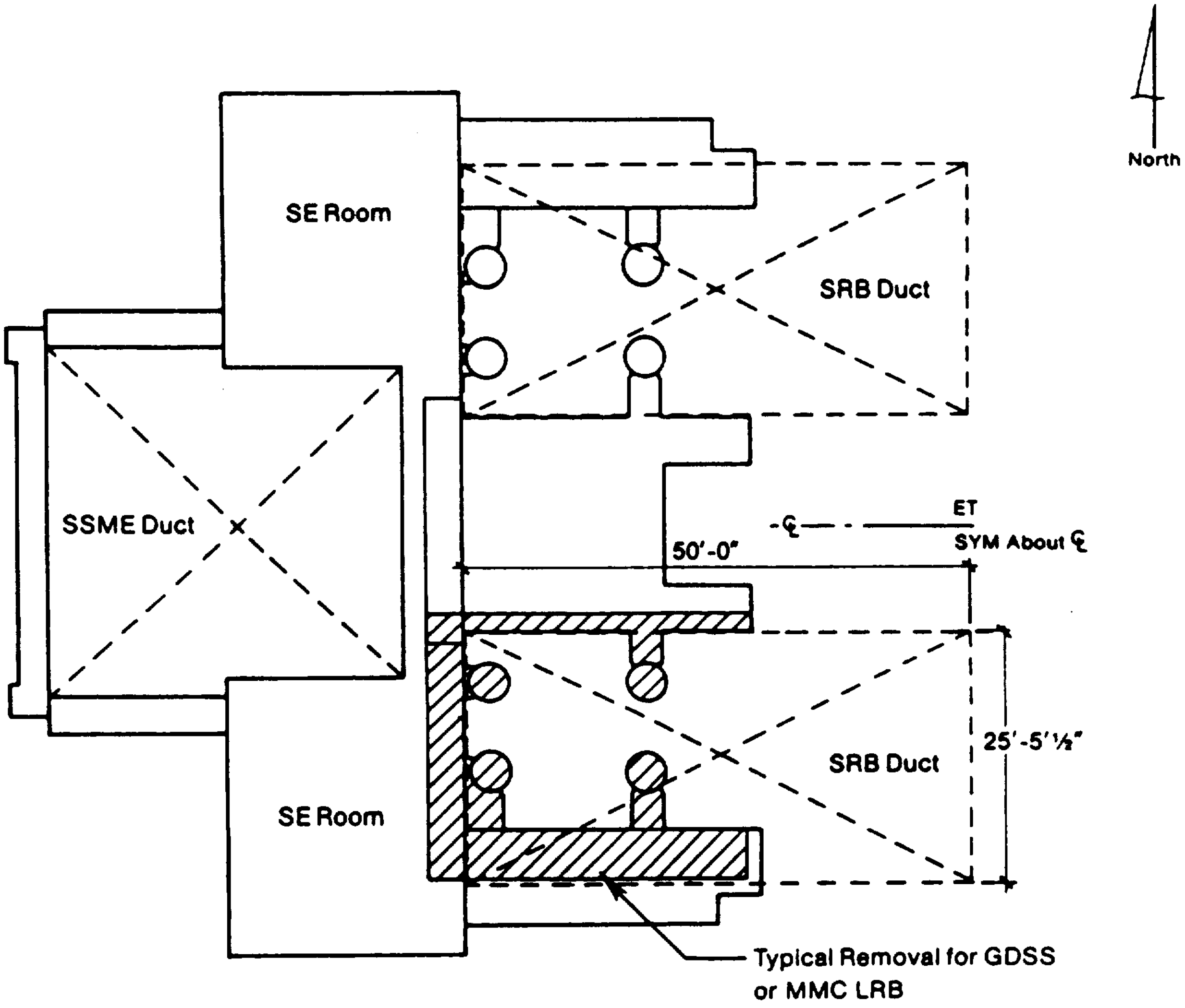

Figure 17.3.2 Launch Mount Modifications.

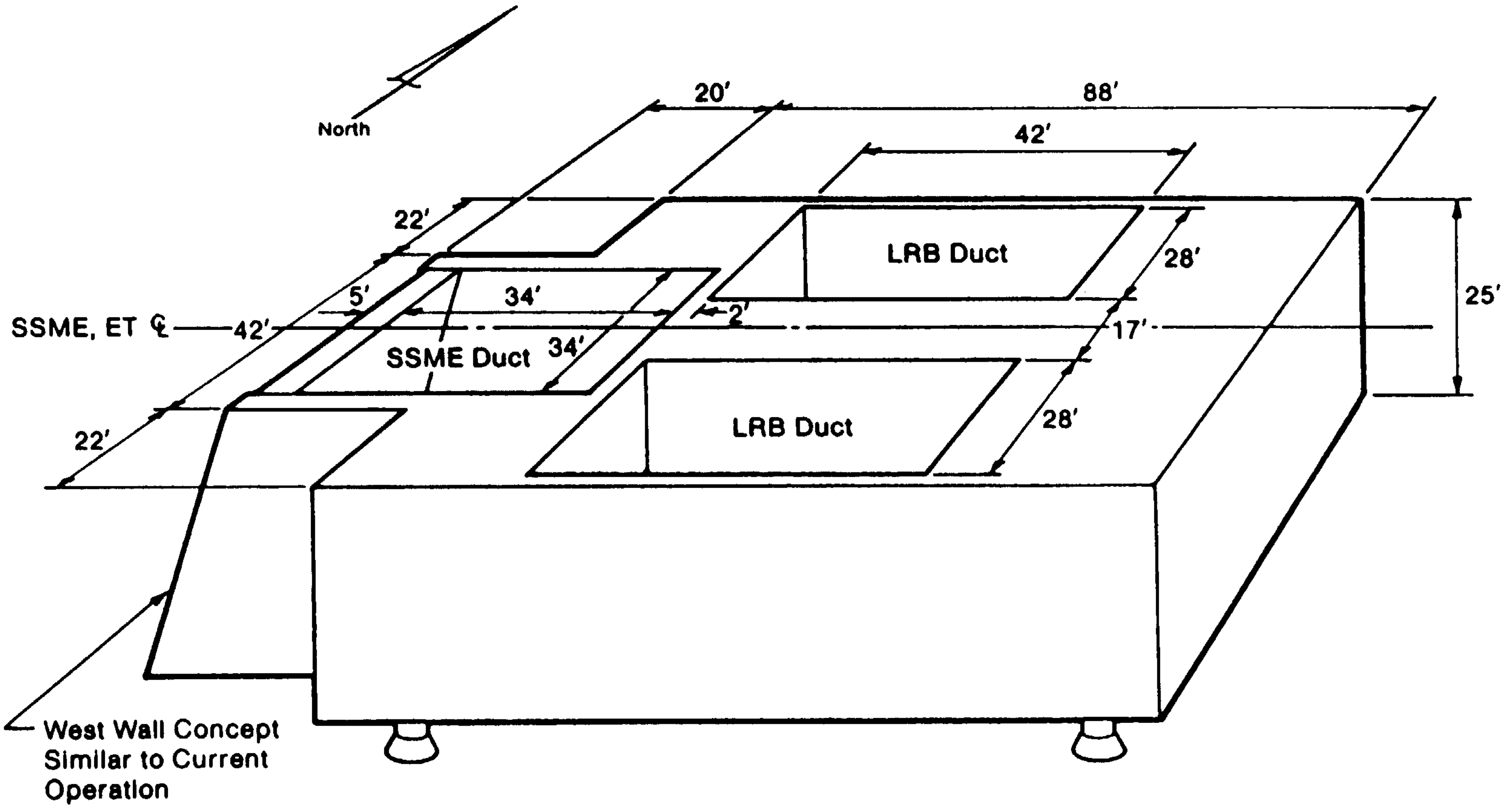

Figure 17.3.3. New Launch Fixture.

The VLS SSME exhaust duct water and steam injection concept will be retained while the launch fixture upper deck cooling and booster sound suppression will be adapted from the KSC concept. Injection location of the booster exhaust duct steam inerting, if necessary, will require detailed analysis.

The SE currently contained within the launch mount will be incorporated into the new launch fixture.

### 17.3.4 Propellant Facilities/Equipment Modification

The additional propellant tanks required will be located as shown on the SLC-6 plot plan in figure 17.3.4. Preliminary design, which was beyond the scope of this assessment, will be required before establishing final site locations. Some excavation into the hill side will be required to locate the additional LH2 dewar as shown and some fill will be required for the location shown for the RP-1 tank. Siting the new LOX dewar as shown will require relocating a portion of the local access road.

The new access tower, shown south of the launch mount, will be required only if LH 2 is selected for the LRB fuel. The tower position will be established such that it will not interfere with the movement or positioning of the MST.

## 17.4 SLC-6 CONVERSION TO LRB DOES NOT IMPACT RE-ACTIVATION SCHEDULE

Detailed studies of VLS re-activation from the planned mothball status have not been performed. For the purpose of this assessment the VLS studies for re-activation from minimum facility caretaker status were modified to account for additional staffing time required and increased facility restoration time. The engineering assessment of the VLS modifications required to convert to LRB operation shows that the effort can be completed prior to the initiation of the re-activation GSTs and flow tests. It is anticipated that the LRB conversion schedule will be paced by the procurement and installation of the new cryogenic dewar(s). See Figure 17.4

## 17.5 TECHNICAL ISSUES

To avoid major modification to the MST, the LRB size and weight will be limited by the capacity of the current MST crane system. The crane limit is 200 tons and therefore will be able to handle

- **Modifications are Similar to KSC Plans**

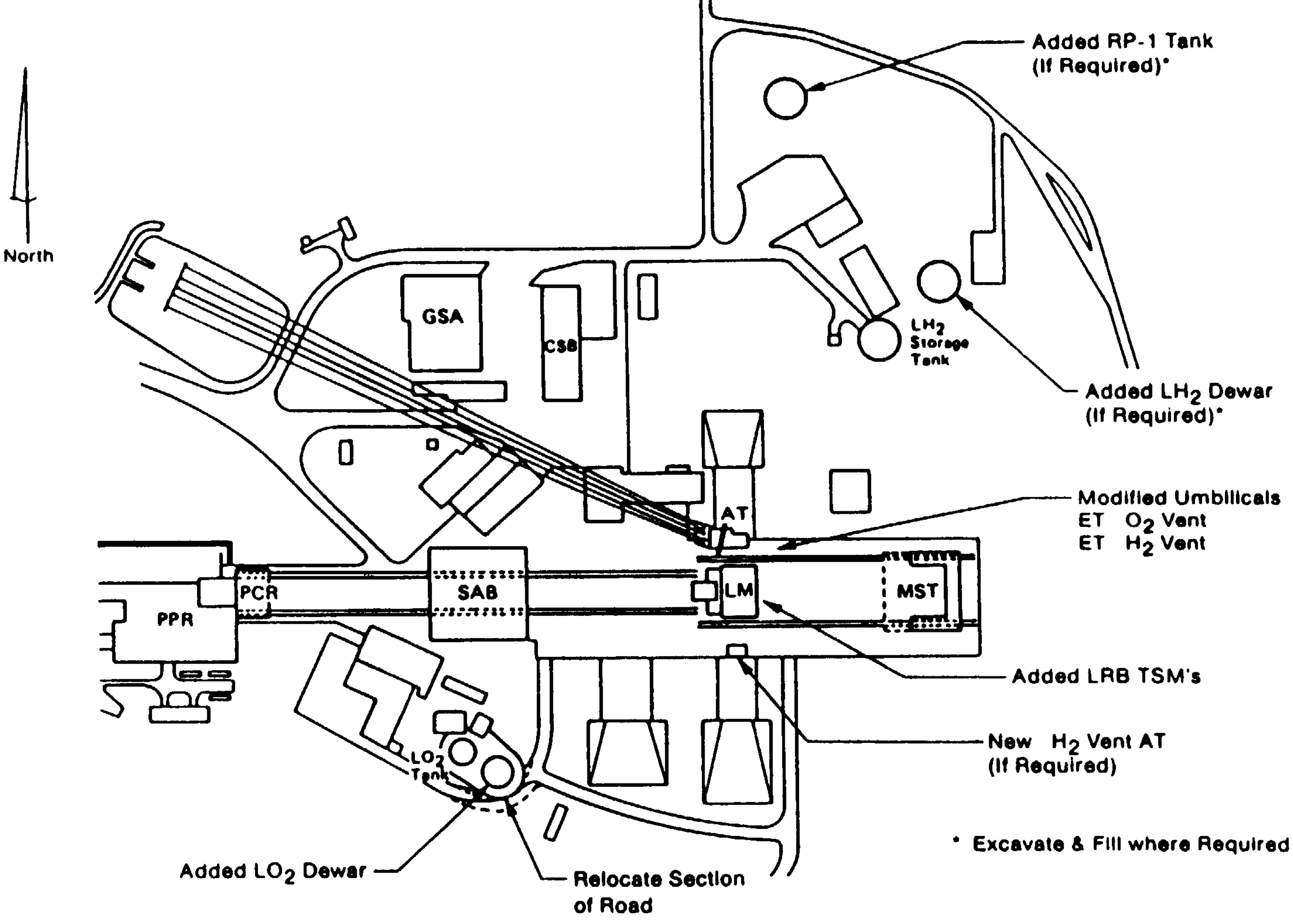

Figure 17.3.4. SLC-6 Propellant Facilities/Equipment Modifications.

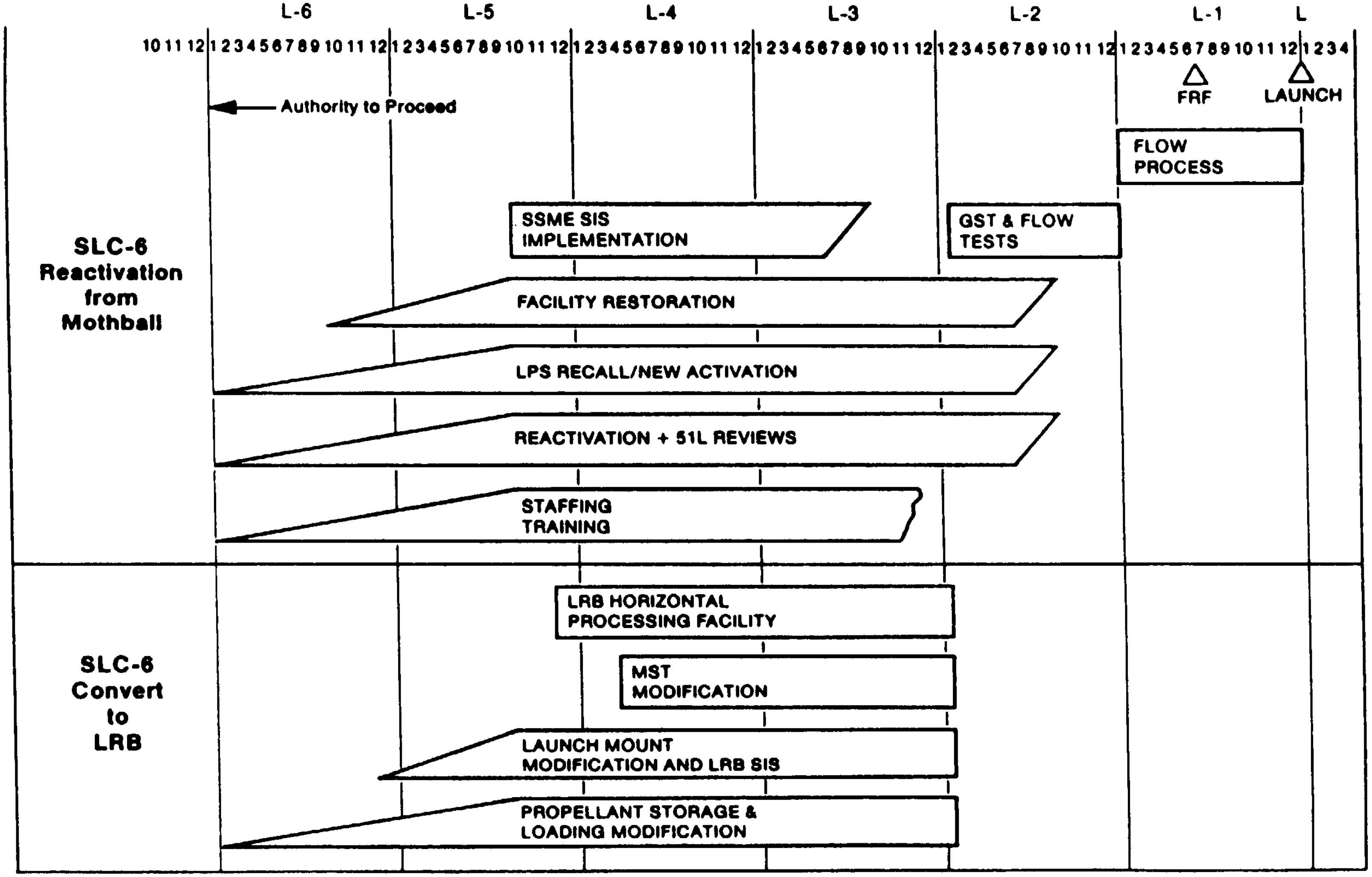

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Figure 17.4. SLC-6 Conversion to LRB/No Impact to Reactivation Schedule.

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an LRB and lifting equipment up to 400 KLBs if its length does not exceed 196 feet. A problem exists only if the General Dynamics pressure fed LO2/RP-1 booster is selected. Its 200 feet length and 228 KLBs weight exceed the existing capacity. The length could be accommodated by special lifting equipment which would utilize a counterweight and a pickup location below the top of the long LRB. However, with this counterweight system the LRB weight would be limited to something slightly less that 200 KLBs. Otherwise a major modification to the MST would be required.

The only issue with the LCC is the validity of the assumption that upgrading the equipment to the technology being proposed for KSC (or equivalent) will be included in the VLS re-activation plan.

Making the decision on which method of launch pad modification will be more cost effective will require preliminary designs of both concepts. These preliminary designs were beyond the scope of this assessment. In order to provide a cost assessment the new launch fixture was selected as baseline for VLS LRB incorporation.

The cursory scope of this assessment precluded the identification of all possible technical issues.

## 17.6 ASSESSMENT OF COST FOR LRB IMPLEMENTATION

The cost assessment shown in Figure 17.6 was based on past experience and studies at LSOC/VLS. Data obtained during the VLS HDS program, the SLC-6 for Titan IV study, initial procurement costs of similar items and experience in basic construction cost analysis were used to develop the cost assessment. The values shown include a 40% factor to cover contractor fees, government support and a management reserve.

## 17.7 SUMMARY

The VLS/LRB assessment clearly indicated that incorporation of a Liquid Rocket Booster for Shuttle vehicle launches at VLS is viable.

There are very few technical issues associated with the VLS facility. Either the modified launch mount or a new launch fixture provide vehicle holddown and exhaust plum control similar to that indicated for KSC. The major question posed by the VLS booster closed duct will be - will inerting be required? If analysis indicates that inerting will be required the SIS solution requires only design and verification.

| COST ELEMENT | $ IN MILLIONS |
|---|---|
| LAUNCH PAD | 50 |
| PROPELLANT SYSTEMS | 25 |
| HORIZONTAL PROCESSING FACILITY | 25 |
| MISCELLANEOUS & TECHNICAL UNCERTAINTIES | 35 |
| TOTAL | 135 |

ASSESSMENT INCLUDES ENGINEERING, INTEGRATING CONTRACTOR AND CONSTRUCTION MANAGEMENT.

ASSESSMENT EXCLUDES EQUIPMENT COMMON WITH KSC - LRB BARGE, LRB LAND TRANSPORTER AND LRB LIFTING/HANDLING SE.

Figure 17.6. Assessment of Cost for LRB Implementation.

All other modifications will be identical or nearly identical to those planned for KSC.

- Converting SLC-6 for LRB usage will be technically viable
- VLS on-pad vehicle integration simplified with LRB
- LRB holddown and exhaust plume control will be similar to KSC concept - steam inerting may be required
- Platform mods will be a simplified version of KSC
- New propellant facilities will be similar to KSC
- LRB horizontal processing facility will be incorporated
- Modern LCC will allow incorporation of LRB consoles
- Few technical issues have been identified
- 135 million dollar cost assessment appears reasonable

## 17.8 RECOMMENDATION

LSOC/KSC consider using VLS to pathfind the LRB implementation into the Shuttle program.

- Processing development would be achieved without any impact to KSC SRB Shuttle launches
- Integration of a developed system at KSC would be low technical and schedule risk

VLS should be considered as the LRB vehicle development static hot firing test facility.

- Required modification could be cost effective
- Testing would not interfere with other Shuttle facilities

# VOLUME III

## *SECTION 18*

# LRB ENGINE PROCESSING STUDY

ROCKWELL INTERNATIONAL CORP.
ROCKETDYNE DIVISION

# LIQUID ROCKET BOOSTER ENGINE PROCESSING STUDY

APPENDIX (SEE VOLUME V, SECTION 18)

A. Liquid Rocket Booster Phase II Study Report
Rocketdyne Division of Rockwell International, for
General Dynamics Space Systems Division
(NASA Contract No. NAS8-37137)

B. Data Package - SSME GSE
R. F. Austin - 9/86

C. Liquid Rocket Booster Integration
Second Progress Review
G. S. Waldrop - Presentation

# LIQUID ROCKET BOOSTER ENGINE PROCESSING STUDY

## INTRODUCTION

The Rocketdyne Division of Rockwell International Corporation has been assisting the Lockheed Space Operations Company in the Liquid Rocket Booster Integration Study. Rocketdyne's function involves examining the various Liquid Rocket Booster (LRB) engine concepts and attempt to evaluate their impact to the processing of the liquid rocket booster at the launch site.

The configuration of the liquid rocket booster vehicle, and its engines, continues to be in the conceptual design phase. This presents some difficulty in predicting very accurately and completely all of the items that should be considered for hardware processing at the launch site. However, given the definition of the vehicle, basic engine characteristics, and the launch facilities environment, representative processing impacts can be developed. Throughout this evaluation "lessons learned" and "conservative approach" ideas have been identified to immediately and up-front alert both the design and launch site communities of items that must be considered in order to insure a smooth transition that will be mandatory for this program.

In evaluating the liquid rocket booster and its processing concepts, it was found that the LRB engine processing methods would be very similar to that of the present Space Shuttle Main Engine. It was also obvious that given the basic concept physical dimensions and weight of the LRB engine, the type and size of much of the processing ground support equipment was also similar to that now being used by the Space Shuttle Main Engine. Therefore, included in this report will be found references to existing Space Transportation System processing items, by program model number when applicable, to be used as a processing concept baseline idea. The writer in no way insenuates that duplicates of this hardware will be required but rather indicates the basic design concepts to be used for improvements and commonality considerations.

## INTRODUCTION (CONT.)

The types of engines being considered for the liquid rocket booster, and the basic concept that they will be expendable, indicates reduced maintenance once received at the launch site. As the engine designs begin to solidify, it is conceived that numerous innovative ideas will be incorporated to insure that if for some reason, say, engine component replacement and/or engine replacement is required, minimal impacts to the schedule would be realized. The engine processing flows developed for this study attempted to reflect reasonable adjustments in timelines/manpower for LRB engine design concepts as we know them now.

The concept of retrieving either the entire LRB, or its propulsion-avionics package, and recycling the engines was not considered during this study phase. It is felt that not enough definition of the type, location, and method of landing existed to warrant consideration at this time. However, it is inconceivable that engine refurbishment at the launch site could be cost effective for anything other than a "soft-dry-land" landing. Exposure of liquid propellant engines to hard impacts, salt water, etc., most assuredly would dictate major refurbishment at the "factory", and not at the launch site.

It is the purpose of this liquid rocket booster engine processing study to surface and promote the ideas for properly processing engines from the launch operations community viewpoint. Considerations for the enhancement of safety, reliability, maintainability, cost effectiveness and reduction in launch operation timelines, were foremost during this entire study and this presentation.

## ENGINE CHARACTERISTICS

The Liquid Rocket Booster Engine, even though still in the conceptual design phase, has been defined to such a degree that major processing impacts can be identified and evaluated. The general characteristics so presented were used to,

a) Evaluate handling concepts
b) Identify concepts for major ground support equipment
c) Establish baseline checkout requirements
d) Formulate a baseline processing schedule

and then

e) Consider special facility requirements to accomplish the processing operations

The data used for this engine processing study has been taken from the presentation of General Dynamics Space Systems Division, the Rocketdyne Division of Rockwell International Corporation, Martin Marietta Manned Space Systems, and Tech Systems of the Aerojet Company. Figures ENG-1 through ENG-8 are a compilation of data gathered from the various presentations. However, in a general summary, the following is a list of the characteristics most prevalent to this engine processing study:

- Propellants/Type Engine Selected
  - Liquid Oxygen/RP-1 - Pressure Fed
  - Liquid Oxygen/RP-1 - Pump Fed
  - Liquid Oxygen/Liquid Hydrogen - Pump Fed

- Pneumatic Requirements
  - Gaseous Nitrogen
  - Gaseous Helium

- Electrical Requirements
  - 5 VDC
  - 28 VDC
  - 500 VDC

- Avionics
  - Supervisory Controller (Each Engine)

- Engine Valve Actuators
  - Electric
  - Possibly some pneumatics

## ENGINE CHARACTERISTICS (CONT.)

- Gas Generator For Pump Fed Configuration
  - Turbine Drive
  - Possible solid propellant charge spin-up

- Ignition System
  - Augmented Spark - LOX/$LH_2$
  - Hypergol Package - LOX/RP-1
  - Possibly some pyrotechnics

- Physicals
  - Weight Range (approximate)
    4500 LB to 8100 LB
  - Dimensions (approximate)
    - Length - 135 inches to 189 inches
    - Exit Diameter - 92 inches to 109 inches

- Expendable Engines

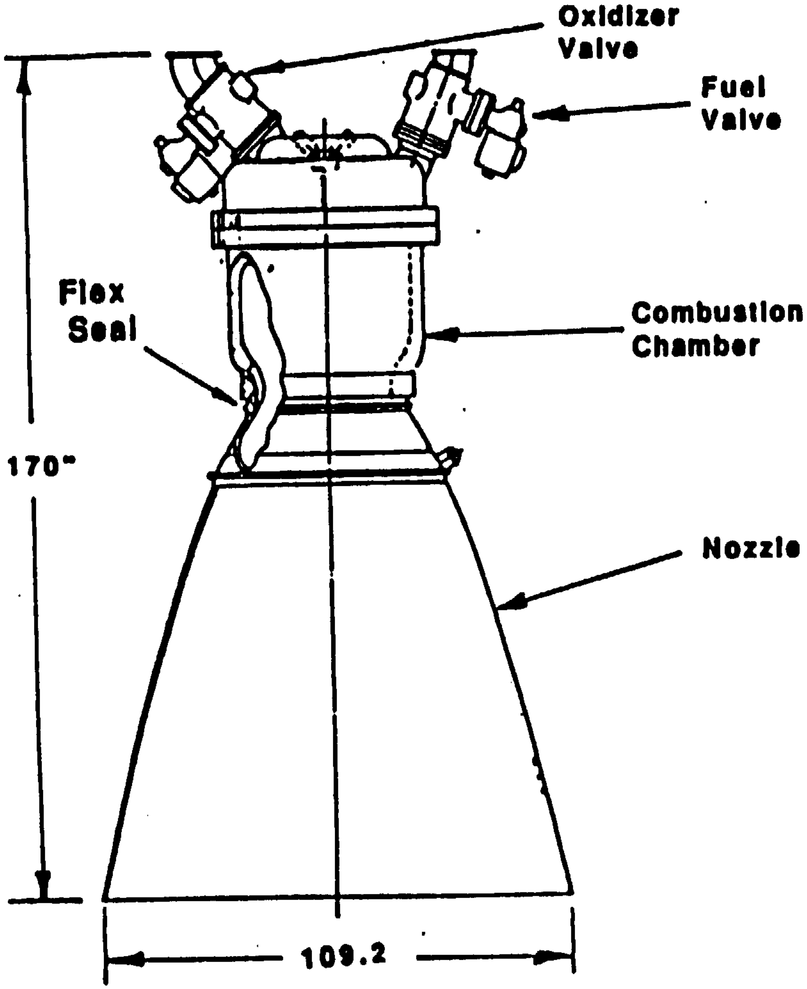
When examining the physical characteristics of size and weight, it becomes obvious that the LRB engine may well be around the general size and weight of the present Space Shuttle Main Engine. The SSME weighs around 7000 pounds, has an exit diameter of approximately 90 inches, with an approximate height of 168 inches. These comparable features were quite useful in evaluating the handling and ground support equipment impacts.

Other characteristics identified, to date, should not pose a major impact to processing and/or launch operations. The indications are that the LRB engines will be "minimal" maintenance engines. One vehicle contractor has envisioned that the LRB would be assembled closeby Kennedy Space Center and delivered to the launch site completely checked-out and ready to fly.

Detailed engine concept reports from all the engine contractors was not available to this writer. However, the Rocketdyne report was and is included with this report to further enhance the launch operations community knowledge as to what type of engines are being proposed and the efforts being put forward at the Engine Design Centers.

FIG. ENG-1

# LRB PRESSURE FED ENGINE
## LO2/RP1



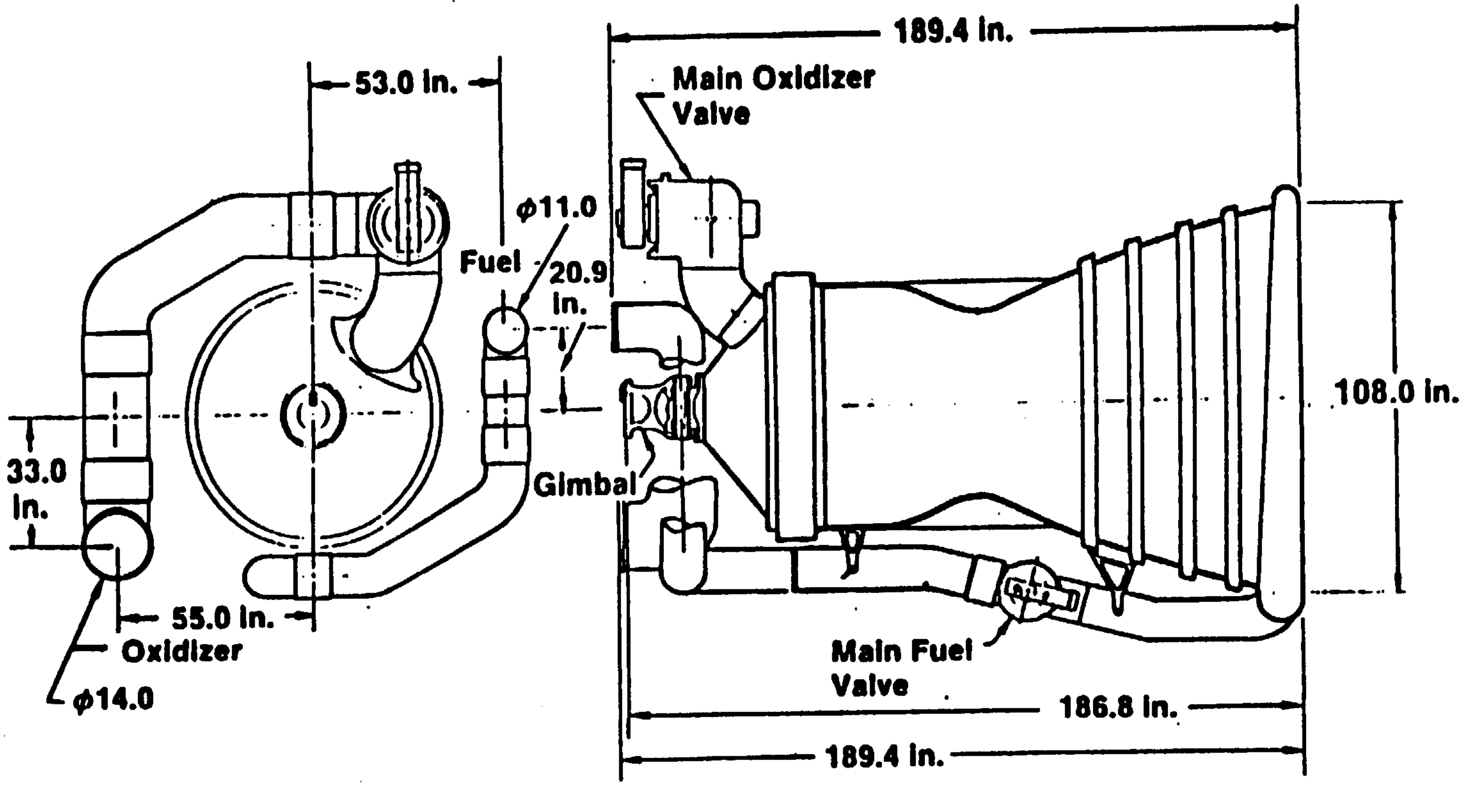
| | MPL | FPL |
|---|---|---|
| Thrust, S.L. klbs | 440 | 750 |
| Thrust, Vac klbs | 578 | 887 |
| ISP, S.L. sec | 242 | 270 |
| ISP, Vac, sec | 317 | 319 |
| Mixture Ratio | 2.67 | 2.67 |
| Total Flow Rate, lb/sec | 1821 | 2773 |
| Chamber Pressure, Psia | 408 | 660 |
| Exit Pressure, Psia | 7.3 | 11.7 |
| Expansion Ratio | 11.47 | |
| Chamber Type | Ablative | |
| Nozzle Type | Ablative | |
| Weight, Dry, lbs | 4500 | |
| Propellants | LO2/RP1 | |
| Gimbal Angle | ±6° | |
| Gimbal Type | Head End<br>Flex Seal (Optional) | |
| Throttle Range | 65 - 100% | |

FIG. ENG-2

GENERAL DYNAMICS
*Space Systems Division*

# LRB Pressure-Fed LOX/RP-1 Engine System

LRB



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Rocketdyne Division

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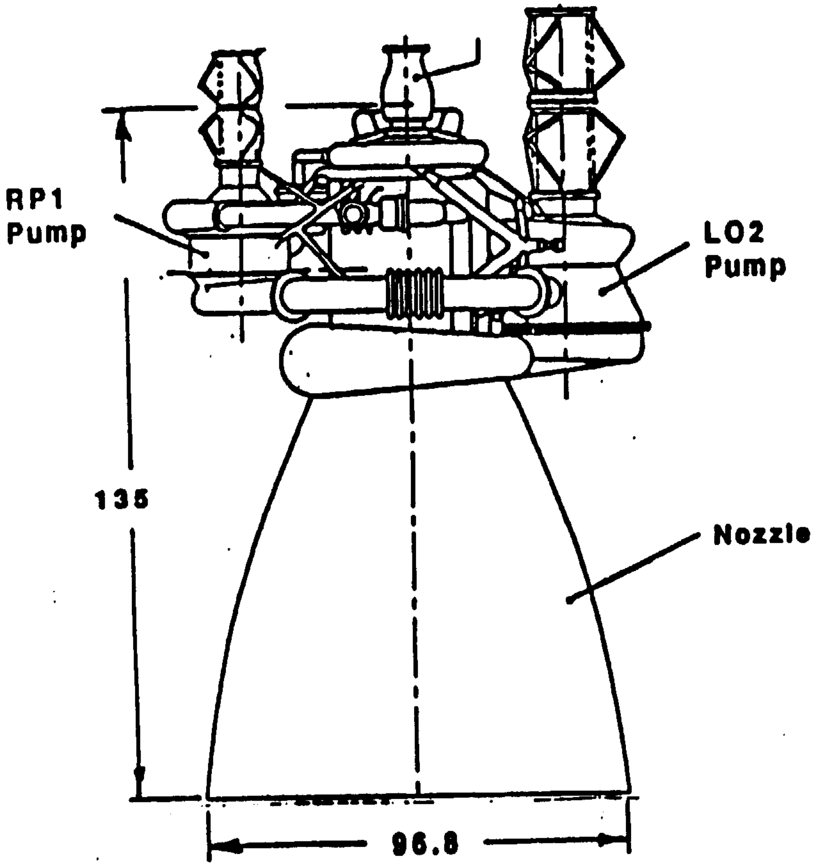
FIG. ENG-3

# LRB PUMP FED ENGINE
## LO2/RP1



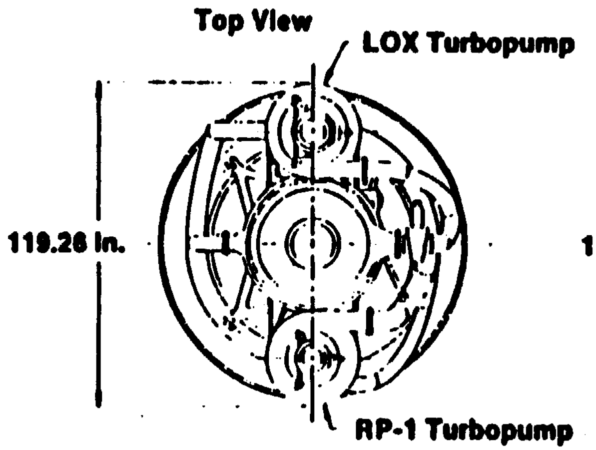
| | NPL | EPL |
|---|---|---|
| Thrust, S.L. klbs | 513 | 685 |
| Thrust, Vac. kbs | 623 | 788 |
| ISP, S.L. sec | 265 | 277 |
| ISP, Vac, sec | 322 | 318 |
| Mixture Ratio | 2.6 | 2.5 |
| Total Flow Rate, lb/sec | 1933 | 2473 |
| Chamber Pressure, Psia | 1033 | 1300 |
| Exit Pressure, Psia | 5.9 | 7.7 |
| Expansion Ratio | 21.2 | |
| Nozzle Type | Carbon-Carbon | |
| Weight, Dry, lbs | 6807 | |
| Engine Cycle | Gas Gen | |
| Propellants | LO2/RP1 | |
| Gimbal Type | Head End | |
| Gimbal Angle | ±6° | |
| Throttle Range | 65 - 100% | |

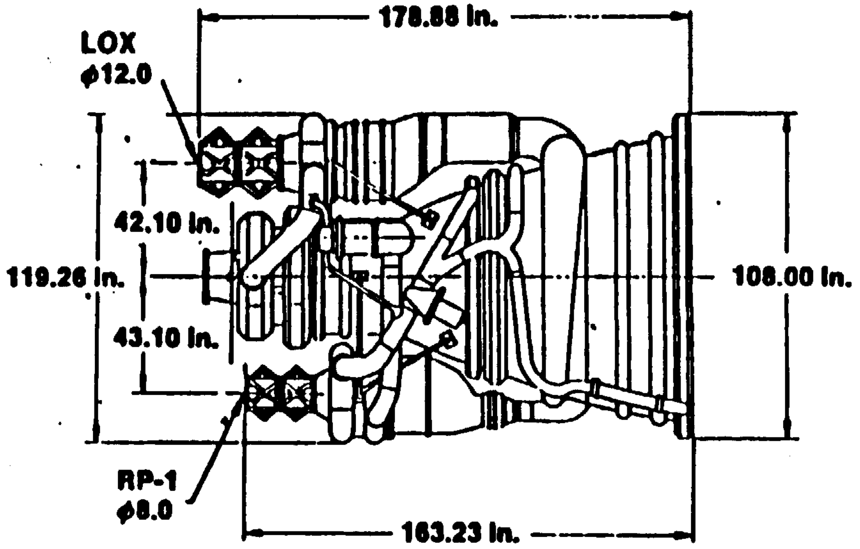
FIG. ENG-4

GENERAL DYNAMICS
*Space Systems Division*

# LRB LOX/RP-1 Pump-Fed Engine

LRB





Rockwell International
Rocketdyne Division

88D-9-1938

FIG. ENG-5

# LOX/RP-1 Pump-Fed Engine Characteristics

**LRB**

- Values at EPL (110% nominal)

| | |
|---|---|
| • Thrust | 673 klb (sl)<br>791 klb (vac) |
| • Specific Impulse | 274 s (sl)<br>322 s (vac) |
| • Chamber pressure | 1,402 psia |
| • Engine MR | 2.5 |
| • $N_C^*$ | 96% |
| • GG gas temperature | 1800°R |
| • Pump inlet pressure | |
|   • LOX | 65 psia |
|   • RP-1 | 45 psia |
| • Pump discharge pressure | |
|   • LOX | 2,175 psia |
|   • RP-1 | 3,028 psia |

| | |
|---|---|
| • Cycle | Gas generator |
|   • Nozzle ε | 27:1 |
|   • Engine diameter | 120 (in.) |
|   • Engine length | 179 (in.) |
|   • Engine weight | 8,108 (lb) |
| • Series turbines | (Fuel/LOX) |

- No boost pumps
- Hypergolic ignition
- One stage turbines
- Channel wall MCC
- Tubular nozzle
- Self impinging injector design with OFHC Cu rings

Rockwell International
Rocketdyne Division

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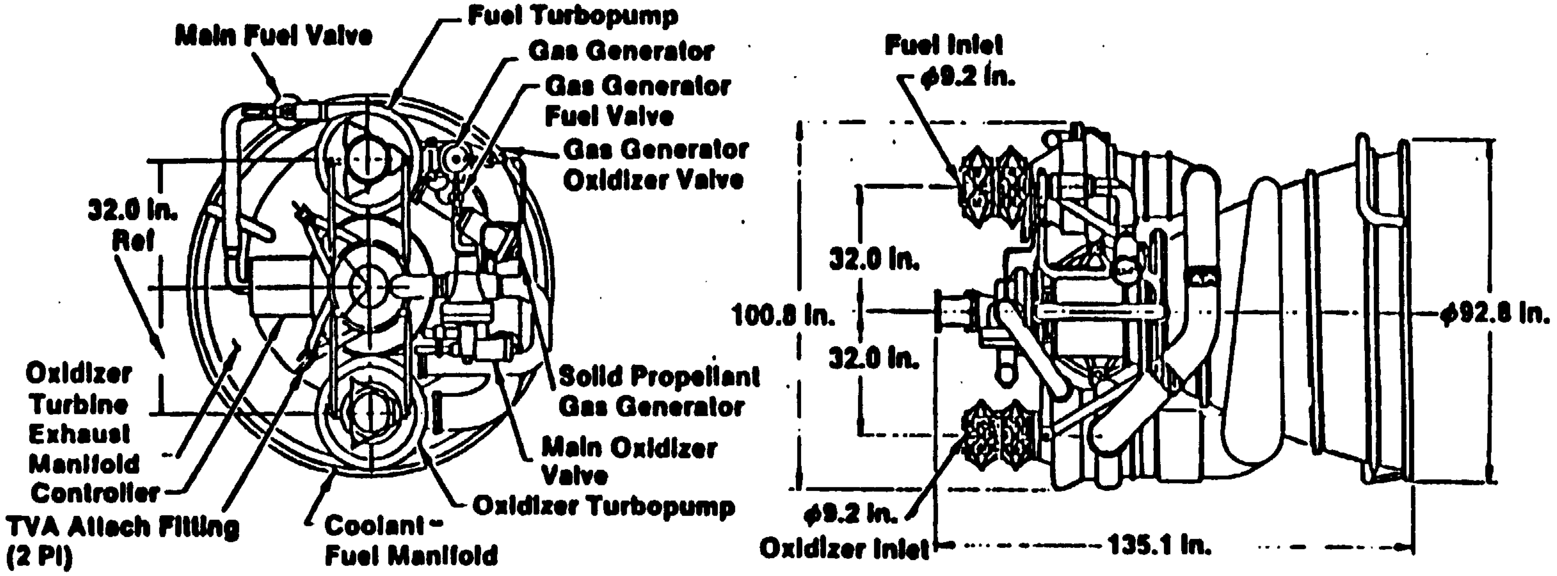
41-29-0

FIG. ENG-6

**GENERAL DYNAMICS**
*Space Systems Division*

# LRB LOX/Hydrogen Engine

**LRB**



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Rocketdyne Division

88D-9-1942

FIG. ENG-7

GENERAL DYNAMICS
Space Systems Division

# LOX/H2 Pump-Fed Engine Characteristics

LRB

| | |
|---|---|
| • Values at EPL (110% nominal) | |
| • Thrust | 543 klb (sl)<br>620 klb (vac) |
| • Specific Impulse | 374 s (sl)<br>427 s (vac) |
| • Chamber pressure | 2,538 psia |
| • Engine MR | 6.0 |
| • $\eta_{c^*}$ | 99% |
| • GG gas temperature | 1600°R |
| • Pump inlet pressure | |
| • LOX | 65 psia |
| • $H_2$ | 25 psia |
| • Pump discharge pressure | |
| • LOX | 3,782 psia |
| • $H_2$ | 4,571 psia |

| | |
|---|---|
| • Cycle | Gas generator |
| • Nozzle $\varepsilon$ | 41 |
| • Engine diameter | 101 (in.) |
| • Engine length | 135 (in.) |
| • Engine weight | 6,672 (lb) |
| • Series turbines | (Fuel/LOX) |
| • No boost pumps | |
| • Augmented spark ignition. | |
| • Two stage turbines | |
| • Channel wall MCC | |
| • Tubular nozzle | |
| • Concentric element injector design with rigimesh transpiration $H_2$ cooled face | |

Rockwell International
Rocketdyne Division

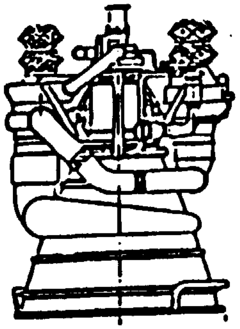
88D-9-1940
41-30-0

FIG. ENG-8

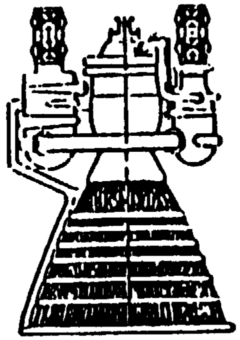
**GENERAL DYNAMICS**
*Space Systems Division*

# LO2/LH2 PUMP-FED ENGINES FOR LRB

LRB



**BASELINE**



**ALTERNATE**

| | | |
|---|---|---|
| • Engine Cycle | LO2/LH2 Gas Generator | LO2/LH2 Split Expander |
| • Thrust, vac EPL | 612 klb | 629 klb |
| • Weight | 6,737 lb | 5,089 lb |
| • Isp, sl/vac | 374.1/426.3 sec | 352.7/418.5 sec |
| • Mixture Ratio | 6.0 | 6.0 |
| • Area Ratio | 40.1 | 18.2 |
| • Pc, EPL | 2538 psia | 840 psia |
| • Throttling Capability | Continuous; 110% to 65% | Continuous; 100% to 65% |
| • Engine Control | Closed Loop | Closed Loop |
| • Min Inlet Pressure | LO2 - 65; LH2 - 25 psia | LO2 - 47; LH2 - 25 psia |
| • POGO Suppression | He Accumulator | He Accumulator |
| • Bleed Systems | Required | Required |
| • Boost Pumps | None | None |
| • Engine Reliability | 0.99 @ 90% Confidence | 0.99 @ 90% Confidence |
| • Risk Evaluation | Low; Cost Verification is needed | Technology & Low Cost Verification is needed |

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## ENGINE PROCESSING OPERATIONS

The considerations for the liquid rocket booster engine processing operations have been broken down into four (4) basic major categories. These categories should include the hardware handling, hardware replacement (from an entire engine replacement down to a component level replacement), verification of engine functional integrity, and the final closeout items required for the launch phase of the operation.

The liquid rocket booster engine conceptual design configurations integrated into the use of new and existing and/or modified Kennedy Space Center Launch Complex 39 facilities, and the vehicle processing philosophy, set the stage for anticipated engine processing flows. However, out of the design centers, both vehicle and engine, are emerging concepts that are enhancements for the launch operations community. One concept out of the liquid rocket booster vehicle community is that the contractor might propose to assemble and completely checkout the hardware in close proximity to the launch site, and then deliver to the launch complex a "flight ready" vehicle. This then would indicate minimal "component" level checkout and would lend itself to "stack and go" with only end-to-end integrated verifications and launch closeout operations left before the initiation of terminal countdown. There is every indication from the engine design community that the designs for these future engines will be robust and sensitive to cost effective processing and launch operations. Such issues as using proven and substantiated flight engine design and technology coupled with innovative processing concepts of ease of engine changeout and on-board health monitoring systems, should enhance the processing of a liquid rocket booster engine.

However, because of a "lessons learned" background and the desire to face the experienced reality of a "conservative approach", this study has chosen to up-front point out the operations that we believe might be representative of a "worst case" operation of an engine replacement.

## ENGINE PROCESSING OPERATIONS (CONT.)

Figure OPS-1 indicates in a general sense the flow, both engine and ground support equipment (GSE), expected for an engine removal. The flow very closely approximates those operations now being experienced by the Space Shuttle Main Engine, but with much reduced timelines to compensate for anticipated innovative "engine changeout" designs.

Figure OPS-2 is a representation of that flow process for the installation of a replacement engine and its processing through launch. Figure OPS-3 depicts this study's evaluation of the timeline and manpower requirements for those operations.

Major engine component level changeout was given a cursory evaluation, only. Future engine designs, by at least one contractor, indicate that possibly an engine changeout was the preferred approach rather than tackle a component changeout with the inherent "component level" replacement operations coupled with the "component level" integrity checkout verification testing. Even though a generic component replacement flow timeline has not been presented, the other portions of this study have identified at least the conceptual designs of the ground support equipment that would be required for such an operation. Experience in processing the SSME has shown that removing an engine to perform the major maintenance off-line is the most cost effective approach. The present plans of the LRB engine community is to have adequate spare engines at the launch site to support any required engine changeout. The innovative concepts to greatly reduce the timelines and efforts associated with an engine changeout indicate that the engine could be changed out before the component GSE could even be staged. However, "contingency planning" for engine major component replacement should be initiated during the design phase of the engine. To this writer, it would appear that the existing" SSME LRU Installation/Removal Set (H70-0528)" would be an excellent candidate for "shared use GSE" considerations. Commonality-in-use designs in adapters for LRB engine component replacement should represent significant cost savings over the design and purchase of a dedicated LRU set just for use with the LRB engine. This concept, then, would be the "contingency planning" for potential LRB engine major component replacement. Operationally, the procedures for such an operation have been baselined with the SSME and should be relatively straight forward when addressing the LRB engine required operation.

Success oriented and cost effective engine processing operations can only be realized through a timely/early establishment of a competent launch site processing and operations support team. The "early" recognition of required specialized disciplines, proper "normal flow" mainstream staffing, adequate processing support personnel, and a "contingency personnel" staff for both abnormal flow operations and a hedge for personnel related impacts is a must for a smooth transition to the liquid rocket booster environment. All too often staffing requirements have been dictated by the level of activity. Therefore, a "minimal" staff has been involved in the initial development of processing operations procedures, etc. It is the purpose of this study to promote the timely placement of the complete launch site engine processing team at the very onset of the program. This ensures that the knowledge base is rooted at the beginning of the program and not phased-in during the "heat" of operations, especially during the transition from one hardware concept to another. Figure OPS-4 attempts to project a possible staffing concept for the processing of the eight (8) LRB engines. The staffing level is an attempt to project a three (3) shift coverage for engine operations support in the disciplines of engineering, technicians, quality engineering/control, and safety. We have envisioned a one (1) shift requirement for administration personnel, scheduling, configuration management and GSE engineering, and a two (2) shift coverage for secretarial functions, logistics, and GSE technicians. It is envisioned that both the technician supervisors and the engineering lead engineers will be "hands-on" personnel located at the center of activity and not solely dedicated to administrative duties. The bulk of the administrative functions should be handled by the "Operations Manager" for a specific discipline or for off-shift operations. The rather "lean" staff was generated based on the concepts being projected for minimal maintenance engines, reduced timelines for required testing/maintenance, and available adequate spare engines (reducing the possibility of component level replacements, etc.).

This staffing level does not take into account the very remote possibility that the Vandenberg Launch Site might be activated with an eye toward a "shared test team". Should this in fact occur, significant adjustments up in staffing would be required.

In considering the personnel issues, the cultural environment existing in the Space Transportation System dictates numerous training and certification requirements for workers at the launch site whether they touch flight hardware or not. These courses are numerous and command a significant amount of man hours for generic training, initial certification, refresher training, and then the re-certification cycle. Tables OPS-1 and OPS-2 represent a tabulation of the various training and mandatory certification courses that are required of the SSME processing community. The courses beginning with the letter prefixes, such as "ES-20A-LSC", are launch site requirements. The courses that are pure numbers, such as "1017", are design center requirements most often addressing a very sensitive subject and requiring very specialized training in order to properly process that specific component. It should be noted that some of the highly technical inspections are only taught at the main factory in Canoga Park, California. Such items as course "1005 - Eddy Current Inspection" is taught only at the main plant and will be noted that it encompasses an entire week for that worker. Proper planning in maintaining current certifications occupies a large part of the training coordinator's time. The launch site environment, at this time and it is not likely to change, says that "....if you are not current with a required certification, then you can not perform any work requiring that certification...".

Taking into account the launch site emphasis on training and the design center's sensitivity toward excellence in job performance, there is no reason to believe that there will be any major changes (deletions) in the type and number of courses/certifications listed on Tables OPS-1 and OPS-2 for LRB engine processing personnel.

Of course, the specific issues such as "SSME Familiarization" would most likely not be required, however, a replacement course such as "LRB Engine Familiarization" is sure to be added.

Some of the additions to the training/certification requirements as a result of the proposed LRB engine configurations might include, (depending on engine configuration selected):

- LRB Engine Familiarization
- Propellant Handling Safety - RP-1
- Engine Hypergol Ignition System
- Pyrotechnic Device Handling
- Thermal Protection System Familiarization
- Fuel System Preparation For Launch
- Various KSC Related Safety Courses
  - LRB Vehicle Familiarization
  - Horizontal Processing Facility Familiarization
  - LRB Engine Access Platform Safety

Also, included for information purposes is the KSC Training Master Course List as Table OPS-3.

A measure of success of any operation involving the processing of flight hardware can be attributed to the accuracy, clarity, and completeness of the operating procedures used for that operation. During the conceptional design phase of the program is the time to establish the basic list for processing procedures. The development of proper "Operations and Maintenance Instructions" (OMI) must be initiated in the very early stages of hardware design, development, and ground testing. This OMI development must be continued throughout the hardware development phase with close launch site coordination with the design centers to insure that when the hardware reaches the launch site, the procedures will be ready to support the operations.

## ENGINE PROCESSING OPERATIONS (CONT.)

All too often ground support equipment is designed in one local without the knowledge of the launch site/flight hardware configuration and limitations, and miles away launch site personnel attempt to develop an OMI from the designer's prints. "Lessons learned" have shown that the lack of close coordination between design centers and the launch center can prove chaotic when neither the hardware nor the OMI can support the operation because both are in error.

The identified characteristics of the various proposed liquid rocket booster engines, even though in their conceptual design phase, can lead to the skeleton, or basic list, of OMI's that may be required for engine processing. These might include (depending on the engine type/configuration selected):

- Engine Off-Loading/Receiving/De-Packaging
- Engine Receiving Inspection
- Engine Packaging/Loading (For Shipment)
- Leak and Functional Checkout (Shop and Integrated)
    - External Leak Checks (Joints, etc.)
    - Internal Leak Checks (Valve Seats, etc.)
    - Flow Checks (Purges, etc.)
    - Actuator Functionals
    - Controller Verification
    - Flight Readiness Test
- Engine Installation/Removal - Horizontal
- Engine Installation/Removal - Vertical
- Thermal Protection System Installation
- Line Replaceable Unit (LRU)
    - Gas Generator
    - Main Oxidizer Valve
    - Main Fuel Valve
    - Oxidizer Pump
    - Fuel Pump
    - Controller
    - Electrical Harness
    - Valve Actuator

ENGINE PROCESSING OPERATIONS (CONT.)

  - Pogo System
  - Pneumatic Control Package
  - Major Ducting
- Ground Support Equipment Preparations
- Ground Support Equipment PMOMI's
- Component Handling
- "Closeout" For Launch
  - Ignition System Checkout
  - Ignition System Installation
  - Chamber/Fuel System Preparation
  - Final Thermal Protection System Closeout
- Recycle After On-Pad Scrub and/or Abort

In addition to the engine-only processing OMI's, the engine processing community will be involved in the integrated operations OMI's to insure the "Launch Team" has incorporated the correct data and requirements for the LRB engines.

It has been proposed that a "pathfinder" vehicle be provided to verify the operations prior to an actual LRB flow. This coupled with the recommendation that at the beginning of the program both the design center(s) and the launch operations personnel (at the component level) establish an active working group to develop procedures should provide for effective hardware processing on the first LRB flow.

Table OPS-4 has been provided to show the various OMI's now used in the processing of the Space Shuttle Main Engine. What is missing from the list is the numerous PMOMI's used in maintaining the ground support equipment.

Operations and Maintenance Instructions is another of the "Achilles Heel" at the launch site. Proper OMI's will be a must in bringing on line the liquid rocket booster, especially when attempting to phase-in a new technology and not impact the on-going launch site operations and launch rates of the STS. In order to insure that these goals are met, OMI requirements identification, development and verification

## ENGINE PROCESSING OPERATIONS (CONT.)

must be initiated at the onset of the program. The success of OMI development will depend on the persistant and close coordination between design center(s) and launch site, and with properly trained and knowledgeable personnel at the launch site. When the equipment is already in route to the launch site is not the time to begin developing processing procedures. The use of the LRB engine ground test program can be very valuable when developing procedures for the launch complex.

FIG. OPS-1 LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE REMOVAL

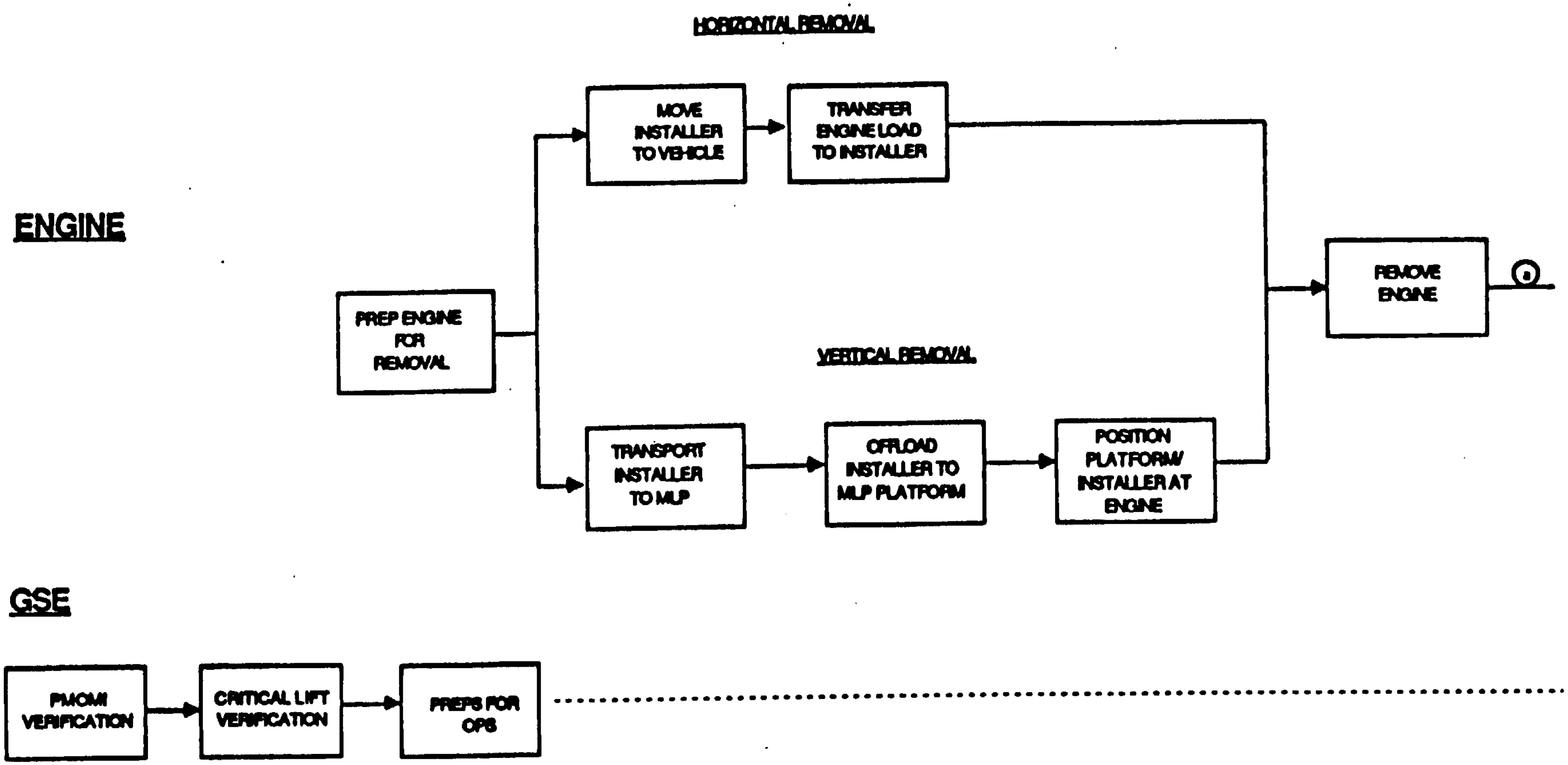


FIG. OPS-1 LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE REMOVAL (CONT.)

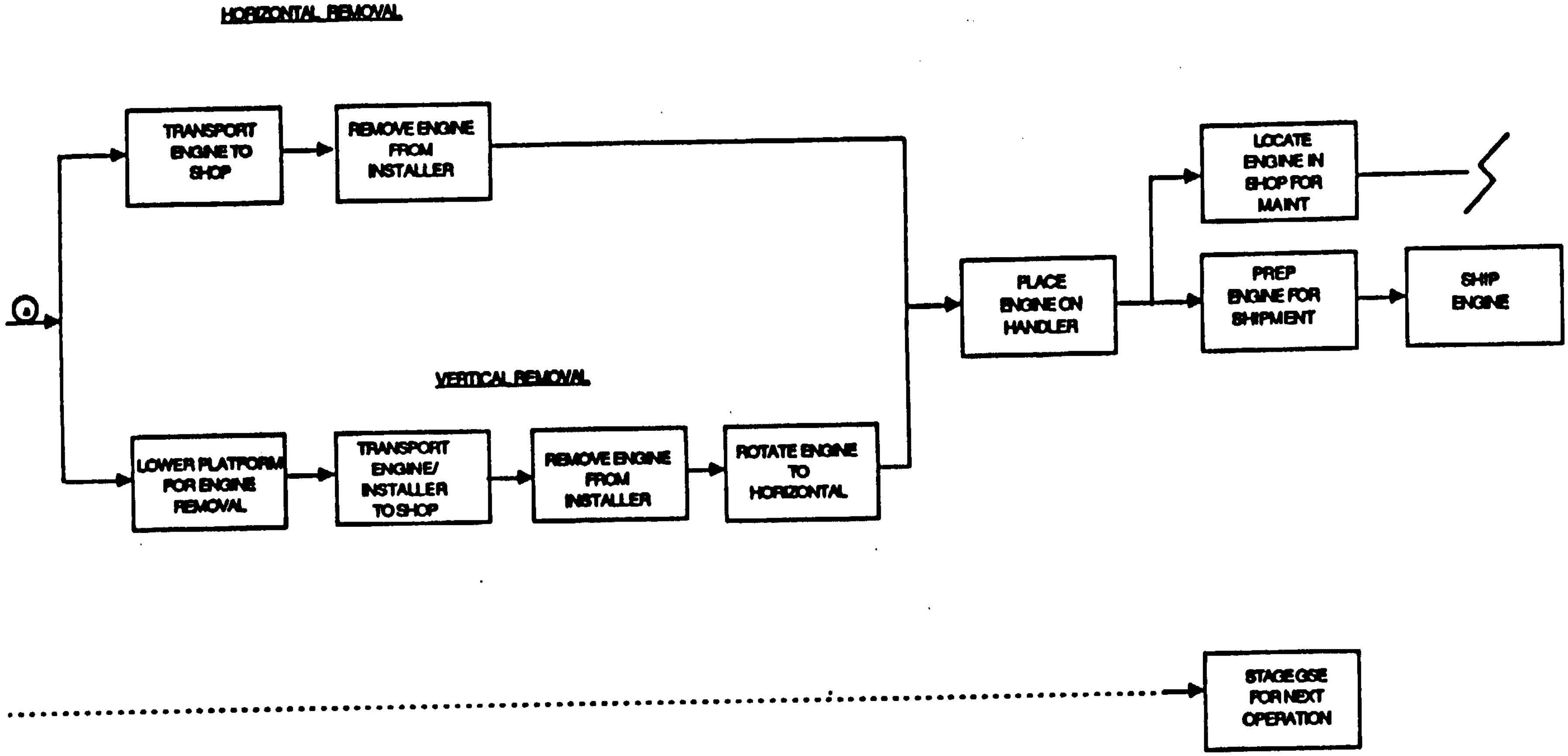


FIG. OPS-2 LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE INSTALLATION

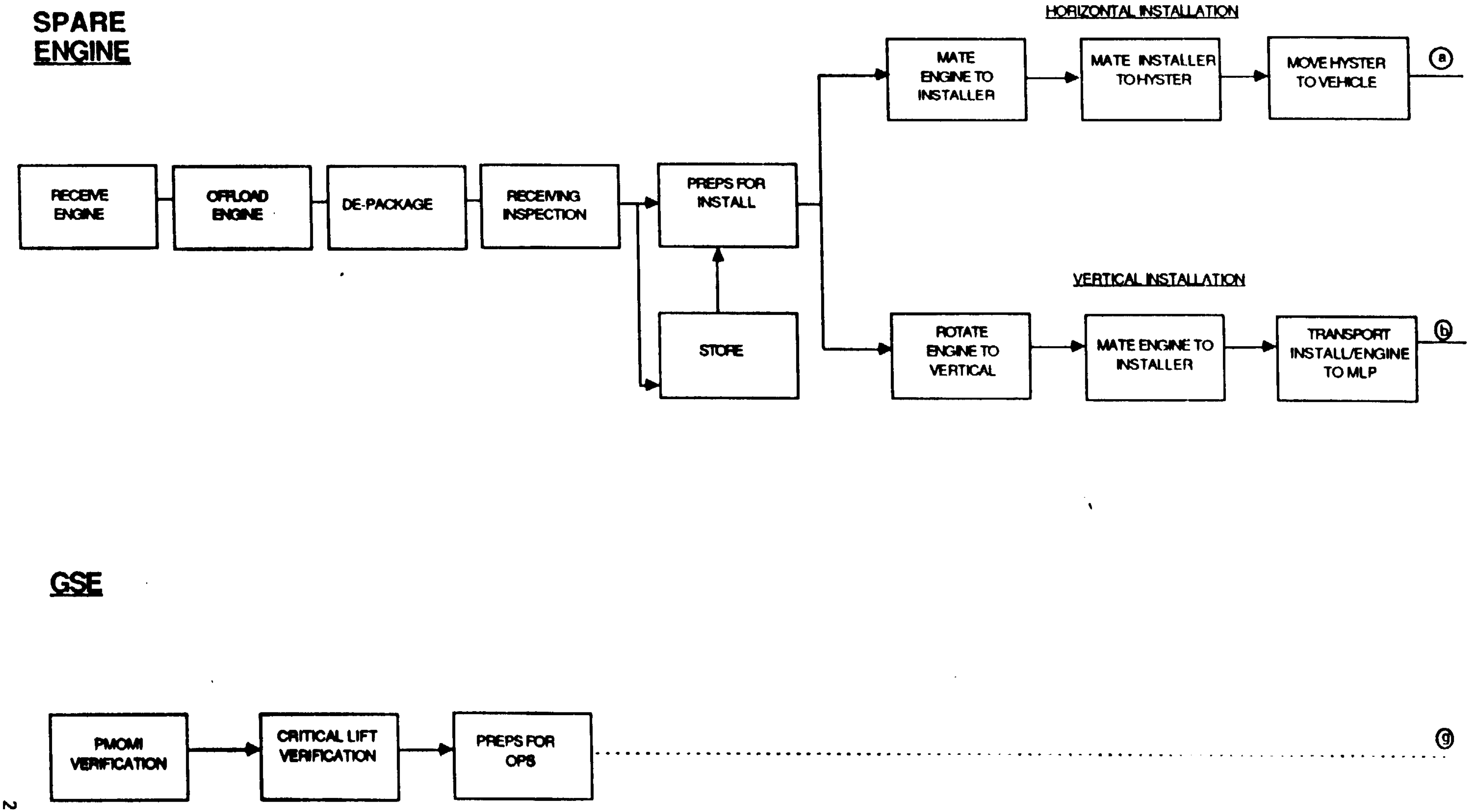


FIG. OPS-2 LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE INSTALLATION (CONT.)

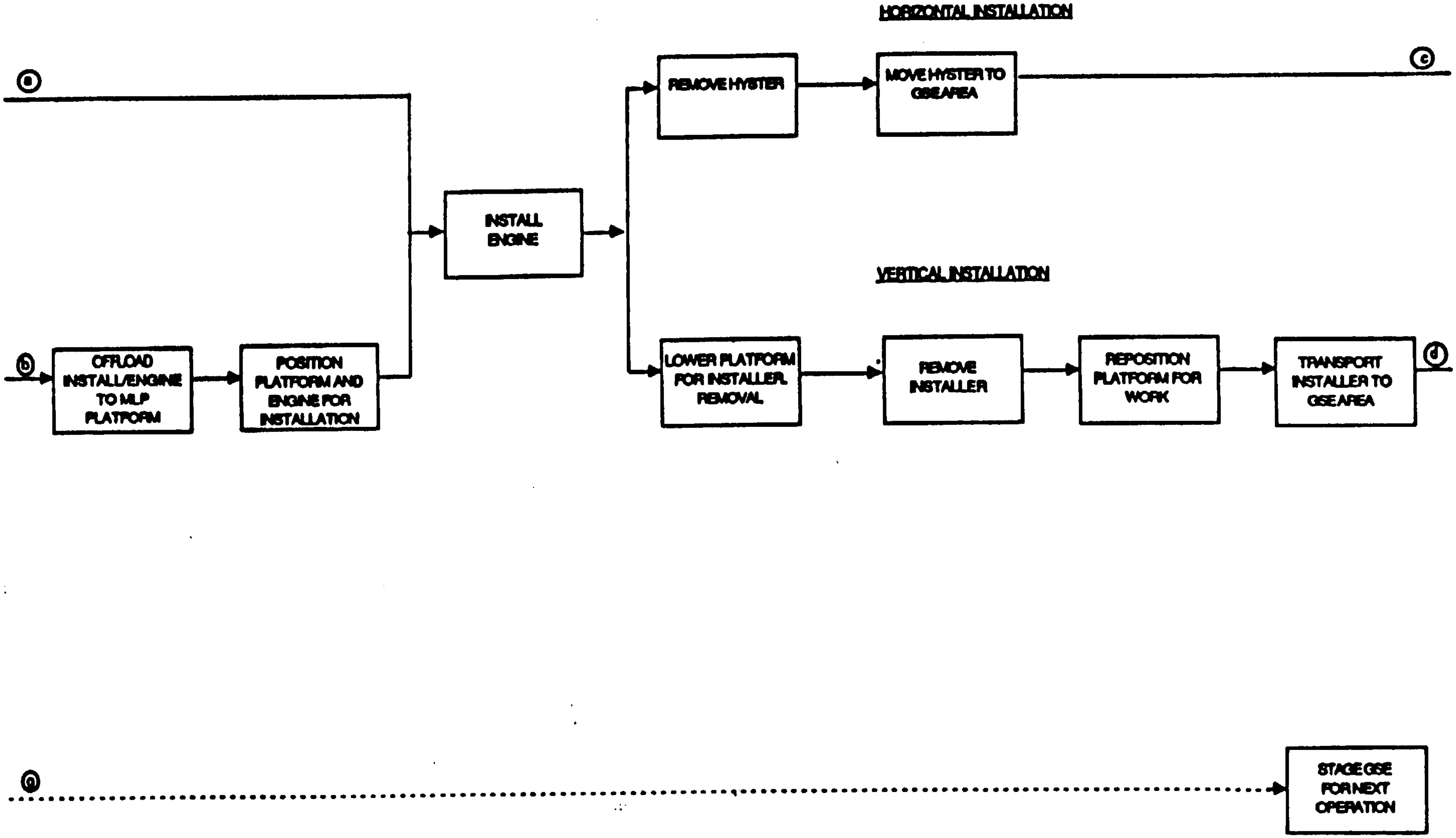


FIG. <u>OPS-2</u> LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE INSTALLATION (CONT.)

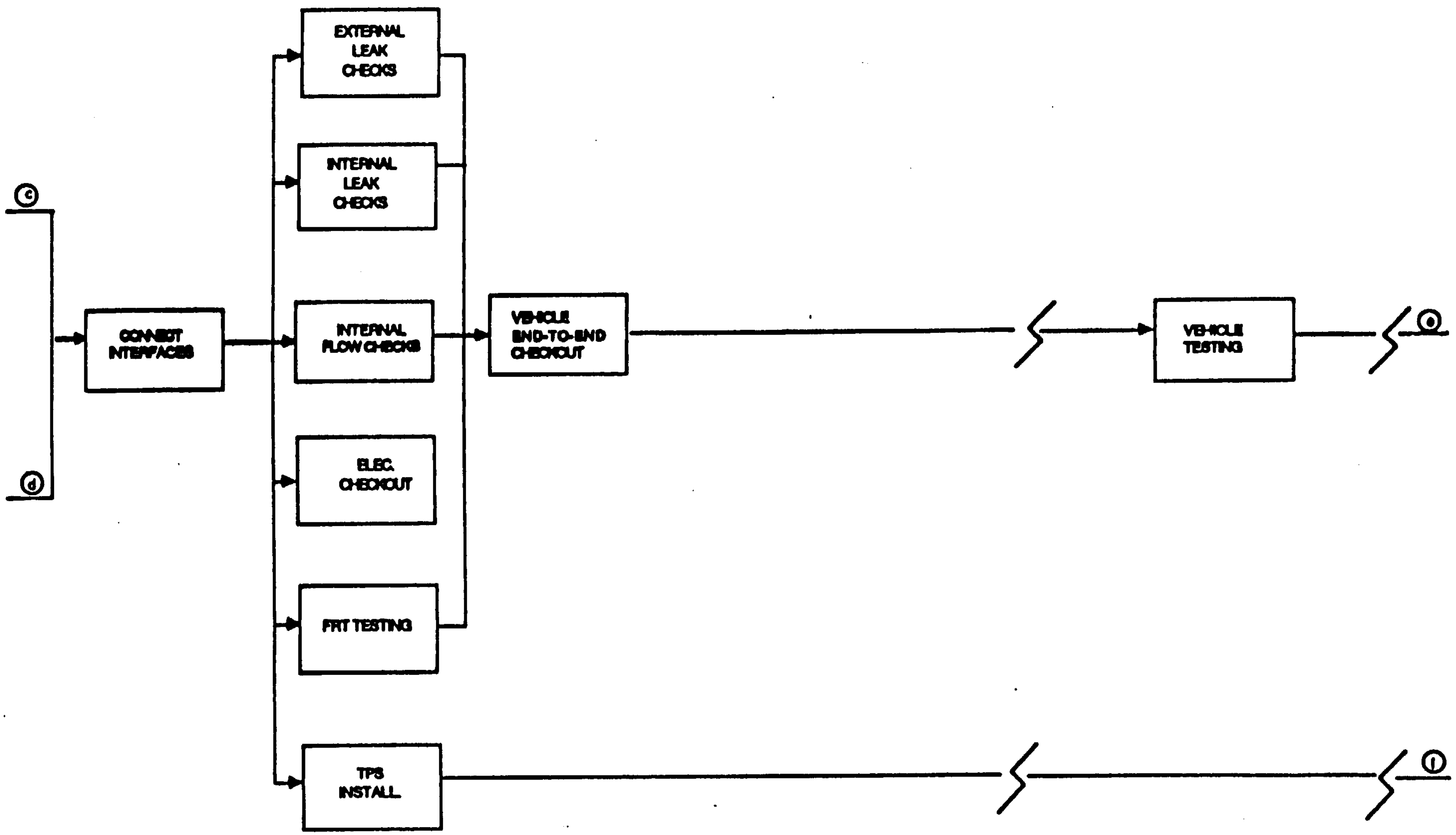


FIG. OPS-2 LIQUID ROCKET BOOSTER
TYPICAL SINGLE ENGINE FLOW
ENGINE INSTALLATION (CONT.)

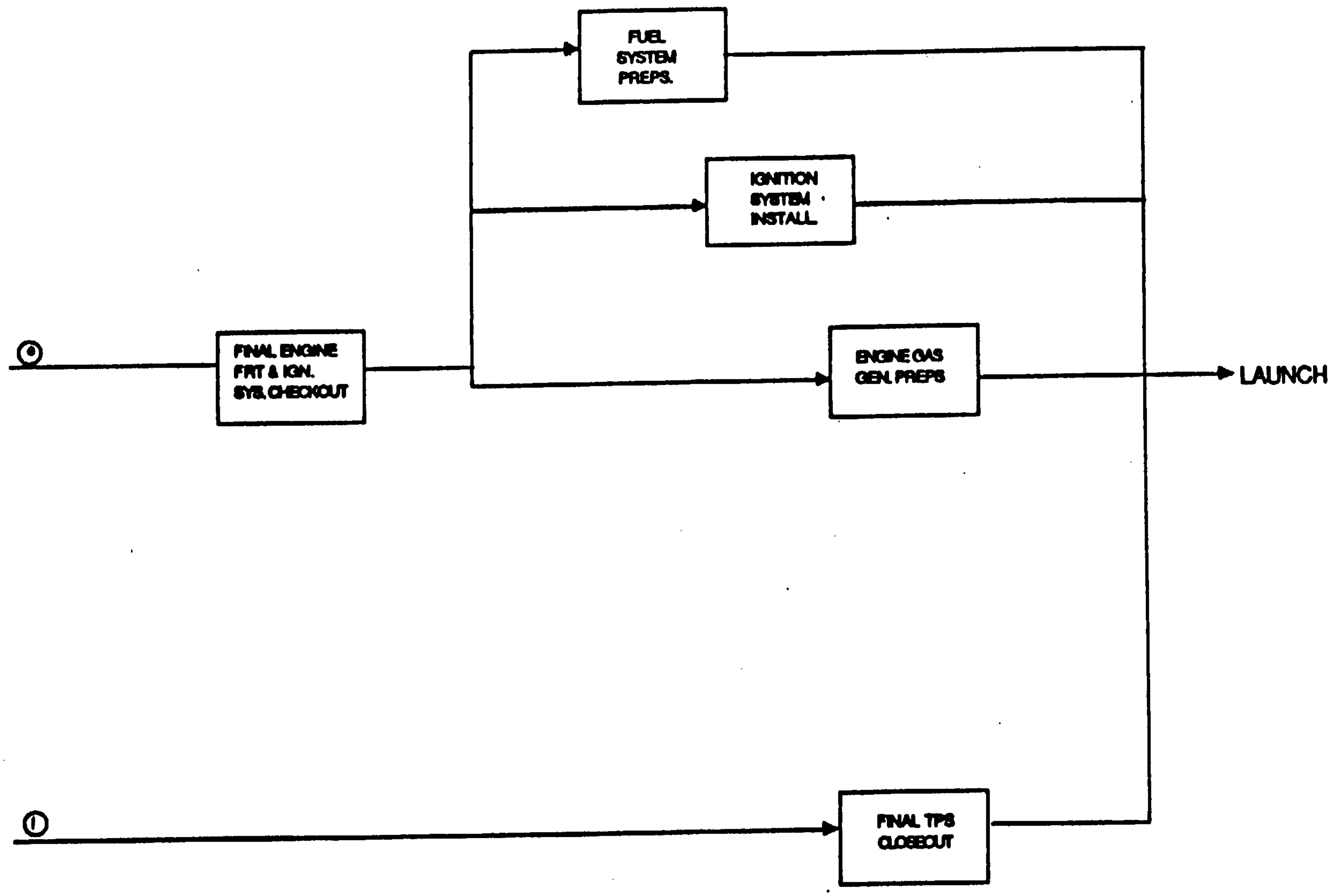
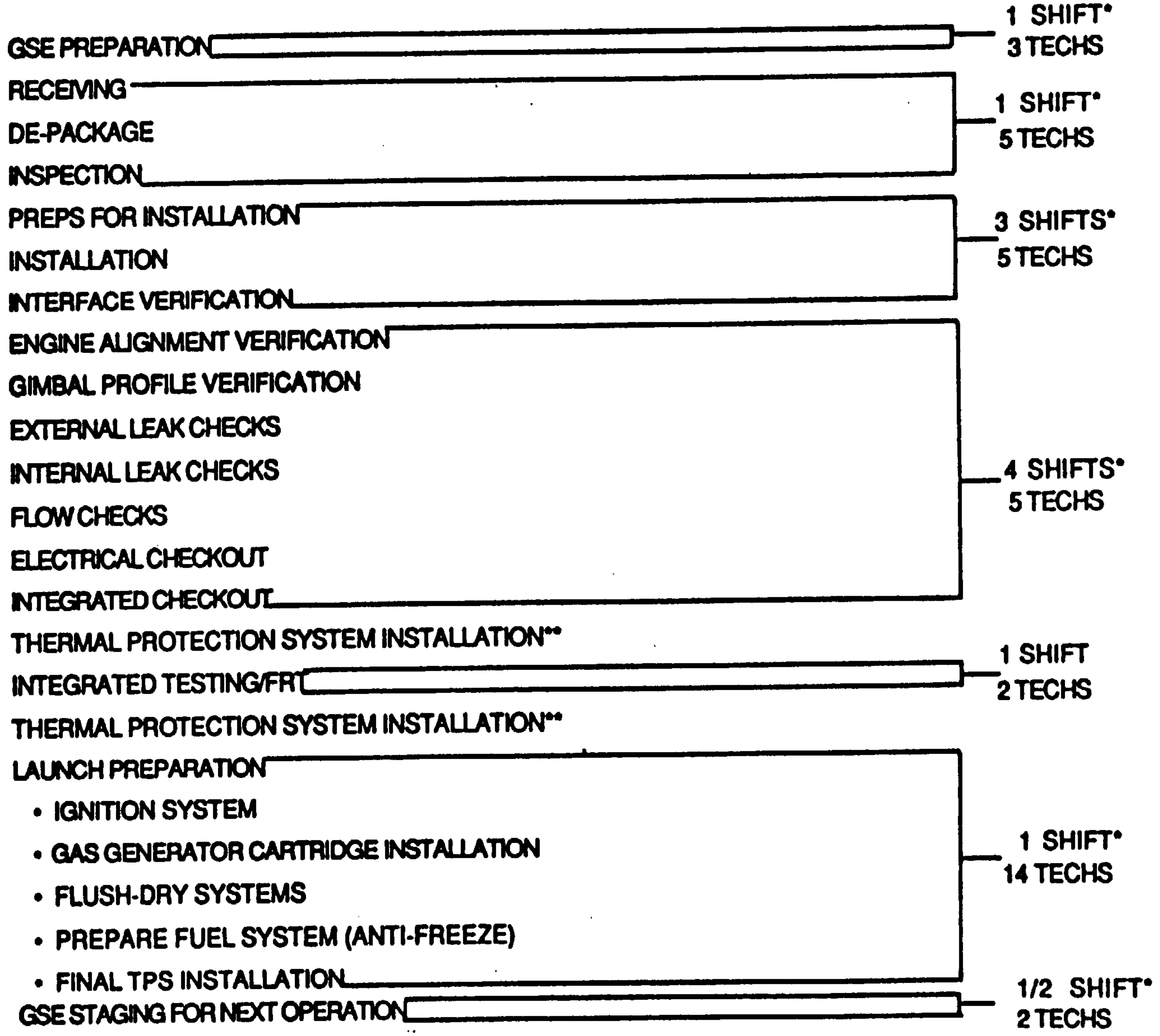


FIG. <u>OPS-3</u>

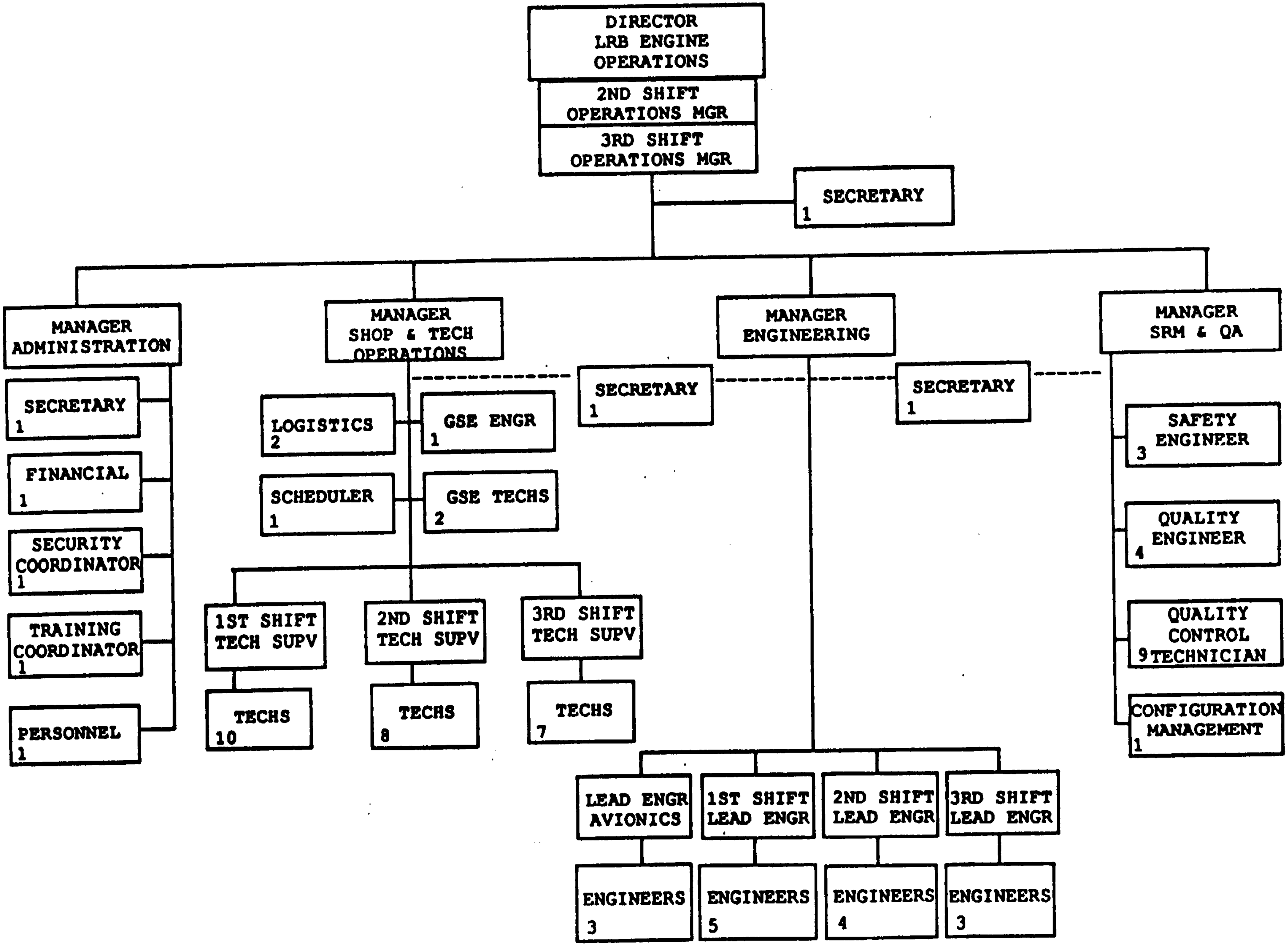
## LIQUID ROCKET BOOSTER
## TYPICAL SINGLE ENGINE FLOW
## ENGINE INSTALLATION



| Task | Shifts / Techs |
|---|---|
| GSE PREPARATION | 1 SHIFT*<br>3 TECHS |
| RECEIVING<br>DE-PACKAGE<br>INSPECTION | 1 SHIFT*<br>5 TECHS |
| PREPS FOR INSTALLATION<br>INSTALLATION<br>INTERFACE VERIFICATION | 3 SHIFTS*<br>5 TECHS |
| ENGINE ALIGNMENT VERIFICATION<br>GIMBAL PROFILE VERIFICATION<br>EXTERNAL LEAK CHECKS<br>INTERNAL LEAK CHECKS<br>FLOW CHECKS<br>ELECTRICAL CHECKOUT<br>INTEGRATED CHECKOUT | 4 SHIFTS*<br>5 TECHS |
| THERMAL PROTECTION SYSTEM INSTALLATION** | |
| INTEGRATED TESTING/FRT | 1 SHIFT<br>2 TECHS |
| THERMAL PROTECTION SYSTEM INSTALLATION** | |
| LAUNCH PREPARATION<br>• IGNITION SYSTEM<br>• GAS GENERATOR CARTRIDGE INSTALLATION<br>• FLUSH-DRY SYSTEMS<br>• PREPARE FUEL SYSTEM (ANTI-FREEZE)<br>• FINAL TPS INSTALLATION | 1 SHIFT*<br>14 TECHS |
| GSE STAGING FOR NEXT OPERATION | 1/2 SHIFT*<br>2 TECHS |

* PER ENGINE    ** 18 SHIFT TOTAL - 10 TECHS

FIG. OPS-4 LIQUID ROCKET BOOSTER ENGINE STAFFING REQUIREMENTS



## TABLE OPS-1

## ENGINE PROCESSING PERSONNEL TRAINING AND CERTIFICATION

## REQUIRED TRAINING AND CERTIFICATION

| CERTIFICATION COURSE NO. | TITLE | COURSE HOURS |
|---|---|---|
| ES-20A-LSC | REVIEW OF DC ELECTRONICS | 4.0 |
| ES-301-LSC | DC FUNDAMENTALS | 40.0 |
| ES-501-LSC | WIRE TERMINATION | 12.0 |
| ES-503-LSC | ELECTRICAL CONNECTORS MATE/DEMATE | 3.0 |
| ES-507-LSC | ELECTRICAL BONDING & GROUNDING | 3.0 |
| MS-502-LSC | TORQUE & SAFETY WIRING | 3.0 |
| OV-540-LSC | ORBITER MOVE DIRECTOR | 12.0 |
| OV-220-LSC | ORBITER CONVOY OPERATIONS | 4.0 |
| QG-232-KSC | FORKLIFT SAFETY FAMILIARIZATION | 2.0 |
| QG-342-KSC | BREATHING APPARATUS FOR C/S | 2.0 |
| QG-501-KSC | ALL MODES OF ESCAPE OPERATIONS | 4.0 |
| QS-502-LSC | PENETRANT INSPECTION | 20.0 |
| TG-340-LSC | CRANE OPERATOR SAFETY TRAINING | 2.0 |
| 1000 | ADHESIVE BONDING | 4.0 |
| 1017 | EDDY CURRENT - PREBURNER LOX POST-INSPECTION | 24.0 |
| 1005 | EDDY CURRENT INSPECTION | 36.0 |
| 1006 | ELECTRO-CHEMICAL ETCHING | 3.5 |
| 1042 | EXTENSOMETER - ERDMAN | 2.0 |
| 1018 | LUBE ANTI-SEIZE | 2.0 |

# TABLE OPS-2

## ENGINE PROCESSING PERSONNEL TRAINING AND CERTIFICATION

## REQUIRED TRAINING ONLY

## NO CERTIFICATION REQUIREMENTS

| CERTIFICATION COURSE NO. | TITLE | COURSE HOURS |
|---|---|---|
| OV-251-LSC | SSME FAMILIARIZATION | 3.0 |
| OV-256-LSC | ORBITER HYDRAULIC SYSTEMS FAM | 2.5 |
| OV-301-LSC | SSME | 6.0 |
| OV-306-LSC | ORBITER HYDRAULIC SYSTEMS | 3.0 |
| OV-331-LSC | LPS FAMILIARIZATION | 12.0 |
| QG-226-KSC(D) | TWO-WAY RADIO & OIS FAM | 2.5 |
| QG-230-KSC | RIGGING FUNDAMENTALS | 3.0 |
| QG-245-LSC | WORK AT HEIGHTS SAFETY | 2.0 |
| QG-304-KSC | CPR & ELECT SHOCK 1ST AID (QG-313-KSC ANNU) | 4.0 |
| QG-313-KSC | CPR & ELECT SHOCK FIRST AID REFRESHER | 2.0 |
| QS-504-LSC | AIR PURIFYING RESPIRATOR | 1.0 |
| QT-514-LSC | CRYOGENIC SEALS/TORQUE WRENCHES | 3.0 |
| 6000 | BORESCOPE HANDLING | 2.0 |
| 4002 | CONFINED SPACE ENTRY | 2.0 |
| 5007 | HYDRAULIC AND PNEUMATIC PRESSURE SAFETY | 16.0 |
| 2012 | PRIME MOVER LICENSE | 2.0 |

## TABLE OPS-3 JOHN F. KENNEDY SPACE CENTER

## TRAINING MASTER COURSE LIST

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| NUMBER | TITLE | INSTRUCTOR | C-LEN | R-LE |
|---|---|---|---|---|
| OV-58A-LSC | RSI TILE STEP & GAP EVALUATION | ALLBRIGHT | 16.0 | 8.0 |
| OV-590-LSC | HYPER QD INSTALLATION | SCOBBY | 3.0 | 3.0 |
| OV-591-LSC | ORB HOIST & HANDLING HARDWARE | DI WATLINGTON | 8.0 | 8.0 |
| OV-592-LSC | ORB STRUCT MATE | DI WATLINGTON | 8.0 | 8.0 |
| OV-593-LSC | ORB LO2/LH2 UMBILICAL MATE | DI WATLINGTON | 8.0 | 8.0 |
| OV-595-LSC-REV | RSI MIX CRIB ATTENDANT | BOWMAN | 4.0 | 4.0 |
| OV-596-LSC | RSI DEWPOINT MEASUREMENTS | ALLBRIGHT | 4.0 | 2.0 |
| OV-5AA-LSK | OPF/HB BRIDGE BUCKET | SCOBBY | 2.0 | 2.0 |
| QF-04A-KSC | AF HANGAR FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-280-KSC | O&C BLDG. FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-28S-KSC | SAEF FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-28V-KSC | VPF FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39L-KSC | SLF FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39M-KSC | MLP SAFETY FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39N-KSC | ORBITER MAINT. REFURB FACILITY | VIDEO | 0.5 | 0.5 |
| QF-390-KSC | OPF FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39P-KSC-REV 1088 | PAD 39 FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39R-KSC | RPSF FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39V-KSC | VAB FAMILIARIZATION | VIDEO | 0.5 | 0.5 |
| QF-39X-KSC-REV 1088 | SLF-OPF-PAD-RPSF-VAB-MLP-OMRF FAMILIARIZAT | VIDEO | 2.0 | 2.0 |
| QF-45A-KSC | DFRF AREA A SAFETY FAMILIARIZATION | VIDEO | 1.0 | 1.0 |
| QF-OPF-LSK | EMERGENCY VEHICLE ACCESS | DI BUMGARDNER | 0.5 | NONE |
| QF-OPV-LSK | OPF TOOL TETHERING | DI BUMGARDNER | 1.0 | NONE |
| QG-100-KSC | Manatee Safety Awareness | Fld Wildlife | 0.5 | 0.5 |
| QG-101-KSC | FIRE PROTECTION SAFETY ORIENTATION | SIMS | 1.0 | 1.0 |
| QG-102-KSC | TOXIC PROPELLANT SAFETY | SIMS | 2.0 | NONE |
| QG-103-KSC | ENTRY INTO TANKS & CONFINED SPACES | RICHARDSON | 1.5 | NONE |
| QG-104-KSC | HALON 1301 SYSTEM | EGG | 1.0 | NONE |
| QG-106-KSC | TOXIC PROPELLANT REFRESHER | SIMS | 1.0 | 1.0 |
| QG-128-KSC | KSC IND. AREA SAFETY FAMILIARIZATION | VIDEO | 1.0 | NONE |
| QG-150-KSC | STS FLT. VEH. SFT. ORIENT | VIDEO | 1.0 | NONE |
| QG-156-LSC | FLIGHT HARDWARE ACCIDENT PREVENTION | SCOBBY | 1.0 | 1.0 |
| QG-170-LSK | QUALITY AWARENESS PROGRAM | DI ADAMEK | 0.5 | NONE |
| QG-200-LSC | HAZARD COMMUNICATIONS | VIDEO | 1.0 | 1.0 |
| QG-201-KSC | CRYOGENIC SAFETY KSC | SIMS | 1.5 | NONE |
| QG-203-LSC | SPC SELF-AUDIT PROGRAM | DI BLACKMANN | 1.0 | NONE |
| QG-204-KSC | HIGH PRESSURE SYSTEMS SAFETY | SIMS | 2.0 | NONE |
| QG-206-KSC | SOLVENTS & MISC. LIQUIDS SAFETY | BLALOCK | 1.0 | NONE |
| QG-218-KSC | CLOSEOUT CREW FIRE SUPPRESSION | EGG | 2.0 | 2.0 |
| QG-222-KSC | CONTINGENCY CREW FIRE SUPPRESSION | EGG | 4.0 | 4.0 |
| QG-226-KSC(D) | TWO-WAY RADIO & OIS FAM | CLARK | 2.5 | NONE |
| QG-230-KSC | RIGGING FUNDAMENTALS | STOKES | 3.0 | NONE |
| QG-232-KSC | FORKLIFT SAFETY FAMILIARIZATION | CLARK | 2.0 | NONE |
| QG-233-LSK | LOGISTICS EQUIPMENT SAFETY | NONE | 1.0 | NONE |
| QG-245-LSC | WORK AT HEIGHTS SAFETY | BELL | 2.0 | NONE |
| QG-251-KSC | AREA FAM FOR TRADES & CRAFTS PER | SIMS | 3.0 | 3.0 |
| QG-304-KSC | CPR & ELECT SHOCK 1st AID (QG-313-KSC Annu | EGG | 4.0 | 4.0 |
| QG-310-KSC | BASIC 1st AID (QG-311-KSC Annual Req) | EGG | 8.0 | 8.0 |
| QG-311-KSC | BASIC FIRST AID MULTIMEDIA REVIEW | EGG | 4.0 | 4.0 |

## TABLE OPS-3 JOHN F. KENNEDY SPACE CENTER
## TRAINING MASTER COURSE LIST
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| NUMBER | TITLE | INSTRUCTOR | C-LEN | R-LEN |
|---|---|---|---|---|
| EB-307-LSC | SRB ELECTRICAL SUBSYSTEM | LUCAS | 3.0 | NONE |
| EB-503-LSC | SRB AQUACON CONNECTER MATE/DEMATE | LUCAS | 2.0 | 2.0 |
| EG-500-LSK | MDF TERMINAL SOLDERING | WILLIAMS | 4.0 | 4.0 |
| ES-20A-LSC | REVIEW OF DC ELECTRONICS | HODGES | 4.0 | 2.0 |
| ES-301-LSC | DC FUNDAMENTALS | REMNET | 40.0 | - |
| ES-501-LSC | WIRE TERMINATION | REMNET | 12.0 | 8.0 |
| ES-502-LSC | NASA SOLDERING | BUKER | 40.0 | 16.0 |
| ES-503-LSC | ELECTRICAL CONNECTORS MATE/DEMATE | KNIGHT | 3.0 | 3.0 |
| ES-504-LSC | POTTING OF ELECTRICAL CONNECTORS | SCHUTTE | 6.0 | 3.0 |
| ES-505-LSC | SENSOR & STRAIN GAUGE INSTALLATION | SCHUTTE | 24.0 | 12.0 |
| ES-506-LSC | SOLDER SLEEVE INSTALLATION | WILLIAMS | 4.0 | 3.0 |
| ES-507-LSC | ELECTRICAL BONDING & GROUNDING | REMNET | 3.0 | 2.0 |
| ES-508-LSC | SOLDERLESS WIRE WRAPPED CONNECTIONS | WILLIAMS | 4.0 | 3.0 |
| MB-301-LSC-REV | SRB SOLID ROCKET MOTOR | LUCAS | 3.0 | NONE |
| MB-304-LSC | SRB THRUST VECTOR CONTROL SYSTEM | LUCAS | 2.0 | NONE |
| MB-400-LSK | SRB HYDRASET (250 TONS) | CLARK | 3.0 | 3.0 |
| MB-410-LSC | SEALED SURFACE METAL FINISH | DI | 2.5 | - |
| MB-500-LSC | SRB LEAK DETECTOR | LUCAS | 8.0 | NONE |
| MB-505-LSC | SRB GREASE APPLICATION | LUCAS | 2.0 | NONE |
| MS-502-LSC | TORQUE & SAFETY WIRING | REMNET | 3.0 | 2.0 |
| MS-503-LSC | INSTALLATION OF THREADED FASTENERS | SCHUTTE | 8.0 | 4.0 |
| MV-503-LSC | INSTALLATION & REMOVAL OF ROSAN INSERTS | SCHUTTE | 4.0 | 2.0 |
| OB-402-LSC | SRB INTEGRITY CONTROL | LYONS | 1.0 | NONE |
| OE-345-ROC | H70-528 LRU RAIL FAM | ROC | 2.0 | NONE |
| OF-200-LSK | CSTS LH2 | BLALOCK | 2.5 | NONE |
| OF-201-LSK | CSTS LO2 | BLALOCK | 2.5 | NONE |
| OF-210-LSK | PPU ECS FAM | STOKES | 2.0 | 2.0 |
| OF-21A-LSK | OPF/OMRF, ECS FAM | STOKES | 2.0 | NONE |
| OF-21B-LSK | PAD ECS FAM | STOKES | 2.0 | NONE |
| OF-300-LSK | CRYO STORAGE & TRANSFER SYSTEM(LH2) | BLALOCK | 4.0 | NONE |
| OF-301-LSK | CRYO STORAGE & TRANSFER SYSTEM (LO2) | BLALOCK | 4.0 | NONE |
| OF-305-LSK | FUEL CELL SERVICING SYSTEM | BLALOCK | 4.0 | NONE |
| OF-31A-LSK | OPF/OMRF, ECS OPS | STOKES | 8.0 | NONE |
| OF-31B-LSK | PAD ECS O&M | STOKES | 8.0 | NONE |
| OG-100-LSC | EFFECTIVE LEADERSHIP I | HR | 16.0 | NONE |
| OG-101-LSC | EFFECTIVE LEADERSHIP II | HR | 16.0 | NONE |
| OG-102-LSC | EMPLOYEE ORIENTATION | HR | 3.0 | NONE |
| OG-103-LSK | PRACA FAM | RUDOLPH | 3.0 | NONE |
| OG-104-LSC | PROCESS MANAGEMENT SKILLS | HR | 24.0 | NONE |
| OG-105-LSC | FUNCTIONAL SUPERVISION | HR | 8.0 | NONE |
| OG-107-LSC | PERFORMANCE APPRAISAL (SALARIED) | HR | 1.5 | NONE |
| OG-108-LSC | PERFORMANCE APPRAISAL (HOURLY) | HR | 1.5 | NONE |
| OG-109-LSC | SPC DAILOGUE | HR | 28.0 | NONE |
| OG-113-LSC | STRESS MANAGEMENT | HR | 8.0 | NONE |
| OG-114-LSC | TIME MANAGEMENT | HR | 4.0 | - |
| OG-120-LSK | SECURITY ORIENTATION FOR SUPERVISION | SECURITY | 1.0 | NONE |
| OG-121-LSK | CLASSIFIED MATERIAL CONTROL | SECURITY | 1.0 | NONE |
| OG-122-LSK | CLASSIFIED MATERIAL HANDLING | SECURITY | 1.5 | NONE |
| OG-123-LSK | ADP SECURITY | SECURITY | 1.0 | NONE |

## TABLE OPS-3 JOHN F. KENNEDY SPACE CENTER
## TRAINING MASTER COURSE LIST
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| NUMBER | TITLE | INSTRUCTOR | C-LEN | R-LEN |
|---|---|---|---|---|
| OV-3DB-LSC | PAYLOAD COMM SYSTEM | WOLLETT | 3.5 | NONE |
| OV-3DC-LSC | UHF COMM SYSTEM | HODGES | 3.0 | NONE |
| OV-3DD-LSC | CLOSED CIRCUIT TV SYSTEM (CCTV) | HODGES | 3.0 | NONE |
| OV-3DE-LSC | KU-BAND COMM/RADAR SYSTEM | WOLLETT | 4.5 | NONE |
| OV-3DF-LSC | MSBLS | HODGES | 3.0 | NONE |
| OV-3DG-LSC | TACAN | WOLLETT | 4.0 | NONE |
| OV-3DH-LSC | RADAR ALTIMETER SYSTEM | HODGES | 3.0 | NONE |
| OV-400-LSC | STAR TRACKER CARE AND HANDLING | BELL | 2.0 | 2.0 |
| OV-402-LSC | RSI PLUG INSTALLATION/REMOVAL | PERRY | 3.0 | 3.0 |
| OV-403-LSC | RSI TILE HOTWIRE REMOVAL | PERRY | 3.0 | 3.0 |
| OV-502-LSC | SOLDERING OPERATOR LIMITED | BUKER | 24.0 | 8.0 |
| OV-508-LSC | INDUCTION BRAZING | DI BENZIGER | 16.0 | 8.0 |
| OV-509-LSC | DEBRAZING & REBRAZING OF TUBING | DI BENZIGER | 16.0 | NONE |
| OV-510-LSC-REV | ADHESIVE BONDING | PERRY | 24.0 | 8.0 |
| OV-512-LSC | POLYURETHANE FOAM APPLICATION | ALLBRIGHT | 8.0 | 4.0 |
| OV-513-LSC | HEATSINK ADHESIVE BONDING | ALLBRIGHT | 8.0 | 4.0 |
| OV-514-LSC | EXCESSIVE GAP REWORK (TPS328) | BOWMAN | 8.0 | 4.0 |
| OV-516-LSC | FRSI INSTALLATION | BOWMAN | 24.0 | 8.0 |
| OV-517-LSC | RSI TILE STANDARD REPAIR | PERRY | 24.0 | 4.0 |
| OV-518-LSK | SILVER BRAZING | - | 6.0 | 2.0 |
| OV-519-LSC | RSI FLEXABLE INSTALLATION REPAIR | BOWMAN | 8.0 | 4.0 |
| OV-520-LSC-REV | RSI FLEXABLE INSULATION INSTALL | BOWMAN | 48.0 | 16.0 |
| OV-521-LSK | TILE & TPS INSTRUMENTATION BONDING | ALLBRIGHT | 16.0 | 8.0 |
| OV-522-LSC-REV | STANDARD TILE INSTALLATION | ALLBRIGHT | 40.0 | 12.0 |
| OV-523-LSC | ASTRO ARC TUBE WELDING (FLIGHT) | DI BENZIGER | 24.0 | NONE |
| OV-524-LSC | CONFORMAL COATING, RTV 566 | WILLIAMS | 4.0 | 2.0 |
| OV-525-LSK | PROPELLANT SAMPLING | BLALOCK | 2.0 | 2.0 |
| OV-527-LSC | RSI TILE STANDARD REPAIR II | BOWMAN | 16.0 | 4.0 |
| OV-529-LSC | HYDRASET OPERATOR | PERRY | 4.0 | 4.0 |
| OV-52A-LSC | ADVANCED TILE INSTALLATION (.090/.115 | ALLBRIGHT | 8.0 | 4.0 |
| OV-531-LSC | REMOTE CONTROL HYDRASET OPER | PERRY | 16.0 | 4.0 |
| OV-532-LSC | BONDED SENSOR INSTALLATION | WILLIAMS | 40.0 | 16.0 |
| OV-533-LSC | STRAIN GAGE INSTRUMENTATION INSTALLATION | WILLLIAMS | 40.0 | 16.0 |
| OV-540-LSC | ORBITER MOVE DIRECTOR | DI WATLINGTON | 12.0 | 12.0 |
| OV-543-LSC | A70-0889 HYDRAULIC BOOM OPERATOR | DI BAKER | 4.0 | NONE |
| OV-544-LSC | ORBITER HATCH OPERATOR | BELL | 2.0 | 2.0 |
| OV-545-LSC | ORB TOW BAR | DI WATLINGTON | 4.0 | NONE |
| OV-552-LSC | ASTRO ARC TUBE WELDING -GSE | DI BENZIGER | 24.0 | NONE |
| OV-554-LSC | FLUID LINE TCS HEATER INSTALL | - | 8.0 | 8.0 |
| OV-555-LSC | OPTICAL TOOLING OPERATOR | DI STORM | 64.0 | 64.0 |
| OV-556-LSC | DEUTSCH PERMASWAGE & ROLLSWAGE OPER | DI BENZIGER | 4.0 | 4.0 |
| OV-560-LSC | FLUID LINE INSULATION INSTALL | - | 8.0 | 4.0 |
| OV-572-LSK | HAZARDOUS GAS DETECTION SYSTEM | DI SCHWINDT | 20.0 | 20.0 |
| OV-580-LSC | TCS BLANKET OPERATIONS | SCOBBY | 3.0 | 3.0 |
| OV-583-LSC | RCC REPAIR | BOWMAN | 4.0 | 4.0 |
| OV-586-LSC | AMES & DESIGN/MR PILLOW GAP FILLERS | ALLBRIGHT | 16.0 | 8.0 |
| OV-587-LSC | RSI TILE STEP & GAP MEASUREMENT | ALLBRIGHT | 8.0 | 4.0 |
| OV-588-LSC | TILE BOND VERIFICATION | BOWMAN | 8.0 | 4.0 |
| OV-589-LSC | TILE MACHINING | PERRY | 16.0 | 8.0 |

## TABLE OPS-3 JOHN F. KENNEDY SPACE CENTER
## TRAINING MASTER COURSE LIST (CONT.)

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Report: COURSE.LIST
Selection: STATUS equals A

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| NUMBER | TITLE | INSTRUCTOR | C-LEN | R-LEN |
|---|---|---|---|---|
| OV-220-LSC | ORBITER CONVOY OPERATIONS | BELL | 4.0 | NONE |
| OV-224-LSC | PRACA SOFTWARE | DI PETERSON | 4.0 | NONE |
| OV-225-LSC | ORBITER CREW CABIN EMERGENCY EGRESS | DI WELTY | 0.5 | NONE |
| OV-231-LSC | LPS ORIENTATION | WOLLETT | 4.0 | NONE |
| OV-232-LSC | GOAL PROGRAMMING | WOLLETT | 9.0 | NONE |
| OV-242-LSC | RMS GENERAL FAMILIARZIATION | DI CLAMP | 2.0 | NONE |
| OV-243-LSC | ON SITE PORT PURGE UNIT | DI HORN | 1.0 | NONE |
| OV-246-LSK | TEST CONDUCTOR QUALIFICATION AND FIRING RO | RUDOLPH | 3.0 | NONE |
| OV-250-LSC | ORBITER VEHICLE STRUCTURES FAM | LUECKE | 2.0 | NONE |
| OV-251-LSC | SSME FAMILIARIZATION | LUECKE | 3.0 | NONE |
| OV-252-LSC | OMS/RCS FAM | BELL | 3.0 | NONE |
| OV-255-LSC | ORBITER APU SYSTEM FAM | HINCKLEY | 2.5 | NONE |
| OV-256-LSC | ORBITER HYDRAULIC SYSTEMS FAM | HINCKLEY | 2.5 | NONE |
| OV-257-LSC | ECLSS FAMILIARIZATION | BELL | 3.0 | NONE |
| OV-258-LSC | FUEL CELL FAMILIARIZATION | LUECKE | 3.5 | NONE |
| OV-259-LSC | OBRITER ELECT PWR DIST & CONTROL | RICHARDSON | 3.0 | NONE |
| OV-260-LSC | DISPLAYS & CONTROLS FAM | HODGES | 3.0 | NONE |
| OV-261-LSC | CAUTION & WARNING SYSTEM FAM | RICHARDSON | 3.0 | NONE |
| OV-262-LSC | ORBITER DATA PROCESSING SYS FAM | HODGES | 3.0 | NONE |
| OV-264-LSC | COMMUNICATION & TRACKING SYSTEM | LOOSE | 3.0 | NONE |
| OV-268-LSC | COMM & TRACKING GROUND SUPPORT EQUIPMENT | LOOSE | 6.0 | NONE |
| OV-281-LSK | FLIGHT CREW EMERGENCY EGRESS (AIDED)/RESCU | LUECKE | 2.0 | NONE |
| OV-282-LSK | FLIGHT CREW EMERGENCY EGRESS (AIDED) AT PA | LUECKE | 2.0 | NONE |
| OV-289-LSC | CREW MODULE ACCESS (VIDEO) | VIDEO | 0.5 | NONE |
| OV-300-LSC | ORBITER VEHICLE STRUCTURES | LUECKE | 2.0 | NONE |
| OV-301-LSC | SSME | LUECKE | 6.0 | NONE |
| OV-302-LSC | OMS/RCS | LUECKE | 6.0 | NONE |
| OV-305-LSC | ORBITER APU SYSTEM | BELL | 2.0 | NONE |
| OV-306-LSC | ORBITER HYDRAULIC SYSTEMS | LUECKE | 3.0 | NONE |
| OV-307-LSC | ECLSS | LUECKE | 3.0 | NONE |
| OV-308-LSC | FUEL CELLS | LUECKE | 20.0 | NONE |
| OV-309-LSC | ORBITER EP&D CONTROL SYSTEM | RICHARDSON | 4.0 | NONE |
| OV-30A-LSC | ORBITER EPD & C FLT. SUPPORT SYS. | RICHARDSON | 4.0 | NONE |
| OV-310-LSC | DISPLAYS & CONTROLS | DI ANDERSON | 3.0 | NONE |
| OV-313-LSC | INSTRUMENTATION SYSTEM | RICHARDSON | 8.0 | NONE |
| OV-318-LSC | PURGE VENT & DRAIN SYSTEM | BELL | 2.0 | NONE |
| OV-324-LSC | WIND TRUCK OPERATION | DI BAKER | 2.0 | NONE |
| OV-328-LSC | CONTINGENCY SITES GROUND HANDLING | VIDEO | 0.5 | NONE |
| OV-331-LSC | LPS FAMILIARIZATION | WOLLETT | 12.0 | NONE |
| OV-332-LSC | GOAL PROGRAMMING | WOLLETT | 40.0 | NONE |
| OV-350-LSC | ORBITER LIFT SYSTEM | REMNET | 1.0 | NONE |
| OV-3AE-LSC | CONTROLLERS DETAIL | CLARK | 3.0 | NONE |
| OV-3BA-LSC | AEROSURFACE ACTUATORS SYSTEM | LOOSE | 4.0 | NONE |
| OV-3BB-LSC | ASCENT THRUST VECTOR CONTROL SYSTEM | LOOSE | 4.0 | NONE |
| OV-3BC-LSC | HYDRAULIC SUPPORT SYSTEM | HODGES | 4.0 | NONE |
| OV-3BD-LSC | OMS/RCS FLIGHT CONTROL SYSTEM | LOOSE | 4.0 | NONE |
| OV-3BE-LSC | BRAKES/ANTISKID/NOSE WHEEL STEERING | LOOSE | 4.0 | NONE |
| OV-3CA-LSC | C-11 AUTOMATION SOFTWARE FAMILIARIZATION | DI KELLY | 10.0 | NONE |
| OV-3DA-LSC | S-BAND COMMUNICATION SYSTEM | WOLLETT | 4.5 | NONE |

## TABLE OPS-3 JOHN F. KENNEDY SPACE CENTER

## TRAINING MASTER COURSE LIST (CONT.)

File: MASTER.COURSE
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| NUMBER | TITLE | INSTRUCTOR | C-LEN | R- |
|---|---|---|---|---|
| QG-313-KSC | CPR & ELECT SHOCK FIRST AID REFRESHER | EGG | 2.0 | 2 |
| QG-315-KSC | REDCREW CPR(4)FIRST AID(4) | EGG | 8.0 | 8 |
| QG-316-KSC | REDCREW P/S EMERGENCY EGRESS | EGG | 2.0 | 2 |
| QG-330-KSC-REV 0888 | EMERGENCY EGRESS (SLIDEWIRE) | VIDEO | 0.5 | 0 |
| QG-342-KSC | BREATHING APPARATUS FOR C/S | ROWE | 2.0 | 2 |
| QG-501-KSC | ALL MODES PHE SCAPE OPERATIONS | SCOBBY | 4.0 | 4 |
| QG-505-KSC | SPIDER OPERATOR | STOKES | 4.0 | 2. |
| QG-511-LSC | ATMOSPHERIC TEST EQUIPMENT / MANHOLE | RICHARDSON | 2.0 | 1. |
| QG-512-LSC | HYDROGEN GAS LEAK DETECTION | RICHARDSON | 1.0 | 1. |
| QG-555-KSC | HIGH CREW TRAINING | DI CORBETT | 30.0 | NON |
| QG-570-KSC | MINOR HYDRAZINE SPILL & CLEAN-UP | SCOBBY | 1.5 | NON |
| QS-201-LSC | DV QUALITY DESIGNEE | HODGES | 2.5 | NON |
| QS-204-LSK | MANAGEMENT OF HAZARDOUS/TOXIC WASTE | VIDEO | 2.0 | 2. |
| QS-205-LSK | HOW CLEAN IS CLEAN ENOUGH | VIDEO | 1.0 | NON |
| QS-22A-LSK | CREW EMERGENCY EGRESS (PART A) | LUECKE | 2.0 | 2. |
| QS-22B-LSK | CREW EMERGENCY EGRESS (PART B) | LUECKE | 2.0 | 2. |
| QS-300-LSK | MAKING CLOSEOUT PHOTOS | HINCKLEY | 40.0 | 2. |
| QS-502-LSC | PENETRANT INSPECTION | DI JENSEN | 20.0 | NON |
| QS-504-LSC | AIR PURIFYING RESPIRATOR | BLALOCK | 1.0 | 1. |
| QS-54A-LSK | MSC AIR PURIFYING RESPIRATOR (LOGISTICS PE | BLALOCK | 1.0 | NON |
| QT-202-LSC | TPS AREA SAFETY | SCHUTTE | 4.0 | NON |
| QT-514-LSC | CRYOGENIC SEALS/TORQUE WRENCHES | KNIGHT | 3.0 | 3. |
| QT-517-LSC | ET FLIGHT SPLICES | SCHUTTE | 8.0 | 4.0 |
| QT-518-LSC | ET CONTAMINATION CONTROL | CLARK | 1.5 | NONE |
| QT-547-LSC | ELECTRO STATIC DISCHARGE | VIDEO | 1.0 | NONE |
| QT-548-LSC | ADHESIVE BOND ET WIRING | SCHUTTE | 4.0 | 2.0 |
| QV-201-LSC | ORB A/F INSPECTION TECHNIQUES | DI GEIMEYER | 1.0 | NONE |
| QV-251-LSC | NASA RSI MIPS | ALLBRIGHT | 8.0 | 4.0 |
| QV-550-LSC | INDUCT BRAZE & ASTRO ARC TUBE WELDING INSP | DI JENSEN | 2.0 | NONE |
| QV-551-LSC | PRE & POST FLIGHT ORBITER TILE | ALLBRIGHT | 6.0 | 4.0 |
| QV-556-LSC | OPTICAL TOOLING INSPECTOR | DI STORM | 64.0 | NONE |
| QV-559-LSC | ORBITER WINDOW POLISH/INSPECTION | DI JENSEN | 8.0 | 4.0 |
| QV-560-LSC | VISCOSITY TESTING OF RTV COMPOUND | DI | 2.0 | NONE |
| QV-578-LSK | INDUST HYGIENE & HAZ GAS DET | DI KRATT | 7.0 | 7.0 |
| QV-585-LSK | SPACE CRAFT SAFETY ENTRY CHECKS | DI KRATT | 1.0 | NONE |
| QW-28B-KSC | HMF WALKDOWN | HINCKLEY | 1.0 | NONE |
| QW-28E-KSC | LETF WALKDOWN | RICHARDSON | 1.0 | 1.0 |
| SG-200-LSC | PROPERTY CUSTODIAN TRAINING | RICHARDSON | 3.0 | 3.0 |
| SG-202-LSK | LOGISTICS FLIGHT HARDWARE HANDLER | LYONS | 1.0 | NONE |
| SG-203-LSK | LOGISTICS ORIENTATION | VIDEO | 0.5 | NONE |
| SG-205-LSC | KIMS ORIENTATION FOR MANAGERS | - | 12.0 | NONE |
| SG-301-LSC | KIMS CATALOG | - | 12.0 | NONE |
| SG-303-LSC | KIMS GENERAL INQUIRY | - | 12.0 | NONE |
| SG-304-LSC | KIMS COMMODITY MANAGER | - | 12.0 | NONE |
| SG-305-LSC | KIMS RECEIVING (QA) | - | 12.0 | NONE |
| SG-306-LSC | KIMS MSC/LOC/CT/PHY.INV. | - | 12.0 | NONE |
| TG-340-KSC | CRANE OPERATOR SAFETY TRAINING | SCOBBY | 2.0 | 2.0 |
| XG-155-KSC | HEARING CONSERVATION | ROWE | 1.5 | NONE |
| XG-219-KSC | CLEAN ROOM ENTRY | CLARK | 3.0 | NONE |

## TABLE OPS-4

## OPERATIONS AND MAINTENANCE INSTRUCTION
## SPACE SHUTTLE MAIN ENGINE PROCESSING

| OMI NO. | OMI DESCRIPTION |
|---|---|
| V6033 | SSME REC. INSP |
| V5087 | GSE OPS (RTOMI) |
| V3553 | LRU GSE (RTOMI) |
| V5005 | SSME INSTALL HORZ. |
| V5057 | GSE R&R (RTOMI) |
| V5058 | SSME REMOVAL - HORZ. |
| V1011.01 | DRYING |
| V1011.02 | INT/EXT INSP. |
| V1011.03 | TORQUE CHECKS |
| V1011.04 | HEX CHECKS |
| V1011.05 | LEAK CHECKS |
| V1011.06 | FUNCTIONAL CHECKS |
| V1011.07 | 10 START REQUIREMENTS |
| V5E01 | MFV R&R |
| V5E02 | HPOTP R&R |
| V5E03 | CONTROLLER R&R |
| V5E04 | POGO R&R |
| V5E05 | PCA R&R |
| V5E06 | HPFTP R&R |
| V5E17 | OPOV R&R |
| V5E18 | FPOV R&R |
| V5E19 | CCV R&R |
| V5E22 | MOV R&R |
| V5E23 | LPOTP R&R |
| V5E24 | LPFTP R&R |
| V5E26 | TCV ACTUATOR R&R |
| V5E28 | NOZELE R&R |
| V5E29 | GIMB BOLT R&R |
| V5E32 | FBV R&R |
| V5E34 | OBV R&R |
| V5E35 | GCV R&R |
| V1245 | ENG. SHOP LEAK TEST |
| V1246 | KSC FERRY |

## TABLE OPS-4

## OPERATIONS AND MAINTENANCE INSTRUCTION SPACE SHUTTLE MAIN ENGINE PROCESSING (CONT.)

| OMI NO. | OMI DESCRIPTION |
|---|---|
| V1201 | HE SIG. TEST (OPF) |
| V1202 | HE SIG. TEST (VERTICAL) |
| V5062 | SSME VERT. INSTALL |
| V5063 | SSME VERT. REMOVAL |
| V1046 | VERT. INSP/LEAK CKS. |
| V1038 | LANDING OPS |
| V1149 | T.O. LEAK CHECKS |
| V9018 | PROP LOAD (WALKDOWN) |
| V1105 | SSME ALIGNMENT |
| V3569 | MEMORY LOADER |
| V1170 | ENG. HARNESS ELECT. C/O |
| V9001 | ELECT. (RTOMI) |
| V9002 | HYD (RTOMI) |
| S0007 | COUNTDOWN |
| S0008 | INT. TEST |
| S0014 | FRT. |
| S0017 | TCDT |

## ENGINE PROCESSING GROUND SUPPORT EQUIPMENT

The Ground Support Equipment (GSE), realized at this time to support the liquid rocket booster engine operations has been arbitrarily grouped into three (3) operational categories. These operational categories would include a) Engine Handling b) Checkout/Servicing and, c) Facility Support.

The Engine Handling category would include all engine, and engine component, movement and support. Such activities as receiving & shipping an engine, engine preparation for vehicle installation and removal, and component handling/installation/removal would be included in this category.

Engine Checkout and Servicing would include such items as engine protection, inspection, all mechanical/fluid/electrical checkouts, and the servicing and "closeout" requirements for launch.

Facility Support denotes the "Facilities" type GSE required to insure the performance of the first two operational categories mentioned above.

Since the LRB and its propulsion system, remains in a conceptual design stage, detailed definition of all of the GSE was virtually impossible at this writing. However, by utilizing the basic concept presented by the vehicle, propulsion, and launch site integrated contractors, the general operational characteristics and configuration can be defined for the major GSE required to support the processing of the LRB Engines. The projected size and weight of the engine, and the intended complete processing of the system in both the horizontal and vertical positions using the same basic non-integrated and integrated configuration and equipment as the STS, drives the LRB engine processing similarity to the processing characteristics of the Space Shuttle Main Engine. It is from this baseline that the following list of major GSE was derived. Included in the "Item" lists, when applicable, will be the present SSME GSE program model number as a comparison to the general configuration envisioned for the operation. It should be noted that an attempt has been made to attach some rough-order-of-magnitude (ROM) cost value to the GSE. However, these values should be considered as very preliminary in that the detailed definition of the required LRB engine processing GSE does not exist at this time.

These cost figures are submitted as basic ROM's for planning purposes only and do not constitute a firm commitment on behalf of the contractor.

Charts GSE-1 through GSE-3 depict this tabulation of major ground support equipment envisioned to be needed for LRB engine processing.

Also, included with this report is a very detailed compilation of all of the ground support equipment required in the processing of the Space Shuttle Main Engine. This "Data Package" was the work of both Rocketdyne and the Lockheed Space Operations Company and represents an evaluation of that ground support equipment and the importance it commands as a part of engine processing. While some of the items included in the document are basically unique to SSME, and not necessarily applicable to LRB engine processing, they have been retained in the document. Future redefinition of LRB engine requirements may dictate the use of a like or similar item. It should be noted that this "Data Package" is of a 1986 vintage and many of the recommendations for corrections in both paper and hardware have been accomplished or are in the process of such.

One of the most important "lessons learned" issues concerning engine processing GSE is to not allow the program to be maneuvered into such a position where the "loss" of a single piece of GSE can bring the processing operations to a halt. For example, such "single-point-failure" items to the program might well be engine installers, or a "hyster" vehicle, or dedicated critical lift hardware, or lifting/rotating slings. In the STS Program, the loss, either totally or for major repairs, equipment such as the "hyster" or horizontal installer, will bring engine processing operations requiring this type of equipment to a halt for a minimum of two (2) weeks for repairs, to literally months for total replacement of this one-of-a-kind hardware. These type of single-point-failures could be eliminated by up-front considerations for providing duplicates of these very few sensitive items. Another approach might be to evaluate "shared-use-commonality-designs" for these sensitive items such that both the LRB engine GSE and the existing SSME GSE might be available to support all of the critical operations of the entire STS engine processing operations.

ENGINE PROCESS GROUND SUPPORT EQUIPMENT (CONT.)

At this point in time, this study would identify the following very sensitive pieces of engine processing GSE as potential candidates as program processing "single-point-failure" items:

- Engine Installation Equipment - Horizontal
- Engine Installation Equipment - Vertical
- Dedicated Engine Lifting/Rotating Slings
- MLP LRB Engine Access Platforms/Equipment
- Engine Critical Lift Items (Dedicated Design Items)

Ground support equipment has to be one of the "Achilles Heel" in the processing of flight hardware. Cost and operationally effective planning by the launch operations community will dictate/insure that a close coordination between vehicle design and the launch center(s) begins at the very onset of the program to insure that the "GSE-Is-Right" for the processing job at the very first opportunity for use.

FIG. GSE-1

## LIQUID ROCKET BOOSTER
## ENGINE PROCESSING GROUND SUPPORT EQUIPMENT

### ENGINE HANDLING

| ITEM | SIMILAR CURRENT UNIT | DESCRIPTION | COST ROM '88 |
|---|---|---|---|
| HYSTER LIFT TRUCK | H70 - 0764 | USE TO INSTALL AND/OR REMOVE AN ENGINE WITH THE VEHICLE IN THE HORIZONTAL POSITION | $ 900,000 |
| ENGINE HORIZONTAL INSTALLER | H70 - 0568 | USE WITH LIFT TRUCK TO INSTALL AND/OR REMOVE AN ENGINE WITH THE VEHICLE IN THE HORIZONTAL POSITION | $ 665,000 |
| ENGINE HANDLER | H70 - 0901 | USE TO SHIP AND STORE ENGINE. USE WHEN MINOR MAINTENANCE IS REQUIRED AND ENGINE IS IN HORIZONTAL CONFIGURATION. | $ 460,000 |
| ENGINE HANDLER SLING | H70-0902 | USE TO LOAD/UNLOAD ENGINE HANDLER/ENGINE | $ 16,000 |
| INTERFACE SUPPORT PANEL | H70-0911 | USE ALONG WITH HEAVYWEIGHT STRUTS TO SUPPORT ENGINE ON ENGINE HANDLER AND DURING ENGINE ROTATION | $ 75,000 |
| ROTATING SLING | H70-0903 | USE TO ROTATE THE ENGINE TO THE VERTICAL POSITION, FROM THE ENGINE HANDLER | $ 400,000 |
| ENGINE VERTICAL INSTALLER | H70-0774 | USE TO INSTALL AND/OR REMOVE AN ENGINE WITH THE VEHICLE IN THE VERTICAL POSITION | $1,250,000 |
| PROOF LOAD FIXTURE SET | S70-0911 | USE TO PERFORM PROOF LOAD AND CRITICAL LIFT OPERATIONS WITH ENGINE HANDLING EQUIPMENT | $ 600,000 |
| ENGINE MOVER SET | H70-0890 | USE TO MOVE ENGINE WITHOUT THE AVAILABILITY OF THRUST VECTOR CONTROL ACTUATORS | $ 310,000 |
| ENGINE ALIGNMENT SET | A70-0645 | USE TO SET THRUST VECTOR CONTROL ACTUATOR PROPER LENGTH PRIOR TO ENGINE INSTALLATION | $ 925,000 |

FIG. GSE-1

## LIQUID ROCKET BOOSTER
## ENGINE PROCESSING GROUND SUPPORT EQUIPMENT
## (CONT.)

### ENGINE HANDLING (CONT.)

| ITEM | SIMILAR CURRENT UNIT | DESCRIPTION | COST ROM '88 |
|---|---|---|---|
| ENGINE COMPONENT HANDLER SET | H70-0905 | USE TO LIFT VARIOUS ENGINE LINE REPLACEABLE UNITS AND IN CONJUNCTION WITH COMPONENT REMOVAL SET(S) FOR LRU REPLACEMENT. | $ 630,000 |
| ENGINE LRU INSTALL/ REMOVAL SET | H70-0528 | USE TO INSTALL/REMOVE ENGINE COMPONENTS WITH THE VEHICLE IN EITHER THE HORIZONTAL OR VERTICAL POSITION. | $1,160,000 |
| ENGINE/HANDLER MOVER | NO PROGRAM NO. | USE TO MOVE ENGINE/HANDLER IN SHOP AREAS | $ 7,500 |
| ENGINE DOLLY (VERTICAL) | NO PROGRAM NO. | USE TO PROCESS ENGINE IN THE VERTICAL POSITION IN THE ENGINE SHOP | $ 25,000 |
| TVC ACTUATOR LOCKS<br>TVC ACTUATOR SUPPORT SET(S)<br>TVC ACTUATOR EXTEND/ RETRACT LOCKS | A70-0501<br>H70-0629<br>A70-0983 | USE TO POSITION AND HOLD ENGINE IN CERTAIN POSITION WHEN MATED WITH VEHICLE | $ 250,000 |

FIG. GSE-2

## LIQUID ROCKET BOOSTER
## ENGINE PROCESSING GROUND SUPPORT EQUIPMENT

### SERVICE/CHECKOUT

| ITEM | SIMILAR CURRENT UNIT | DESCRIPTION | COST ROM'88 |
|---|---|---|---|
| ENVIRONMENTAL PROTECTION SET | S70-0902 | USE TO SEAL ENGINE OPENINGS FOR ENVIRONMENTAL CONTROL | $ 2,500 |
| INTERNAL INSPECTION EQUIPMENT | C70-0907 | USE TO INSPECT INTERNAL CONDITION OF ENGINE COMPONENTS | $ 200,000 |
| TEST ADAPTER SET | C70-0914 | USED TO CONDUCT SCHEDULED ENGINE LEAK AND FUNCTIONAL CHECKOUT | $ 75,000 |
| FLOW TESTER | C70-0903<br>C70-0904<br>C70-0908 | USE TO MEASURE VARIOUS ENGINE COMPONENT FLOWS/LEAKAGES AS PART OF FUNCTIONAL CHECKOUT | $150,000 |
| REGULATOR PANEL(S) | C70-0743-X | USE AS PORTABLE REGULATOR PANEL FOR FUNCTIONAL CHECKOUT | $ 32,000 |
| ENGINE FLUSH & DRYING UNIT CHAMBER SERVICING | NO PROGRAM NO. | USE TO FLUSH / DRY ENGINE AND BACKFILL CHAMBER AS REQUIRED FOR LAUNCH | $500,000 |
| THERMAL PROTECTION SYSTEM WELDER | NO PROGRAM NO. | USE TO SPOT WELD THERMAL PROTECTION SYSTEM BLANKETS TO ENGINE | $ 75,000 |
| ENGINE COMMAND AND DATA SIMULATOR | NO PROGRAM NO. | USE TO SIMULATE FLIGHT PROFILE FOR SINGLE ENGINE FUNCTIONAL CHECKOUT | $400,000 |

FIG. GSE-3 LIQUID ROCKET BOOSTER
ENGINE PROCESSING GROUND SUPPORT EQUIPMENT

## FACILITY SUPPORT

| ITEM | SIMILAR CURRENT UNIT | DESCRIPTION | COST ROM'88 |
|---|---|---|---|
| LRB ENGINE ACCESS PLATFORM (VEHICLE IN VERTICAL). SIMILAR IN FUNCTIONAL CHARACTERISTICS AS SSME MLP PLATFORMS | A70-0663<br>A70-1265 | USE TO REMOVE/INSTALL ENGINE AND SERVICE ENGINES WITH THE VEHICLE IN THE VERTICAL POSITION | $ TBD |
| LRB ENGINE ACCESS PLATFORM (VEHICLE IN HORIZONTAL). SIMILAR IN FUNCTIONAL CHARACTERISTICS AS THE OPF AFT SWING PLATFORMS. | NO PROGRAM NO. | USE TO SUPPORT ENGINE SERVICING FUNCTIONS WHEN THE ENGINE IS INSTALLED ON THE VEHICLE IN THE HORIZONTAL POSITION | $ TBD |
| LRB ENGINE ACCESS PLATFORMS (VEHICLE IN VERTICAL POSITION IN THE ENGINE SHOP) | NO PROGRAM NO. | USE TO SERVICE ENGINES IN THE SHOP | $150,000 |
| MANLIFT FOR ENGINE CHAMBER ENTRY | NO PROGRAM NO. | USE TO GAIN ACCESS TO ENGINE COMBUSTION CHAMBER WHEN ENGINE IS IN VERTICAL POSITION | $ 75,000 |
| PRIMARY GASEOUS HELIUM REGULATOR PANEL<br>PRIMARY GASEOUS NITROGEN REGULATOR PANEL | S70-0695-1 & 2 | USE FOR SUPPLY OF GAS TO ENGINE AND ENGINE CHECKOUT REGULATOR PANEL(S) | $1,500,000 |
| MASS SPECTROMETER STATION (FIXED & HARDLINED) | NO PROGRAM NO. | USE FOR HIGH RESOLUTION LEAK DETECTION REQUIREMENTS | $200,000 |

## ENGINE PROCESSING FACILITIES

The facility requirements to support the engine related processing activities of the LRB should be confined basically to the LRB Horizontal Processing Facility, LRB Integrated Processing Area, and, the Launch Pad.

Figures FAC-1 through FAC-4 indicate the various areas where engine related work will be performed and/or where "operations staging" will occur. The major level of effort for engine hardware processing should be in the Liquid Rocket Booster Horizontal Processing Facility, both in the engine shop and in the LRB processing area. The suggested space in the Vehicle Assembly Building and at the launch pad would be used for operations staging and not for any type of hardware processing.

One of the "lessons learned" is to up-front identify the need for a properly designed and equipped engine processing shop. Space Shuttle Main Engine operations have indicated that the most cost effective, safe, and reliable method of processing the engine, when major maintenance is required, is to perform the work off-line in an engine shop. By having a properly equipped engine shop, all maintenance operations can be accomplished followed by a complete engine checkout and verification of functional integrity such that the engine is a "flight ready" component when it arrives at the vehicle.

Figures FAC-5 through FAC-9 are photographs of an existing Engine Processing Facility at Rocketdyne in Canoga Park, California. It is in this facility that the Space Shuttle Main Engine undergoes initial build-up as well as complete overhaul operations. The facility has been designed for safe, reliable and cost effective operations and therefore, was used as a baseline for a suggested engine shop layout in the Liquid Rocket Booster Horizontal Processing Facility (See Figure FAC-2).

Figure FAC-5 is a view looking from the processing area through the overhead doorway into the receiving area. This receiving area, or preparation area (referred to in FAC-2), would be utilized to conduct the initial operations of flight hardware receipt, de-packaging, and initial inspection. From this area the hardware would either be moved to a bonded storage area (in the case of a component) or into the engine processing area.

Figure FAC-6 shows the engine has been rotated to the vertical, placed on the "roll-around dolly" and moved into one of the vertical processing stations in the fixed access platforms.

Figure FAC-7 shows how the removable platform center section is handled. Figure FAC-8 then shows how the platforms completely surround the engine and thus offers the best access for engine maintenance. Work stations have been located at each engine processing position. Figure FAC-9 shows the mobile test console that can be moved from station-to-station for engine testing/checkout requirements.

The following is a compilation of requirements for each of the designated areas.

- LRB HORIZONAL PROCESSING FACILITY

This area will be the nucleus for the engine related processing operations. This facility should provide for the receipt, storage, installation/removal, modification, checkout, and maintenance of the engines, and, any related operations associated with the ground support equipment needed for engine processing. Using these baselines, a general description of the facility can be developed to support all phases of engine processing as defined by the conceptual design of the LRB Propulsion System.

- LRB ENGINE PROCESSING AREA
  - Dust Controlled Environment - Standard Commercial Filtration
  - "Positive Pressure" Area
  - Temperature, 72°+/-10°F
  - Relative Humidity, 60% Max.
  - Lighting, 85-90 Ft. Candles White Light
  - Non-Debris Generating Building Materials on Area Interior Surface
  - Light Color Scheme For Interior Surfaces
  - 45 Foot Min. Ceiling Height
  - Non-Static Electricity Generating Floor
  - High-Impact Resistance Sealed Foor

## ENGINE PROCESSING FACILITIES (CONT.)

## ENGINE PROCESSING AREA (CONT.)

- COMMODITIES
  - 3000 PSI Min. Gaseous Nitrogen
  - 3000 PSI Min. Gaseous Helium
  - 125 - 150 PSI Oil-Free Shop Air
  - Potable Water
  - 110 - 120 VAC Electrical
  - 220 - 240 VAC Electrical
  - 440 - 480 VAC Electrical
  - 28 VDC Electrical
- Engine "Command and Data Simulator" Area
- Equipped With Operational Intercommunication System (OIS)
- Estimate Floor Space Requirements at 10,000 Square Feet
- Safety Eyewash Station(s)
- High Volume Interior Exhaust System
- Gaseous Nitrogen/Helium Collector System
- Local Area Voice Paging System
- Telephones (TBD)
- Bonded Flight Hardware Storage Area
- Bonded MR Hardware Crib
- $O_2$(Oxygen) Monitors
- 20 Ton Overhead Crane (Full Traverse of Shop Area)
- 5 Ton Utility Overhead Crane
- Refrigerator - Temperature Sensitive Material

ENGINE PROCESSING AREA (CONT.)

- GSE STAGING/MAINTENANCE
  - Estimate Floor Space Requirements At 8000 Square Feet
  - Environmentally Conditioned Area
  - Lighting, 85-90 Foot - Candles
  - 45 Foot Min. Ceiling Height
  - Light Color Scheme For Interior Surfaces
  - High Impact Resistance Sealed Floor
  - COMMODITIES
    - 3000 PSI Min. Gaseous Nitrogen
    - 3000 PSI Min. Gaseous Helium
    - 125 - 150 PSI Oil-Free Shop Air
    - Potable Water
    - 110 - 120 VAC Electrical
    - 220 - 240 VAC Electrical
    - 440 - 480 VAC Electrical
  - Safety Eyewash/Shower Station(s)
  - Telephones (TBD)
  - Non-Hazardous Chemical Storage
- GSE STORAGE (INACTIVE - SHIPPING EQUIPMENT, ETC.)
  - Estimate Floor Space Requirements At 2000 Square Feet
  - Environmentally Protected Area
  - Lighting, "Warehouse" Grade
- LRB HORIZONTAL PROCESSING FACILITY "COMMON USE" AREAS
  (Requirements To Support LRB Engines)
  - Receiving/Shipping Area (Shared With Other Residents)
    - Enclosed "Dock Area" For Off-Loading/Loading An Engine. Standard "Flatbed" Roadable Van.
    - 45 Foot High Ceilings
    - 20 Ton Overhead Full Traversing Crane
    - Lighting, Warehouse Level

## ENGINE PROCESSING FACILITIES (CONT.)

### ENGINE PROCESSING AREA (CONT.)

- PERSONNEL SUPPORT AREA - 3 SHIFT COVERAGE
  - Estimate Floor Space Requirements at 3500 Square Feet
  - Shop Managers - 7 Offices (Enclosed Area)
  - Administration - 5 Work Stations
  - Shop Engineers - 20 Work Stations
  - Quality Engineers - 4 Work Stations
  - Logistics Personnel - 2 Work Stations
  - Scheduler - 1 Work Station
  - Clerical - 4 Work Station
  - Configuration Management - 1 Work Station
- DATA CENTER
  - Processing Documents
  - Maintenance Manuals
  - Blueprint/Specification Micro-Fische Reader/Copier
  - 6 Computer Stations and Printers
  - 3 Word Processor Stations and Printer
  - 1 Letter Copier
  - 1 Rapi-Fax Machine
  - Environmentally Controlled Area
  - Lighting, 85 - 90 Foot Candles
  - Telephones (TBD)
- SPECIAL AREA REQUIREMENTS
  - Chemical Storage
    - Freon TF
    - Alcohol
    - Leak Detection Fluid
- Pyrotechnic Storage (Potential Hazard)
  - Initiators
  - Squibs
  - Propellant Cartridges
  - Area - TBD
- Chemical Ignition System Cylinder Storage (Potential Hazard)
  - Area - TBD

- LRB INTEGRATED PROCESSING AREA (PRESENT VAB HIGH BAYS)
  - Estimate Floor Space Requirements Equivalent To One (1) VAB High Bay Tower Floor, Environmentally Conditioned. (Preferably the ground level floor area.)
  - Personnel Support
    - Shop Managers - 3 Work Stations
    - Shop Technicians - Staging Area - 20 Personnel
    - Processing Engineers - 6 Engineers
  - Bonded Test and Inspection Records Station
  - Bonded Hardware Staging Area - Mainly Thermal Protection System Items
  - Portable GSE Area
  - "Roll-Away" Tool Chest Area
  - Computer Station/Printer - 2 Stations
  - OIS Stations with Speaker Monitors
  - Commodities
    - 110 - 120 VAC Electrical
    - 220 - 240 VAC Electrical
    - 125 - 150 PSI Oil-Free Shop Air
  - Telephones (TBD)

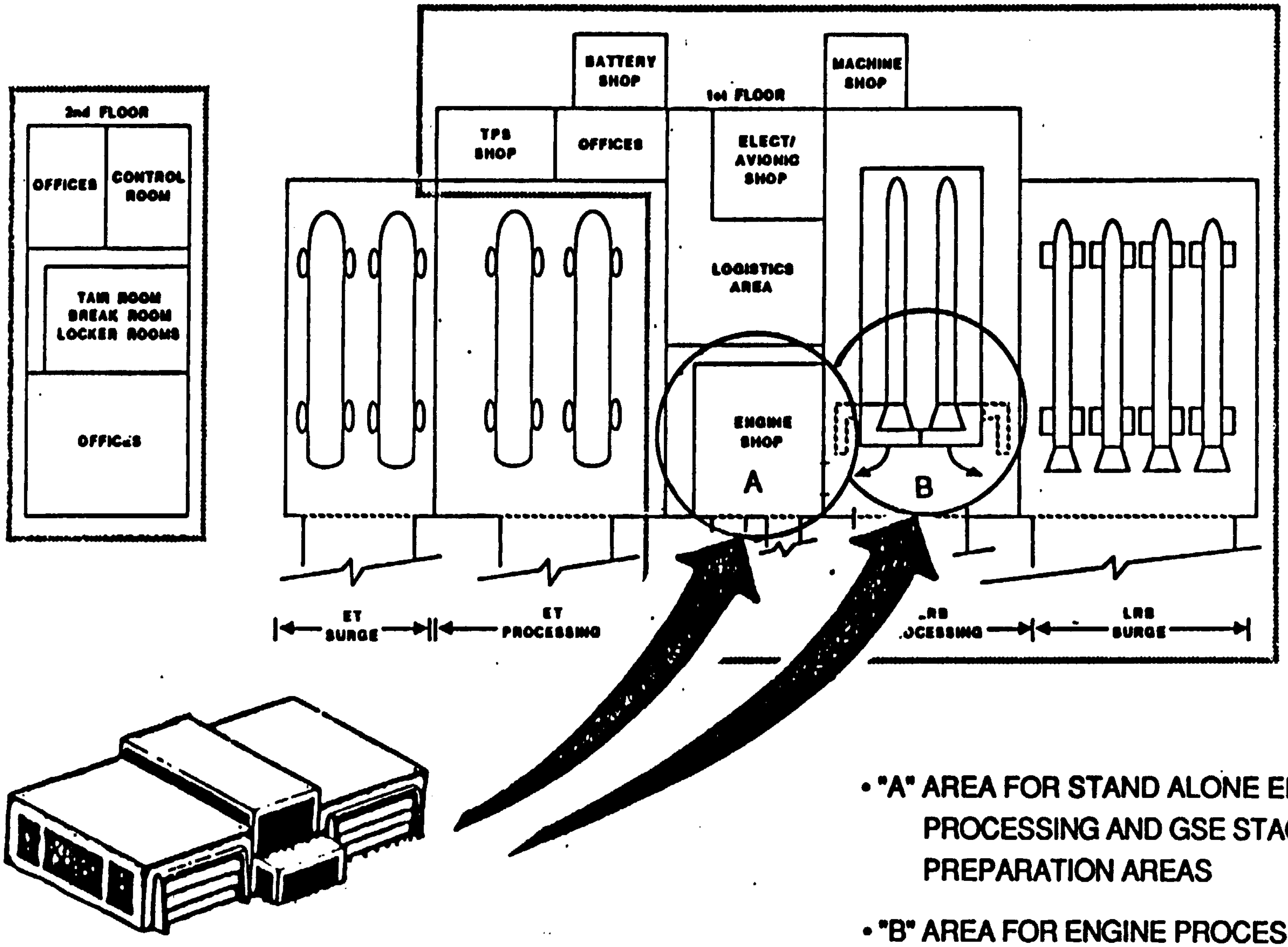
- LAUNCH PAD SUPPORT AREA
  - Estimate Floor Space Requirements Equivalent To Two (2) Existing "Boxcars"
  - (1) Boxcar - Secured Area
    - Flight Hardware Staging
    - Portable GSE Staging
    - Specialized Tool Storage
    - Computer Terminal/Printer
  - (1) Boxcar - Partially Secured Area
    - Personnel Support Functions
  - OIS Stations With Speaker Monitors
  - Telephones - 2 Lines (1-Class A, 1-Class B)
  - Environmentally Controlled Area
  - Lighting, "Office" Level
  - Bonded Test and Inspection Record Cabinets

## ENGINE PROCESSING FACILITIES (CONT.)

A properly sized and equipped engine processing shop will be most important in the pursuit of cost effective launch operations for the LRB engines. It is well documented and recognized that the failure to have proper facilities at the launch site to conduct any type of engine maintenance, whether it be minor or major in nature, will greatly impact success oriented operations planning. "Lessons learned" from the present program can be considered when SSME's have to be shipped either to Canoga Park or to the Stennis Space Center to facilities that are properly sized and equipped for the performance of major maintenance. This in the past has required the temporary relocation of personnel from KSC to assist in the engine refurbishment. This type of an option is not cost effective at all.

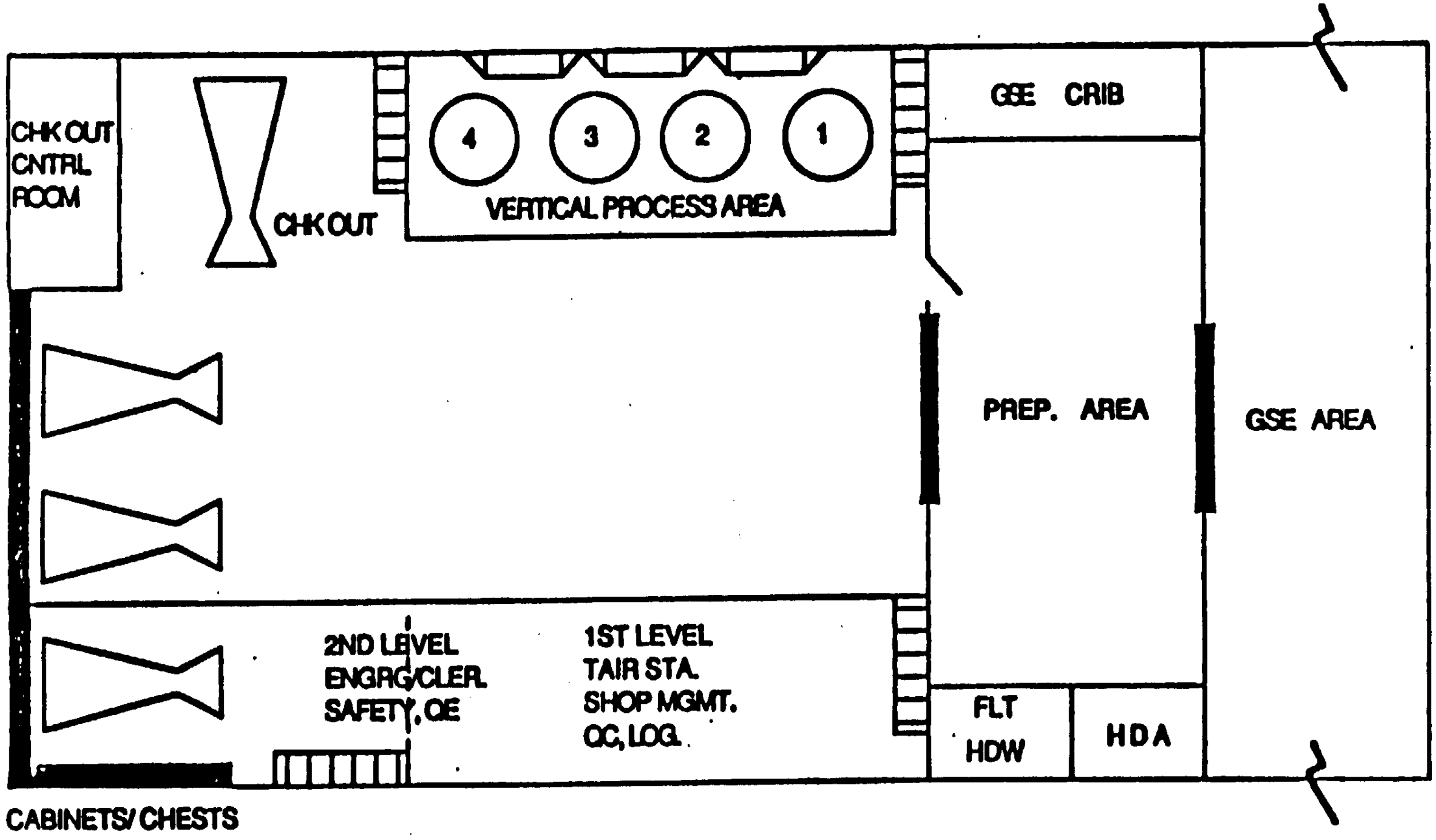
Certainly, during the design phase of the LRB Horizontal Processing Facility, the architects would be advised to seek the assistance of all of the major engine suppliers to insure that the engine processing facility is "right". Not just conferences, but actual visits to the engine supplier facilities, and observing representative processing operations would benefit the faciliity designers in coming up with the proper configuration.

FIG. <u>FAC-1</u> ENGINE PROCESSING FACILITIES
LRB HORIZONTAL PROCESSING FACILITY



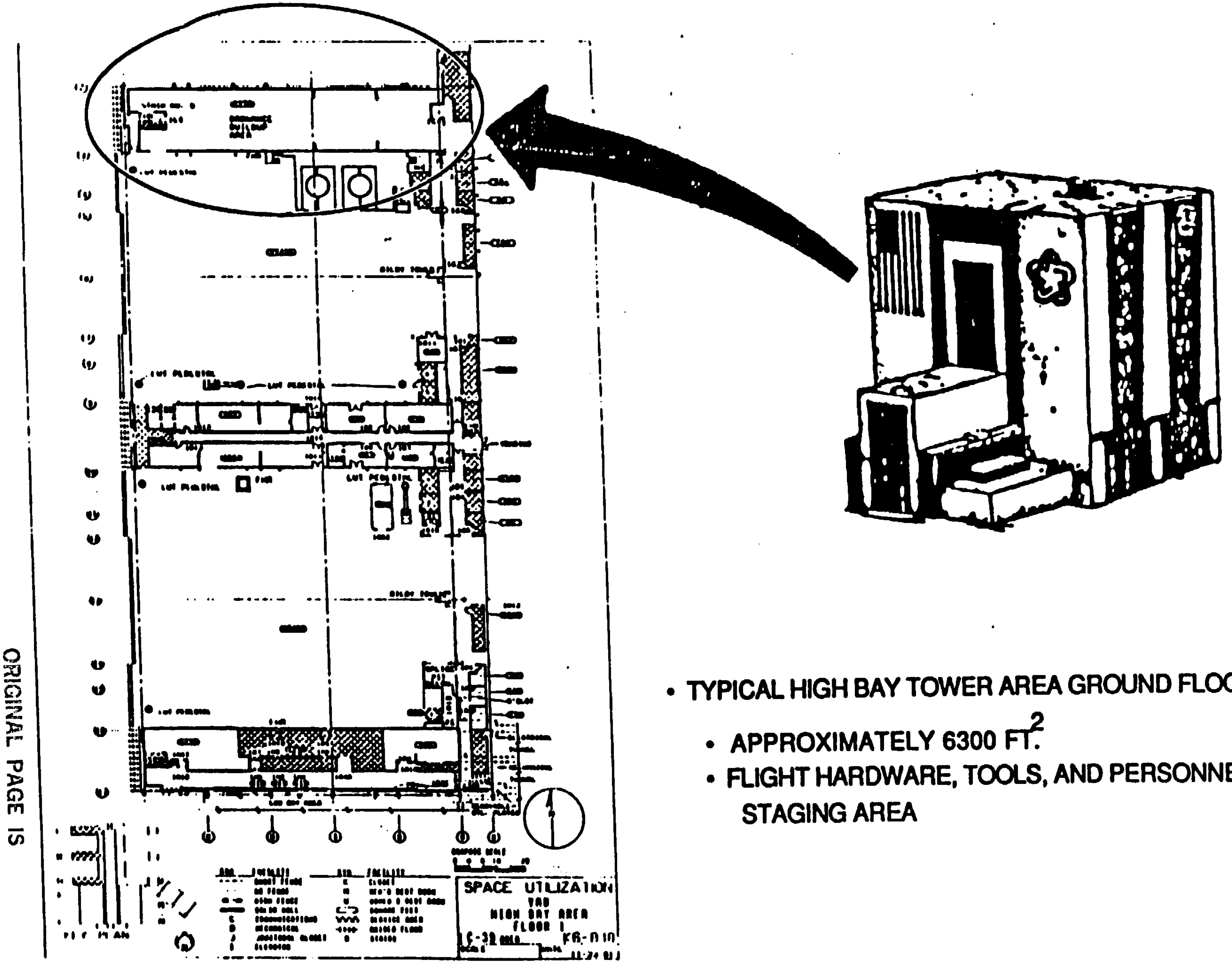
- "A" AREA FOR STAND ALONE ENGINE PROCESSING AND GSE STAGING/ PREPARATION AREAS
- "B" AREA FOR ENGINE PROCESSING WITH LRB VEHICLE IN HORIZONTAL CONFIGURATION

FIG. FAC-2 ENGINE PROCESSING FACILITIES
LRB HORIZONTAL PROCESSING FACILITY
ENGINE SHOP



- TYPICAL LAYOUT FOR STANDALONE ENGINE PROCESSING
  - ALL OPERATIONS, ENGINE AND GROUND SUPPORT EQUIPMENT CONSOLIDATED FOR FLOW ENHANCEMENT
  - PERSONNEL CENTRALIZED AT "WORK AREAS"

FIG. EAC-3 ENGINE PROCESSING FACILITIES
INTEGRATED VEHICLE AREA



- TYPICAL HIGH BAY TOWER AREA GROUND FLOOR LEVEL
  - APPROXIMATELY 6300 $FT.^2$
  - FLIGHT HARDWARE, TOOLS, AND PERSONNEL STAGING AREA

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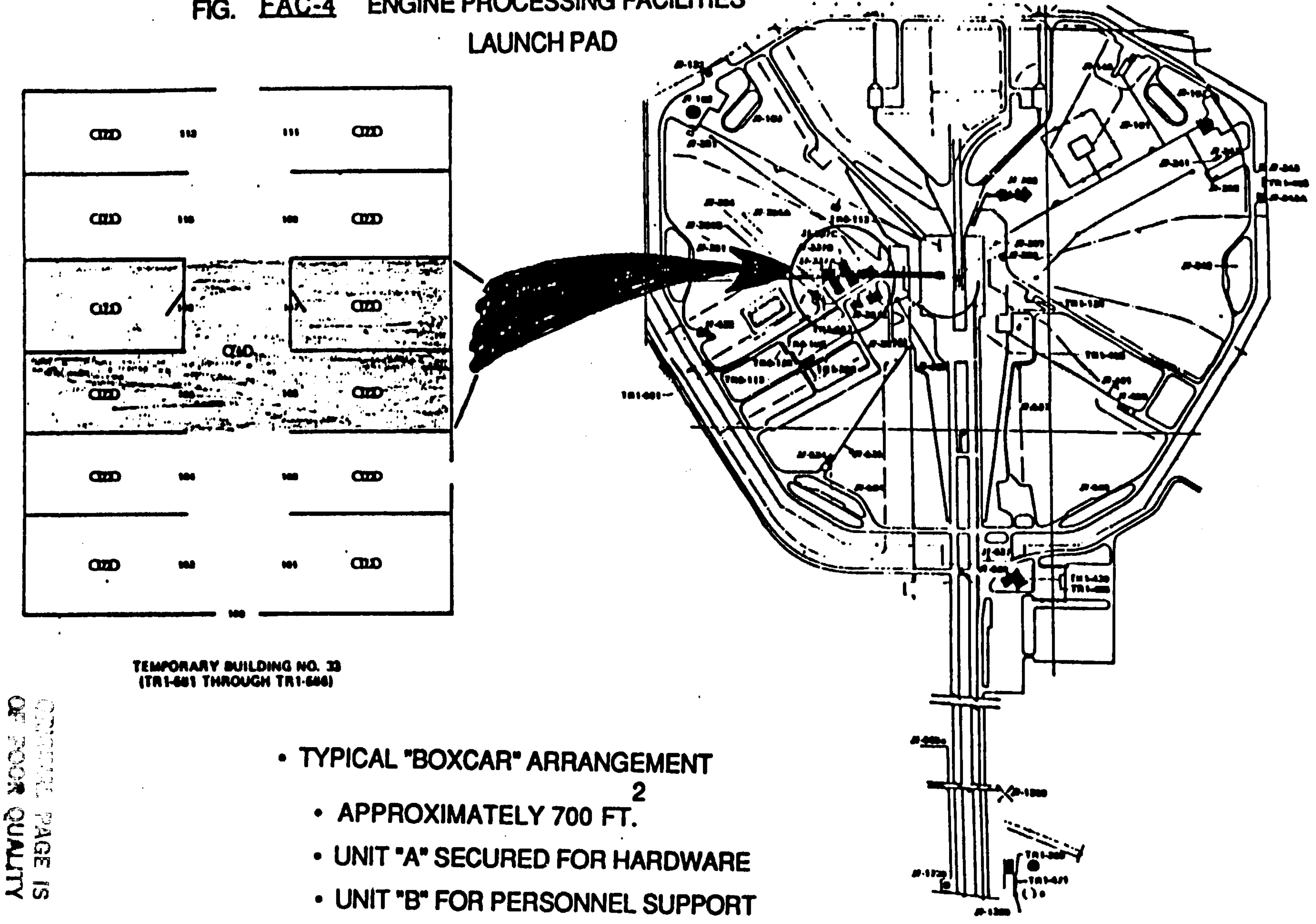
FIG. EAC-4 ENGINE PROCESSING FACILITIES
LAUNCH PAD



- TYPICAL "BOXCAR" ARRANGEMENT
  - APPROXIMATELY 700 FT.$^2$
  - UNIT "A" SECURED FOR HARDWARE
  - UNIT "B" FOR PERSONNEL SUPPORT

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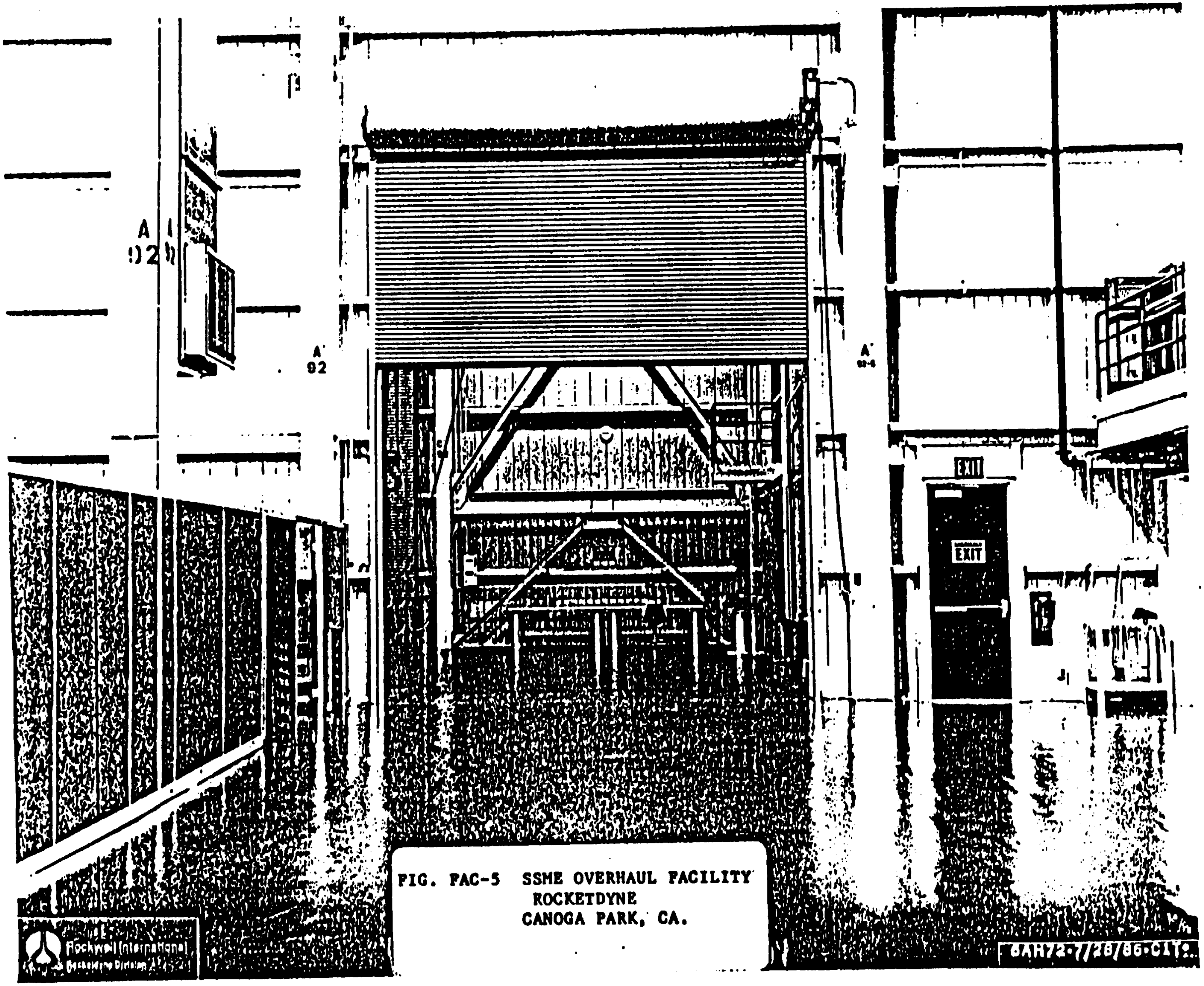

FIG. FAC-5 SSME OVERHAUL FACILITY
ROCKETDYNE
CANOGA PARK, CA.

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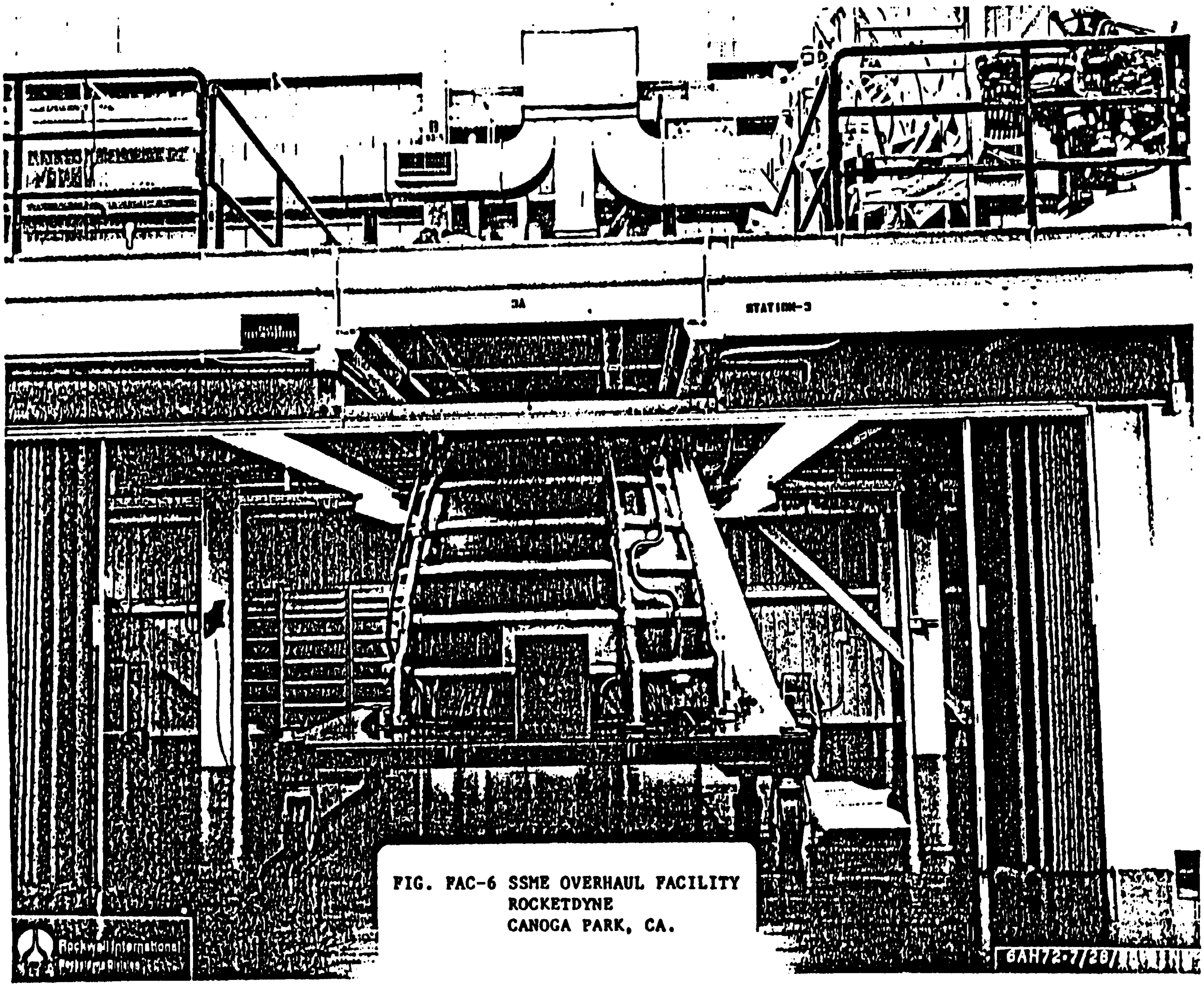

FIG. FAC-6 SSME OVERHAUL FACILITY
ROCKETDYNE
CANOGA PARK, CA.

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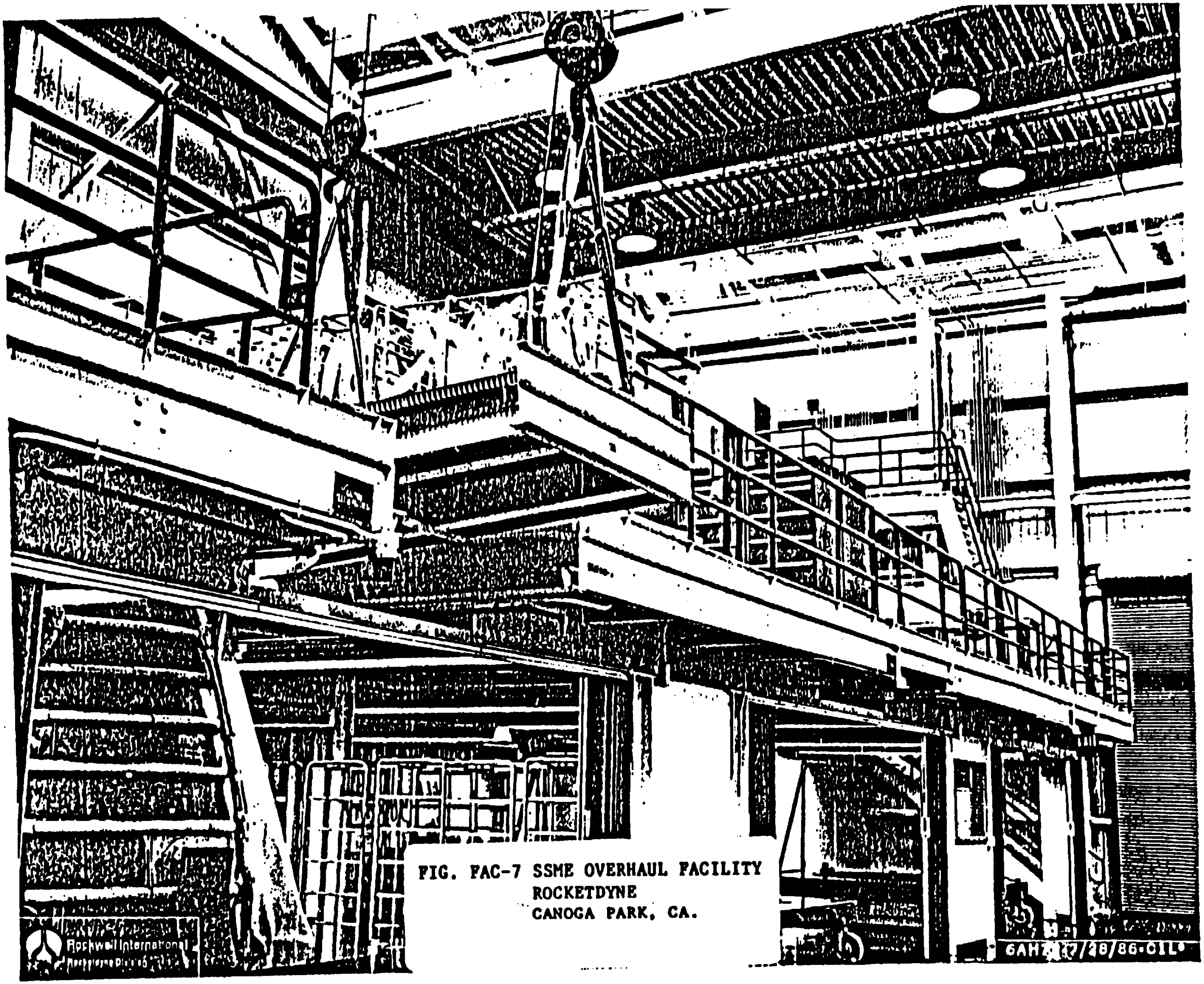

FIG. FAC-7 SSME OVERHAUL FACILITY
ROCKETDYNE
CANOGA PARK, CA.

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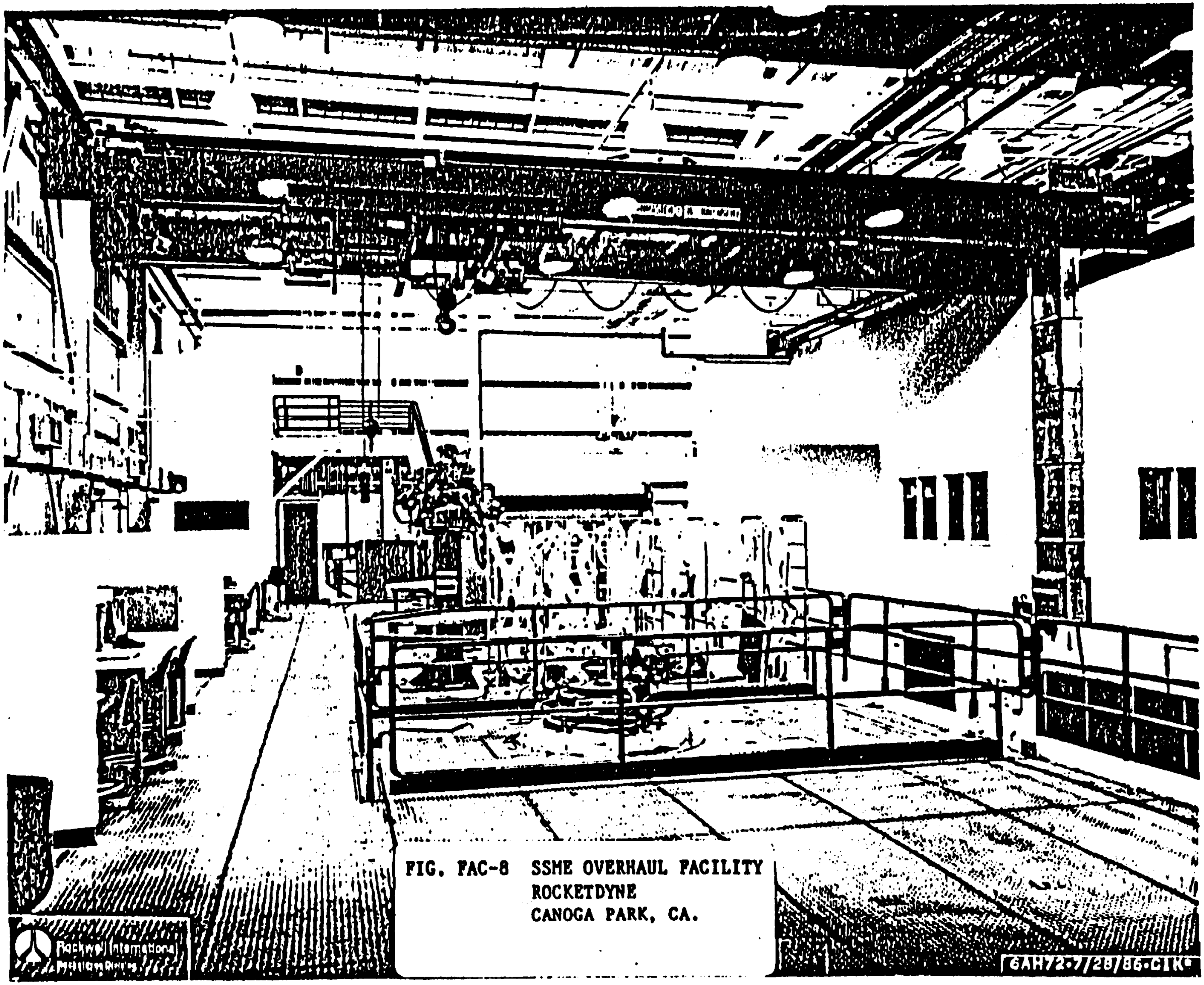

FIG. FAC-8 SSME OVERHAUL FACILITY
ROCKETDYNE
CANOGA PARK, CA.

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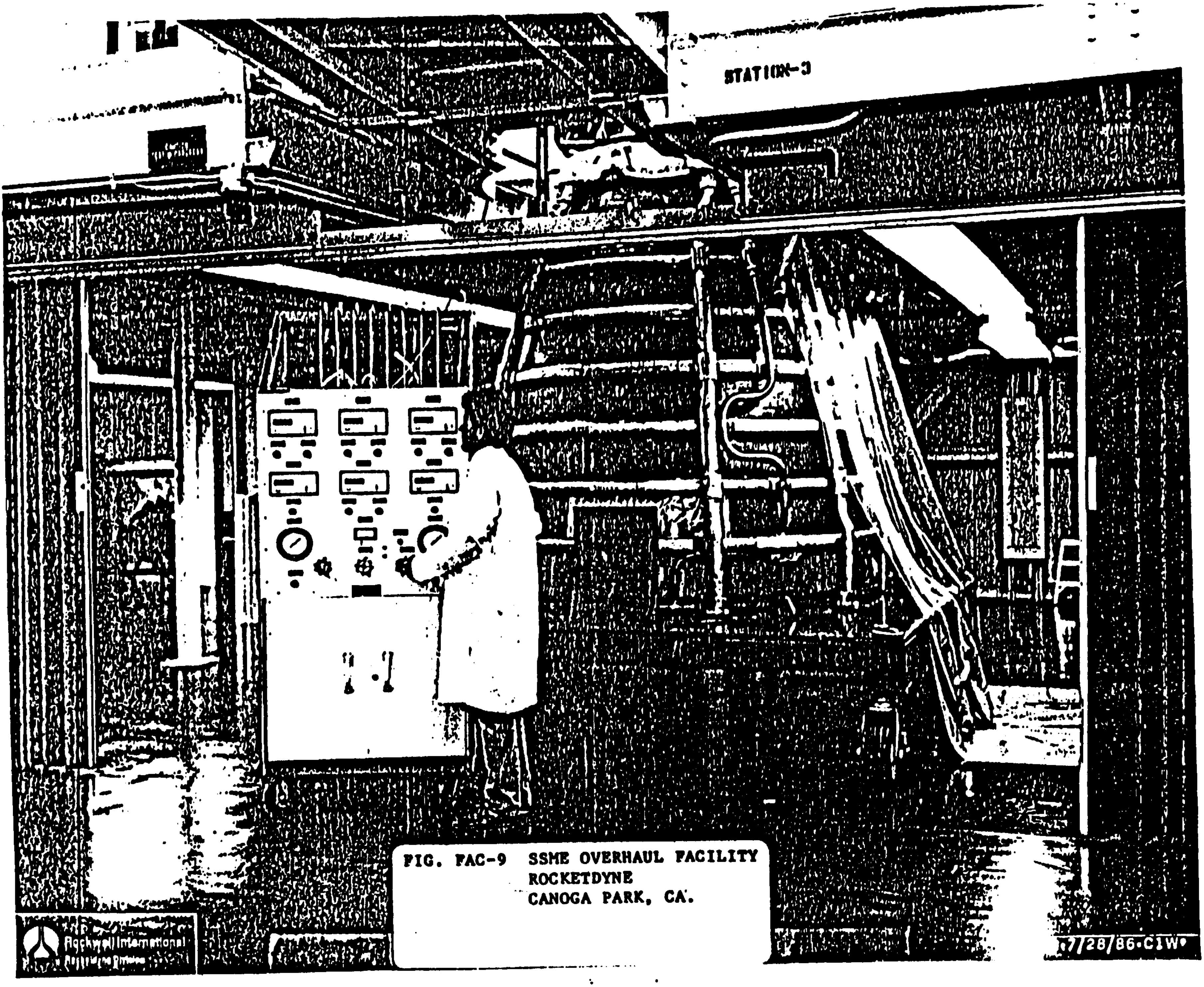

FIG. FAC-9 SSME OVERHAUL FACILITY
ROCKETDYNE
CANOGA PARK, CA.

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## ENGINE PROCESSING AT THE VANDENBERG LAUNCH AND LANDING SITE (VLS)

Launching the Shuttle Transportation System from the Vandenberg Launch Site could pose some significant problems for Liquid Rocket Booster engine processing should the launch frequency not warrant a "duplicate" facility. Significant logistics problems mainly in shared use of engine handling equipment and personnel could, and would, impact Kennedy Space Center operations.

Engine handling equipment envisioned for the Liquid Rocket Booster engine processing such as,

a) Engine Installer - Horizontal
b) Engine Installer - Vertical
c) Engine Installer - Hyster Configuration
d) Engine Rotating Sling
e) Critical Lift Hardware

will be of such a size that most certainly disassembly will be required to reduce the shipping size and weight. Items such as the "Hyster" presently used for engine (SSME) installation in the horizontal configuration would have to be disassembled to such a level that upon reassembly, complete functional checkouts and critical lifts would be mandatory before use with flight hardware. The time required for equipment disassembly, packaging, shipment, receipt, reassembly, functionals and critical lift certifications, is estimated to be at least two (2) to three (3) weeks on each end of the operation.

"Shared Test Team" concepts yet again poses significant impacts to Kennedy Space Center Liquid Rocket Booster engine processing. Staffing requirements for engine processing at Kennedy Space Center was aimed at being "reasonable" to process a minimal maintenance engine for a three (3) shift, five (5) day week with some contingency built-in to accommodate those operations on a periodic seven (7) day basis.

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## ENGINE PROCESSING AT THE VANDENBERG LAUNCH AND LANDING SITE (VLS) (CONT.)

The ferrying of personnel from site-to-site even for "short" periods of time not only strains operations at the prime launch site, but is not conducive to totally productive work at the minor launch site.

There is an extensive experience base in supporting engine processing activities in other areas using Kennedy Space Center - based personnel. This has been accomplished during high activity periods of processing and did in fact place a significant burden on the crew left behind. The "temporary living" situation will always provide hindrances at the "off-site" location.

The recommendation of this study is for the launch site to provide for equipment redundancy in those areas where a single piece of ground support equipment is a "single-point-failure" to the program should that item be lost to the operation. Therefore, in the case of the above mentioned five (5) pieces of major engine handling equipment, redundancy is a must even for Kennedy Space Center operations. With redundancy of this nature, then "shared equipment" becomes less of an impact except for the laborious tasks of moving it somewhere else. The major risks accepted, in the worst case, would be total loss of hardware during shipment thus eliminating the redundancy and placing this item on the list of "single-point-failure" to the program.

The "shared test team" concept would require to up-front properly staff the critical disciplines of engineering and technicians at Kennedy Space Center to provide a contingency "skeleton crew" status. This increase might be at least three (3) each engineers and technicians. This "contingency" pad would be an asset to the prime launch site when considering accelerated launch operations, the possibility of a non-standard work week mode-of-operation, and a needed hedge to fill the gaps created during vacations, illnesses, etc..

## ENGINE PROCESSING AT THE VANDENBERG LAUNCH AND LANDING SITE (VLS) (CONT.)

The unexpected contingency operations that must be accepted in the launch operations community should be more than sufficient to justify the modest staffing increase let alone the possibility of a "shared test team" with VLS.

The purpose of the "skeleton crew" for VLS would be to tend the operations until the level of activity associated with a launch reached a peak demanding the supplemental team for the launch itself. There has been some success at supplementing its launch site crew with specialized personnel from both the factory and ground test activity. This type of supplemental support could greatly ease the burden of personnel drain at the prime launch site.

In summary, supporting "VLS from KSC" for engine processing through the shared equipment/personnel concepts is not a viable approach from the engine community point of view. The engine processing community has always been relatively small when compared to the numbers of vehicles/engines in flow and their required operations. Staffing has always been dedicated to on-site processing requirements and with the "lessons learned" evaluations have shown that any disruption to this "locally dedicated staffing" is not operationally or cost effective to the program and significantly impacts all operations at both launch sites.

Sensitive equipment sharing concepts presents a real logistics nightmare. The potential for having to disassemble "one-of-a-kind" hardware, that was not meant to be disassembled on a frequent basis, packaging, shipment, reassembly, etc., with the risk of damage/loss from disassembly/assembly, and shipment, is not an acceptable cost-effective procedure. This type of concept further burdens the prime launch site staffing to prepare the equipment for shipment and then reconfiguring it at the other end.

## ENGINE PROCESSING AT THE VANDENBERG LAUNCH AND LANDING SITE (VLS) (CONT.)

As a minimum, a "skeleton crew" of properly selected disciplines should be permanently located at VLS to perform the day-to-day operations. Very sensitive GSE must be duplicated rather than shared. Shared personnel must be kept to a minimum and considered as "terminal countdown personnel support" only.

## SUMMARY

The engine processing portion of the Liquid Rocket Booster Integration Study has attempted to point out some of the major engine related issues facing the incorporation of the Liquid Rocket Booster into the Space Transportation System. Even though the engines continue in the conceptual design phase, enough information and detailed definition is available to evaluate their major impacts to the launch operations community.

One of the significant aspects that surfaced during this study was that the physical size of the LRB engines proposed was very close to the size of the Space Shuttle Main Engine. Another significant factor in the proposed Liquid Rocket Booster processing flow is that the processing of the engines looks very similar to the general flow of the Space Shuttle Main Engine. These two (2) major factors basically set the stage as far as being able to examine/evaluate processing facilities, equipment, and flow concepts. The "internal" characteristics of the engines when evaluated did not point up any new major surprises to the launch site. Thus, the checkout phase of the engine processing flow should be straight forward and considered minimal when comparing the LRB engine to the present SSME checkout requirements.

In all areas of this engine processing study, we have attempted to promote ideas based on "lessons learned". For instance, the identification of a proposed engine shop layout, and a detailed list of requirements for that shop, is directly related to the dilemma being faced daily by the SSME processing group. The proposed LRB engine shop layout should prevent the present-day SSME processing ills of 1) not enough space, 2) improper space, 3) fragmented work areas, and 4) no checkout capability and 5) de-centralization of personnel. The "up-front" notification of "engine operations" space requirements in both the Vehicle Assembly Building and at the Pad is also directly related to the inefficient operations experienced in the past by not having such areas. Sprinkled all through the "Data Package" of SSME ground support equipment are lessons learned approaches to ground support equipment redesign.

## SUMMARY (CONT.)

For instance, the "Perfect Engine Tool" (A70-0645) offers significant advantages in processing timelines in engine alignment when compared to the method used during the processing of STS-1. The Data Package is very explicit about improvements in designs that should be considered for engine access when the vehicle is in the vertical.

The typical processing flows, probable staffing requirements, representative lists of processing procedures and training requirements are examples of items that deserve consideration and development during the vehicle/engine systems design and production phase.

Should these issues be addressed up-front in the program, there is no reason to believe that the transition from a solid rocket booster to a liquid rocket booster environment should be anything but smooth and productive. In past program(s) all too often, for instance, ground support equipment was designed/fabricated in one local. Later in time, miles away, the development of procedures was attempted to properly utilize the equipment at the launch site only to find a complete miss-match of equipment, procedure, and vehicle adaptability. Proper up-front staffing and the requirement of "vehicle" design centers working directly with launch site processing/facilities throughout the design phases of both flight and processing hardware should minimize the impacts in developing initially good procedures for processing hardware at the launch site.

The processing of a liquid rocket booster engine will most certainly occupy a good portion of the "critical path" processing flow. Proper up-front planning, the proper utilization of "lessons learned", and the acceptance of "conservative approaches" to engine processing should promote an effective and smooth transition of liquid rocket booster into the Space Transportation System. However, continued close monitoring of the engine developments in the "prime study" is a must to keep abreast of any changes that might impact operations at the launch site.

## SUMMARY (CONT.)

Included below is a recommended list of engine processing related activities that should be considered for the "option phases" of the Liquid Rocket Booster Integration Study:

- Refinement Of Processing Operations
  - Thermal Protection Requirements
  - Reduce Need For Redundant Operations
  - LRU Concepts vs Engine Changeout
- Refinement Of Facility/GSE Requirements
  - Access
  - Handling
  - Preps For Launch
  - Shop
- Evaluate "Alternate Use" LRB For Processing Requirements of Engines
- Evaluate "Shared Use" Of SSME GSE For LRB Engines
- Support LRBI Study Concerning Engine Processing Requirements
- Evaluate cost effectiveness of combining LRB engine and SSME processing into a single facility.

# VOLUME III

## SECTION 19

## EVALUATION OF LRB PROCESSING / STORAGE IN THE VAB

## VOLUME III SECTION 19
## EVALUATION OF LRB PROCESSING/STORAGE IN THE VAB

## TABLE OF CONTENTS

## VOLUME III SECTION 19

## EVALUATION OF LRB PROCESSING/STORAGE IN THE VAB

## FIGURES INDEX

# SECTION 19

# EVALUATION OF LRB PROCESSING/STORAGE IN THE VAB

This study addresses facility requirements for receiving, processing, and storing LRBs in the Vehicle Assembly Building (VAB). The LRB processing flow is analyzed and activation, operational, and safety impacts identified.

The evaluation of the VAB concludes with a strong recommendation for receiving, processing, and storing the ET and LRB in a stand-alone horizontal facility. Also recommended in Paragraph 19.13 is the requirement for a third integration cell for LRBs/Space Shuttle Vehicles (SSVs).

The conceptual baseline for LRB processing requirements for test and checkout of LRB propellant systems and engines is addressed in Paragraph 3.1. It should be noted that both MSFC phase A contractors have accepted the design recommendations necessary to process and store the LRB horizontally.

This study includes a description of current VAB utilization and operations, available space, an LRB processing concept and requirements, and impacts.

## 19.1 ASSUMPTIONS AND GROUNDRULES

### 19.1.1 Assumptions

For the purpose of this study, an LRB is described as an External Tank (ET) with four engines. The function baseline, therefore, is modeled on existing ET and Space Shuttle Main Engine (SSME) functional test and operational requirements. (See Volume III, Section 3.1 for a detailed description of processing requirements.)

It is assumed that the LRB would arrive at KSC via barge at the Turn Basin on a transporter. The transporter would be used throughout the processing flow as well as to store the LRBs temporarily in the horizontal position.

### 19.1.2 Groundrules

For the purpose of this study, existing safety requirements, procedures, and groundrules will be imposed on the processing flow. One such groundrule is that flight hardware cannot be lifted over flight hardware. This groundrule will prevent LRB processing in the horizontal position in the VAB ET processing areas (High Bays 2 and 4), since ET movement/lifting would occur over the LRBs.

During LRB processing or activation of a processing and storage area, operations will be halted and the area cleared when SRBs in the integration bays directly across from the LRB area are being stacked or when ET processing is hazardous (pressurization).

The existing SRB workstands must remain in the VAB to provide backup to the Rotating, Processing, and Surge Facility (RPSF). Any contingency SRB operation on these workstands will halt LRB and ET operations in the particular processing area.

LRB processing/storage area activation must not impact the requirement to process ETs to achieve the flight rate currently manifested as 12 to 14 SRB/SSV flights per year.

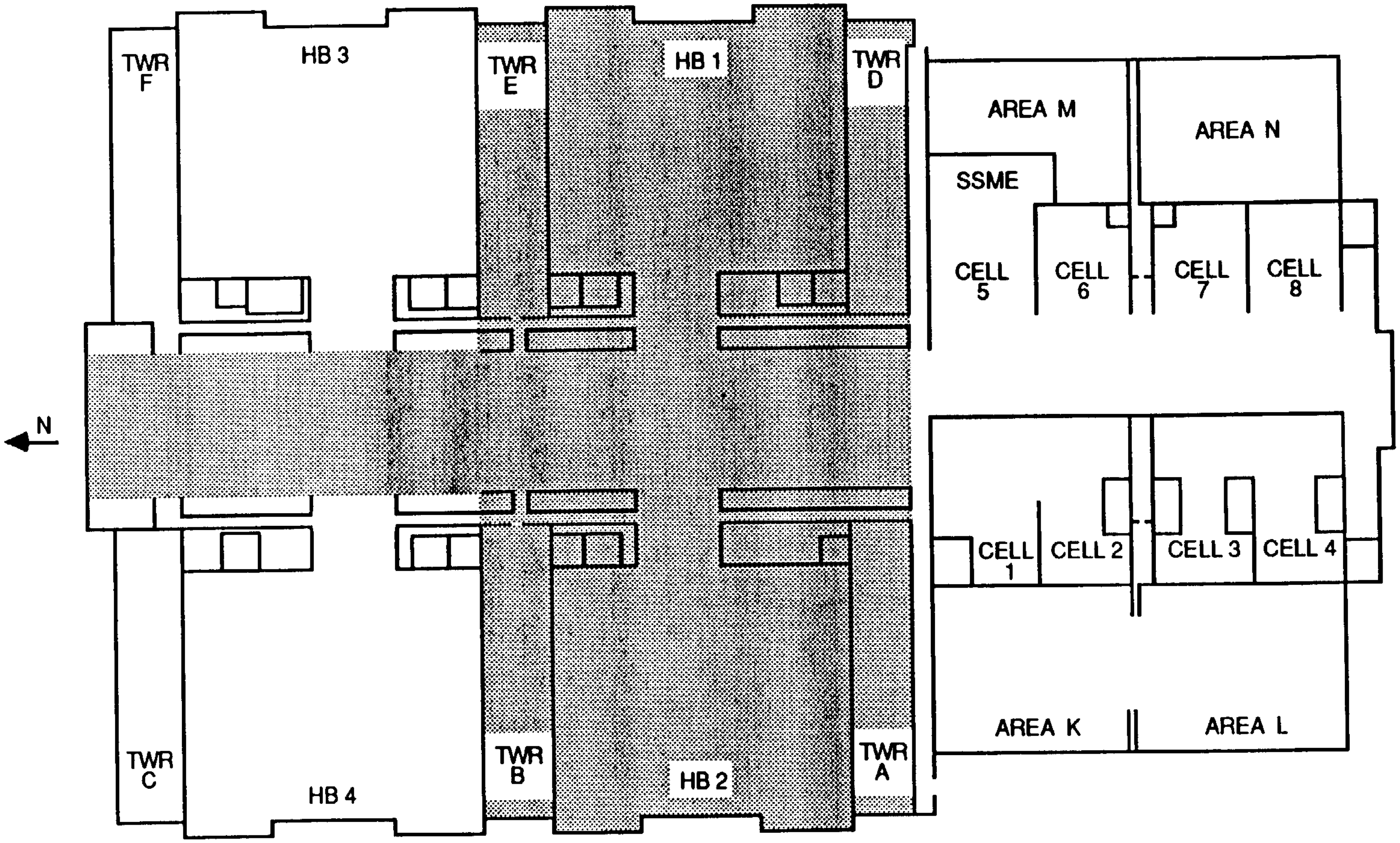
## 19.2 DESCRIPTION OF CURRENT VAB FLIGHT ELEMENT FLOW AND IMPACTS

### 19.2.1 SRB Processing In The VAB

Currently, the SRBs are built up and processed in the RPSF. They are then transported to the VAB, lifted, and stacked on the Mobile Launcher Platform (MLP). During the VAB SRB stacking operations, areas of the transfer aisle and High Bays 2 and 4 are cleared. Figures 19.2.1-1 and 19.2.1-2 show the clear areas for High Bays 1 or 3 stacking. This requirement to clear for SRB stacking would impact the LRB processing schedule as well as the activation of either High Bays 2 and 4 as LRB processing/storage areas.

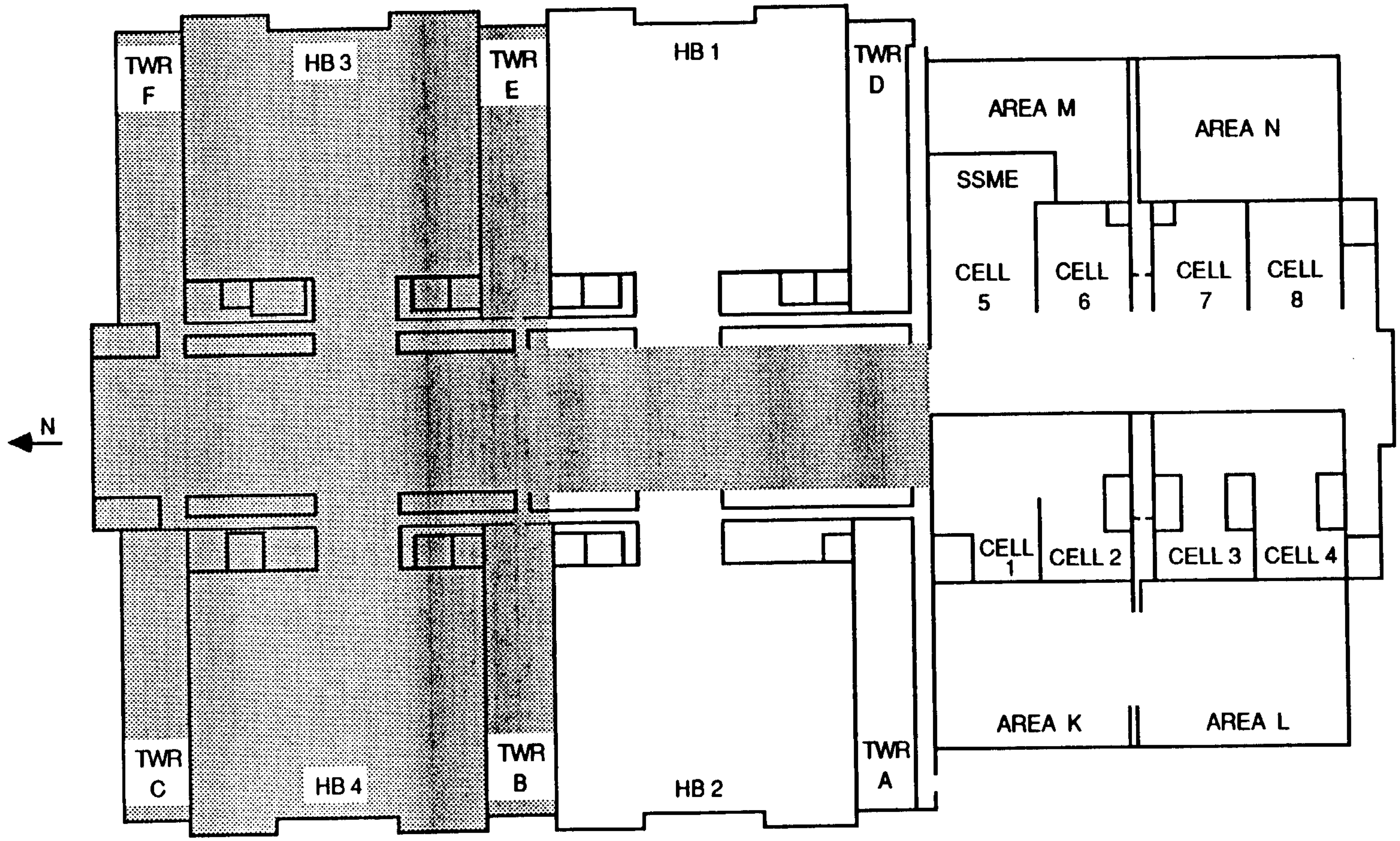
### 19.2.2 Orbiter Processing In The VAB

Currently, the Orbiter is prepared for flight in the Orbiter Processing Facility (OPF). It is then rolled to the VAB, lifted, and mated to the ET/SRBs. During the Orbiter lift operation, the transfer aisle is cleared. Figures 19.2.2-1 and 19.2.2-2 show the clear areas for High Bays 1 or 3 mating.



VAB FLOOR PLAN

Figure 19.2.1-1. VAB High Bay 1 - SRB Stacking Clear Zone.



VAB FLOOR PLAN

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Figure 19.2.1-2. VAB High Bay 3 - SRB Stacking Clear Zone.

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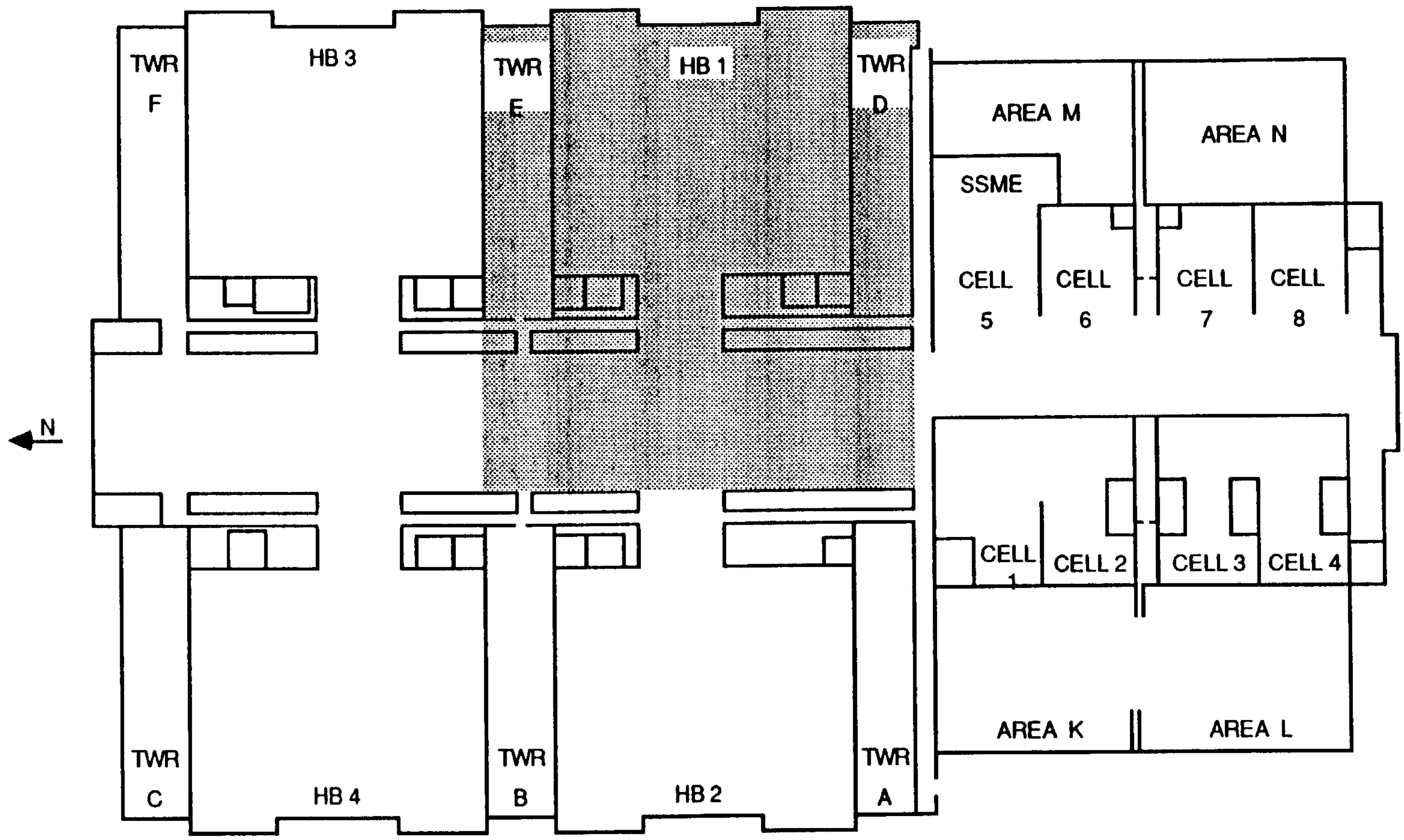
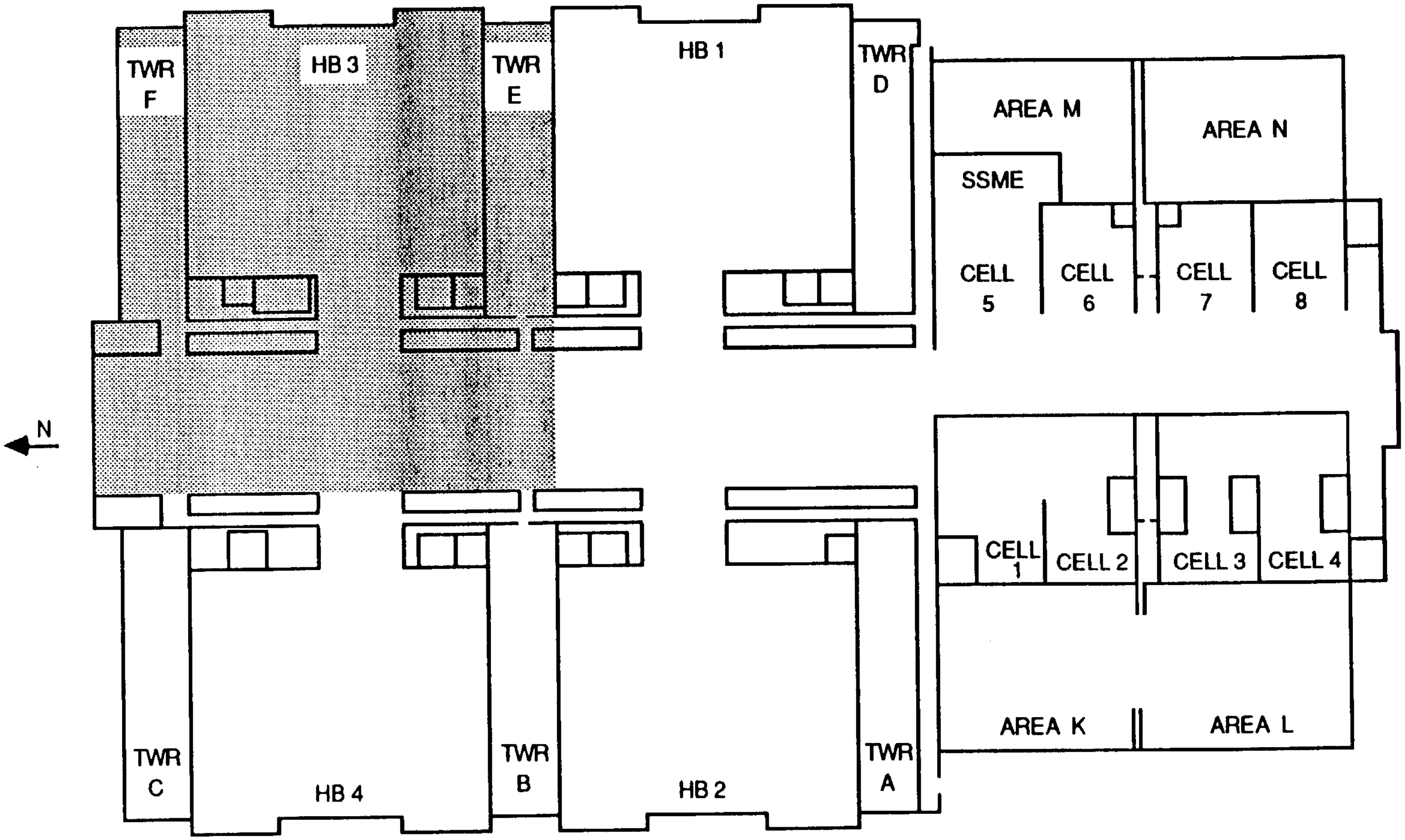


VAB FLOOR PLAN

Figure 19.2.2-1. VAB High Bay 1 - Orbiter Mate Clear Zone.



VAB FLOOR PLAN

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Figure 19.2.2-2. VAB High Bay 3 - Orbiter Mate Clear Zone.

3-19.2 11/5 6:00a

This requirement to clear will require coordination of LRB receiving/lifting schedules with Orbiter lifting/mating operations. Currently, this is done for the scheduling of ET processing.

### 19.2.3 ET Processing/Storage In The VAB

Currently, the ETs are received from Michaud, Louisiana, and rolled to the VAB Transfer Aisle. They are then lifted into one of the checkout cells in either High Bay 2 or 4. During pressurization tests the High Bay being used for ET processing is cleared. Figures 19.2.3-1 and 19.2.3-2 show the clear areas. The requirement to clear the High Bay will impact the LRB processing as well as the activation of the High Bay as an LRB processing/storage area. The same requirement will be levied on the ET processing when LRBs are pressurized.

When required for stacking (mating to an SRB on the MLP, the SRBs are lifted and transferred across the Transfer Aisle to an MLP. During the transfer operation, the processing High Bay, Transfer Aisle, and integration High Bay is cleared. Figures 19.2.1-1 and 19.2.1-2 show the clear area (same as for SRB stacking).

## 19.3 PROPOSED LRB PROCESSING/STORAGE IN THE VAB

The LRBs would arrive at KSC and be rolled on the transporter to the VAB Transfer Aisle. They would then be lifted into checkout cells in High Bay 2 or 4. After checkout, the LRBs would be transferred to storage cells. When required for stacking on the MLP, they would be lifted and transferred across the Transfer Aisle to the MLP. During the pressurization test of the LRB, the High Bay would be cleared (similar to the ET process), impacting ET processing. Figures 19.2.3-1 and 19.2.3-2 show cleared areas for transfer of the LRB from storage to MLP mate. During this transfer, the processing High Bay, Transfer Aisle, and integration High Bay would be closed.

## 19.4 VAB AVAILABLE SPACE FOR LRB PROCESSING

### 19.4.1 High Bay 2

The floor space in High Bay 2 is 152 by 152 ft to an elevation of 112 ft (bottom of steel at Level 10). (See Figure 19.4.1.) At the 112-ft elevation, steel structure measuring 38 by 76 ft. occupies the area on each side of the High Bay door. The ET checkout cells are located adjacent to Tower B between column lines Q and U and rise from the 115-ft elevation to the 267-ft elevation.

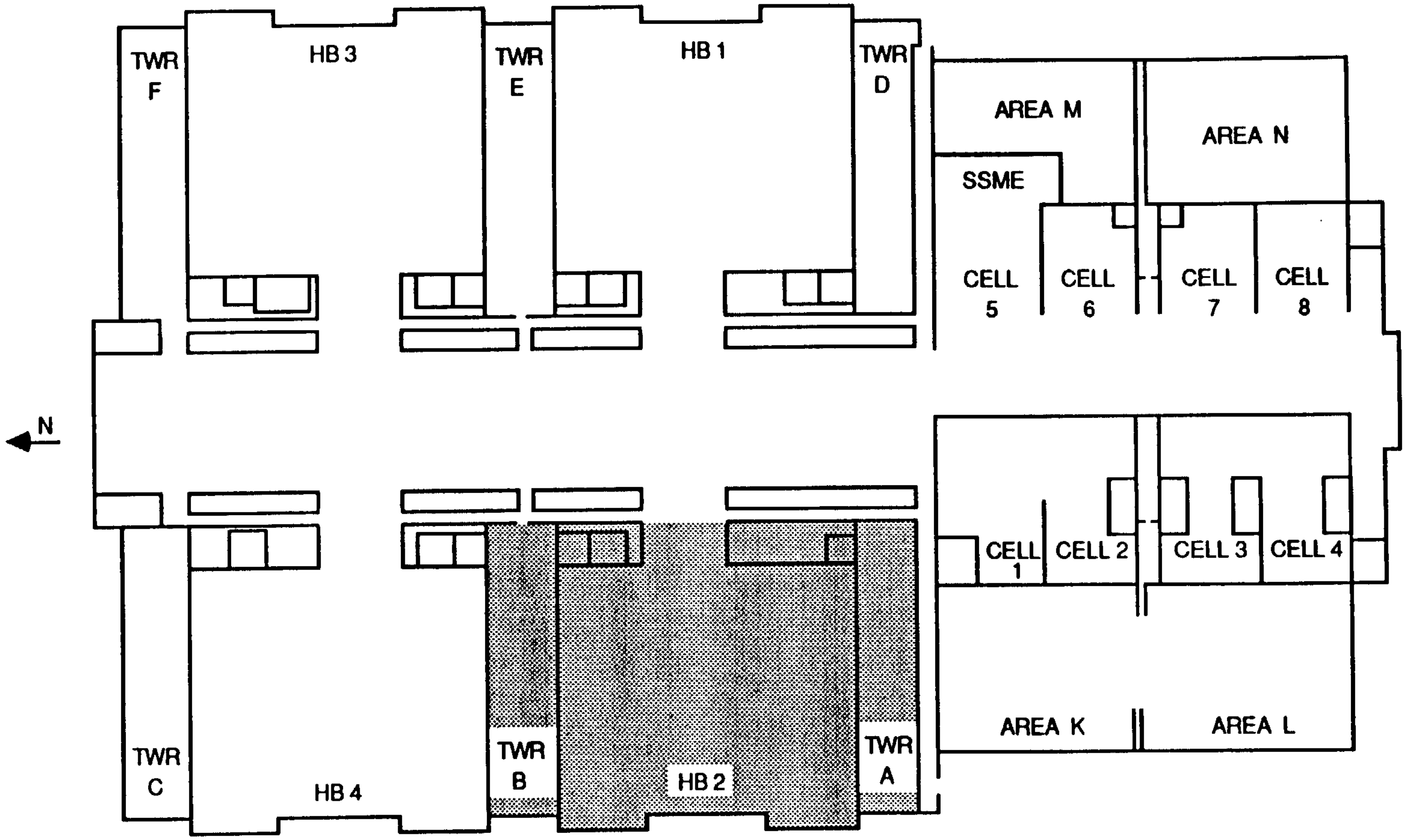

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Figure 19.2.3-1. VAB High Bay 2 - ET Processing and LRB Processing Clear Zone.

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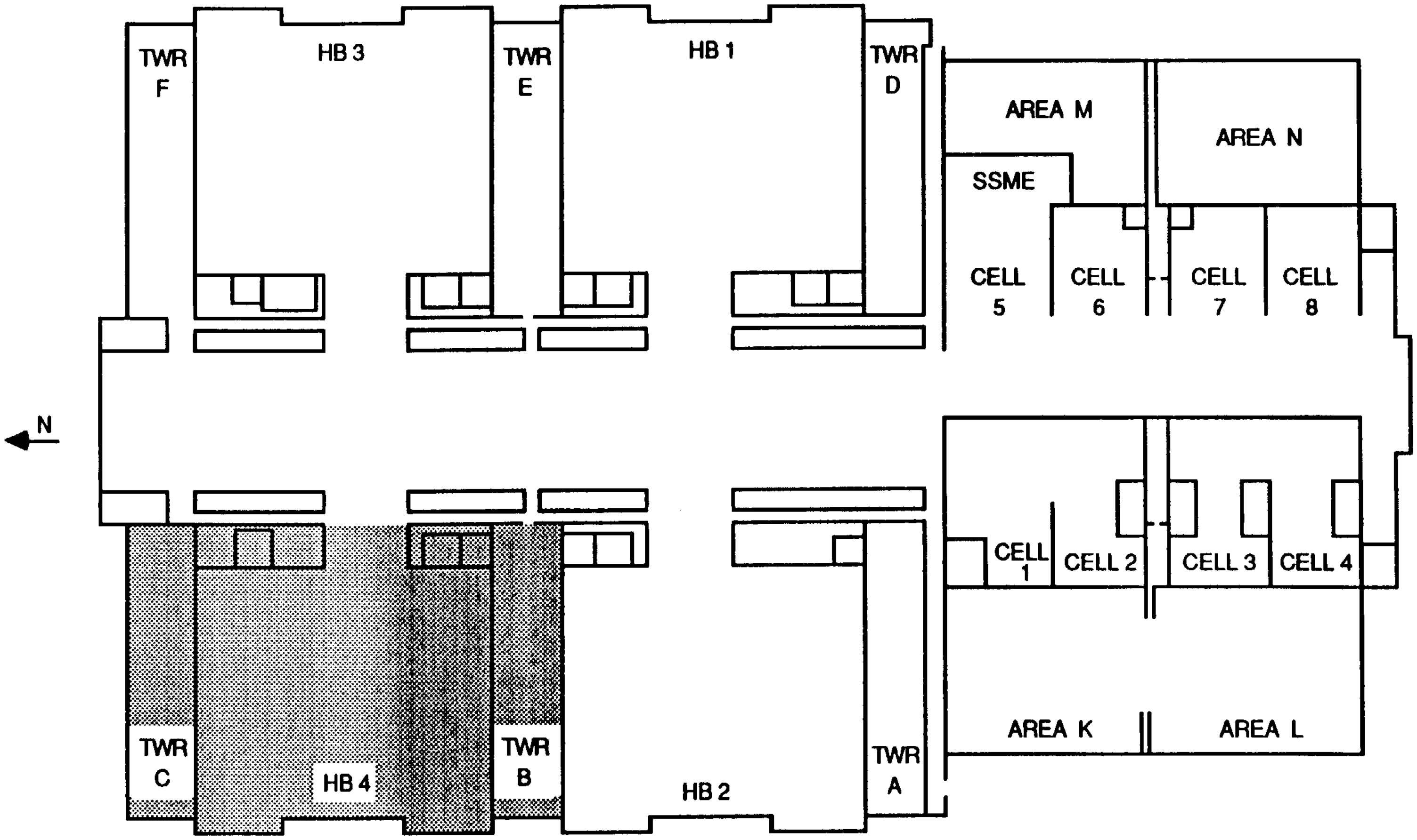

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Figure 19.2.3-2. VAB High Bay 4 - ET Processing and LRB Processing Clear Zone.

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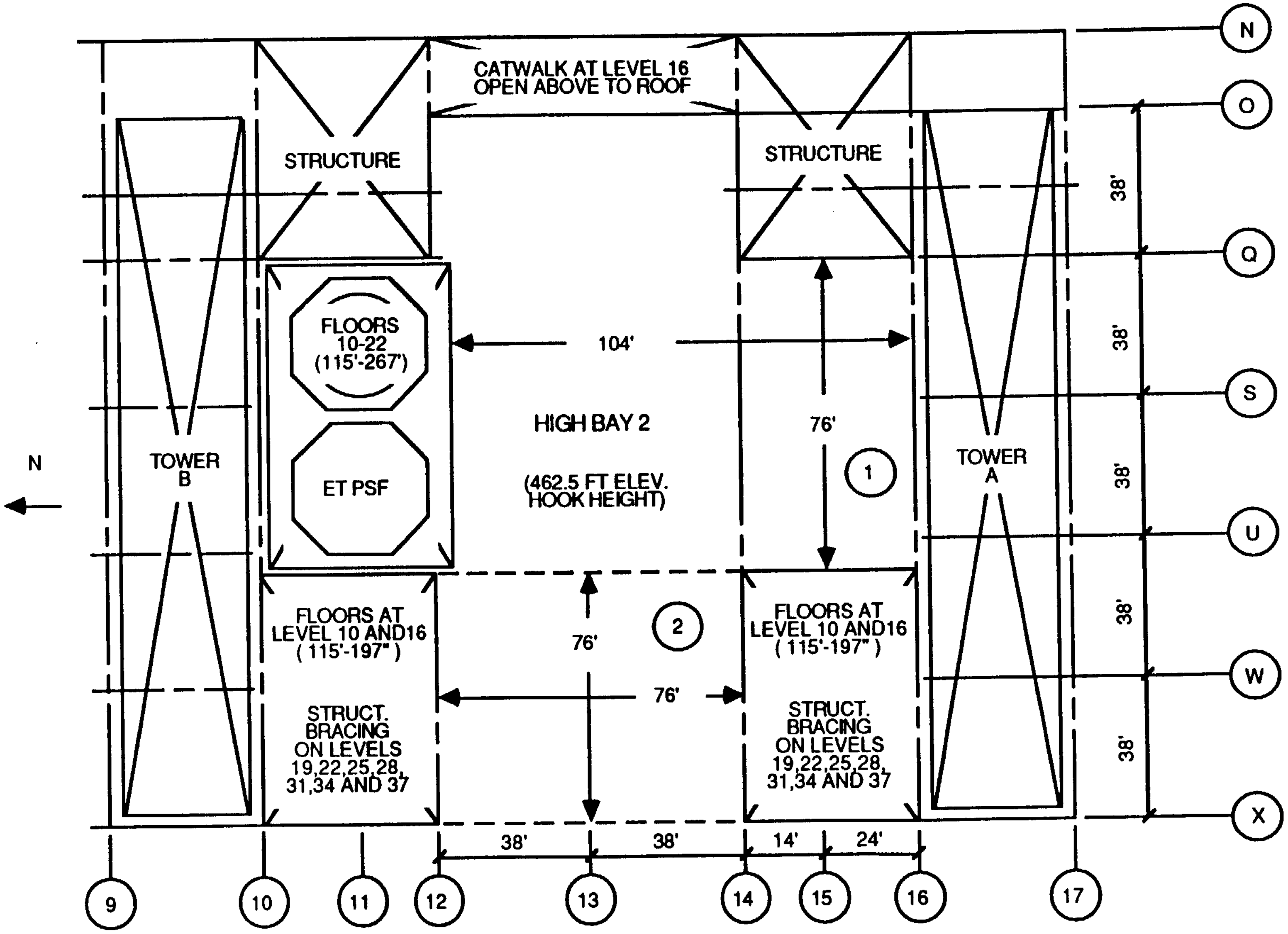

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Figure 19.4.1. Current High Bay 2 Configuration.

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The available space to locate LRB checkout and storage cells is adjacent to tower A between column lines U and Q and in front of the VAB doors attached to the structural steel on column line 12 between U and X and column Line 14 between U and X.

### 19.4.2 High Bay 4

The floor space in High Bay 4 is 152 by 152 ft to an elevation of 112 ft. (Bottom of steel at Level 10). (See Figure 19.4.2.) At the 112-ft elevation, a steel structure measuring 38 by 76 ft occupies the area on each side of the High Bay door. The ET checkout cells are located adjacent to Tower B between column lines Q and U and rise from the 115-ft elevation to the 267-ft elevation. The SRB workstands are located adjacent to Tower C between column lines Q and U.

The available space to locate LRB checkout and storage cells would be in front of the VAB doors attached to the structural steel on column Line 5 between U and X and column line 7 between U and X.

## 19.5 UTILIZATION OF AVAILABLE SPACE

### 19.5.1 High Bay 2

In High Bay 2, the possible locations for LRB cells would be as shown in Figure 19.5.1. A pair of cells can be attached to Tower A and a second pair in front of the High Bay doors. The cells would be elevated from the floor to allow for engine changeout, access to Tower A at floor level, and access to the VAB High Bay doors. The elevation of the LRB cells will be discussed in Paragraph 19.6 (crane evaluation).

### 19.5.2 High Bay 4

In High Bay 4, the possible location for LRB cells would be utilized as shown in Figure 19.5.2. Two pairs of cells would be located in front of the High Bay doors. The cells would be elevated from the floor to allow for engine changeout and access to the High Bay door. The elevations of the LRB cells will be discussed in Paragraph 19.6 (crane evaluation).

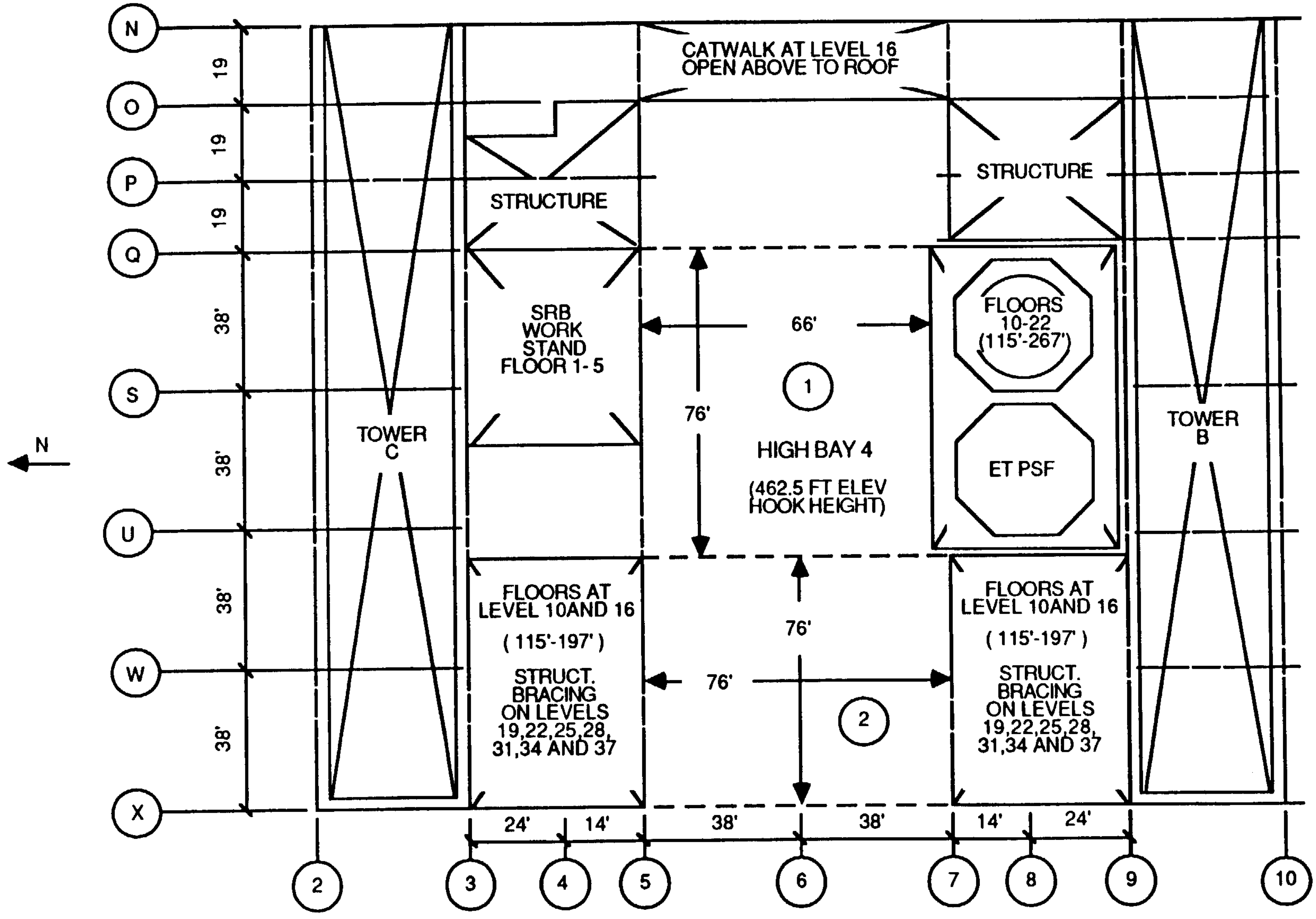

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Figure 19.4.2. Current High Bay 4 Configuration.

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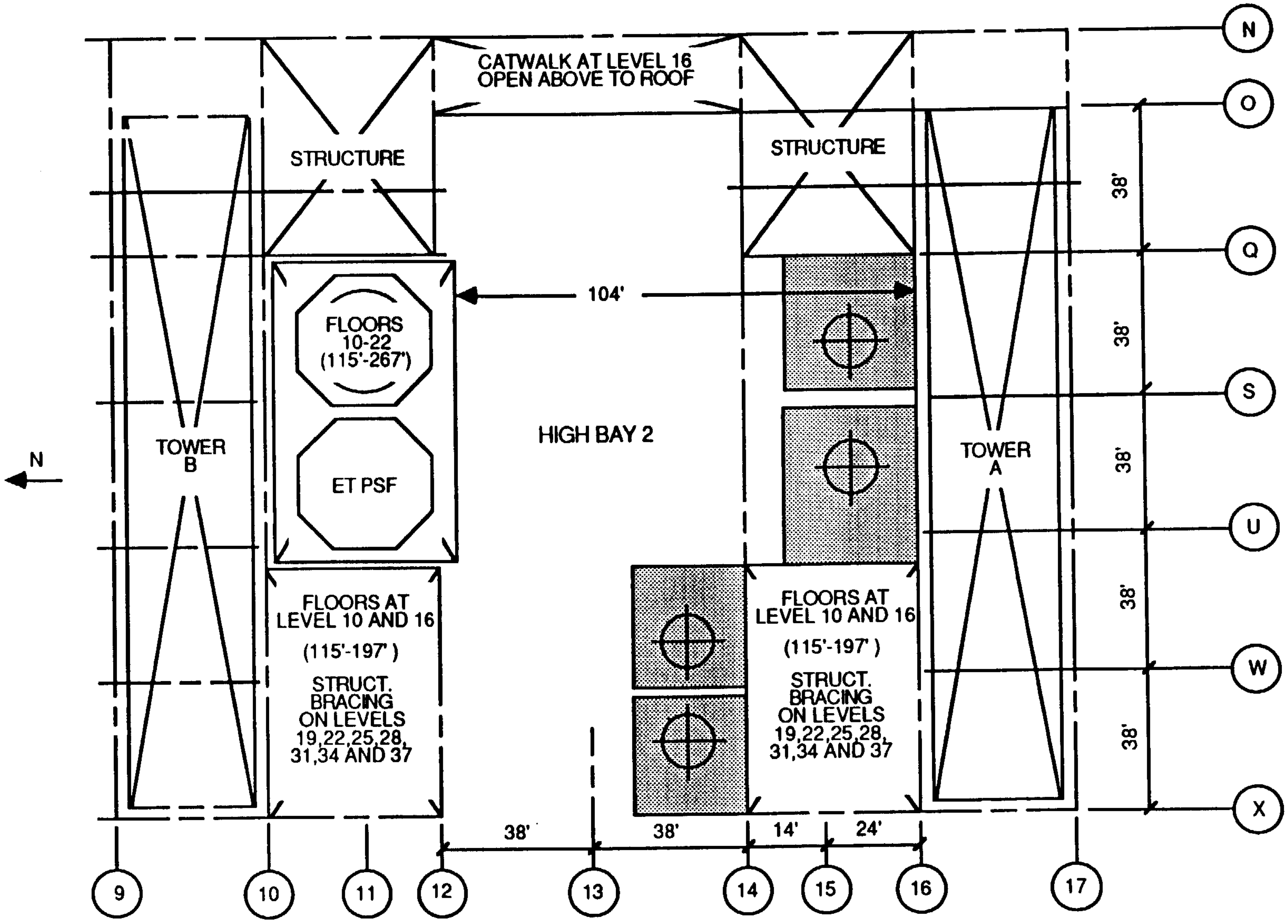

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Figure 19.5.1. Possible LRB Cell Location - High Bay 2.

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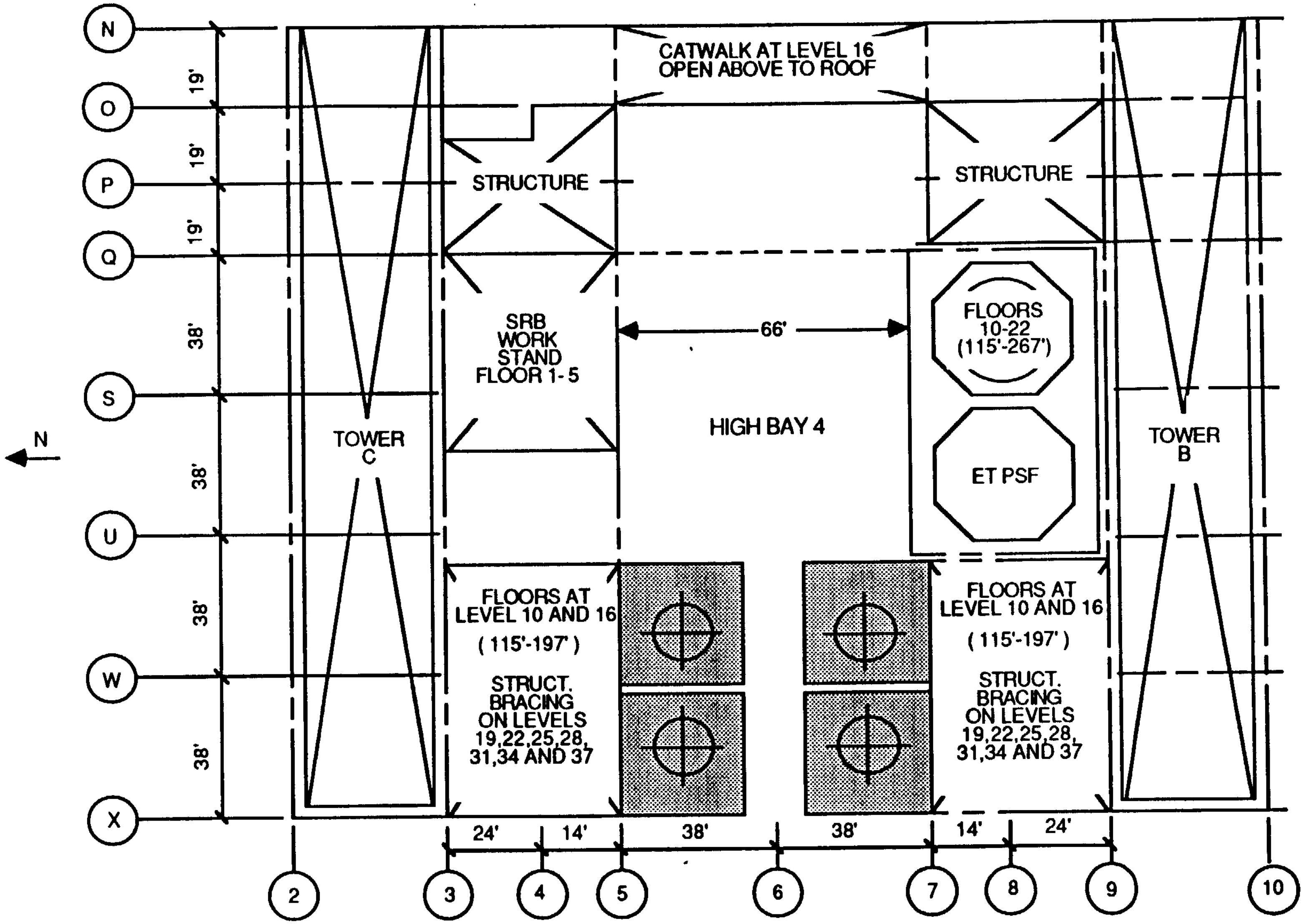

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Figure 19.5.2. Possible LRB Cell Location - High Bay 4.

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### 19.5.3 Envelope

Due to space limitations in the available areas, the LRB cells would be limited to 38 by 38 ft, as shown in Figures 19.5.1 and 19.5.2. A review of the available work platform space for the various LRBs is shown in Figure 19.5.3. Technicians would have 8.6 to 11.5 ft of available platform work space around the boosters. The gap between the platform and booster must be a minimum of 6 inches.

The flip-ups/extendables must fill the gap required to insert the LRBs into the cell. The insertion or extraction requires an 18-in clearance with hard steel. The flip-ups must fill gaps from 4.1 to 7.2 ft wide, as shown in Figure 19.5.3.

## 19.6 VAB HIGH BAY CRANE EVALUATION FOR LRB CELL HEIGHT

### 19.6.1 Cell Height (Top And Bottom)

The VAB High Bay crane has a maximum hook centerline elevation of 462.5 ft. Figure 19.6.1-1 shows the relationship of flight element lengths, crane hook height, and required top and bottom of the cell in the High Bay. For purposes of this study, the height of the sling with hydroset is 33 ft. This is the present distance of the ET nose in relation to the crane hook. Figure 19.6.1-2 tabulates the maximum elevation of an LRB cell and the elevation of the bottom of the cell for each LRB.

The evaluation assumes an 18-in clearance of flight hardware to steel when the booster is lifted over the cell. The booster is supported on holddown posts and haunches when in the cell. In all cases, the bottom of steel of the LRB cells is below Level 10 (112-ft elevation). The best cases are the MMC pump-fed at 110.1 ft and GDSS pump-fed at 110.2 ft. The worst cases are the GDSS pressure-fed at 34.3 ft and GDSS LH2 at 44.0 ft.

### 19.6.2 Vertical Engine Removal/Installation Clearance

Clearance under an LRB cell will be required for removal and installation of engines in the vertical position. Figure 19.6.1-2 shows that there is sufficient clearance for engine changeout. The worst case is the GDSS RP1 pressure-fed with 18.5 ft of clearance with an engine 15.8 ft in length.

|  | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/CH4 | GDSS LOX/LH2 | GDSS LOX/LH2 "FATBIRD" |
|---|---|---|---|---|---|---|---|
| LRB DIAMETER | 15.3 | 16.2 | 14.1 | 15.0 | 15.0 | 16.2 | 17.7 |
| LRB SKIRT DIAMETER | 22.1 | 26.0 | 25.9 | 26.8 | 27.3 | 22.3 | 24.4<br>18.7 |
| CELL OPENING FOR LRB ACCESS | 16.3 | 17.2 | 15.1 | 16.0 | 16.0 | 17.2 | 27.4 |
| CELL OPENING FOR LRB MOVEMENT | 25.1 | 29.0 | 28.9 | 28.9 | 30.3 | 25.3 | 9.7<br>4.4 |
| WORK SPACE (W) | 10.9 | 10.4 | 11.5 | 11.0 | 11.0 | 10.4 |  |
| FLIP-UP WIDTH (F) | 4.4 | 5.9 | 6.9 | 6.9 | 7.2 | 4.1 |  |

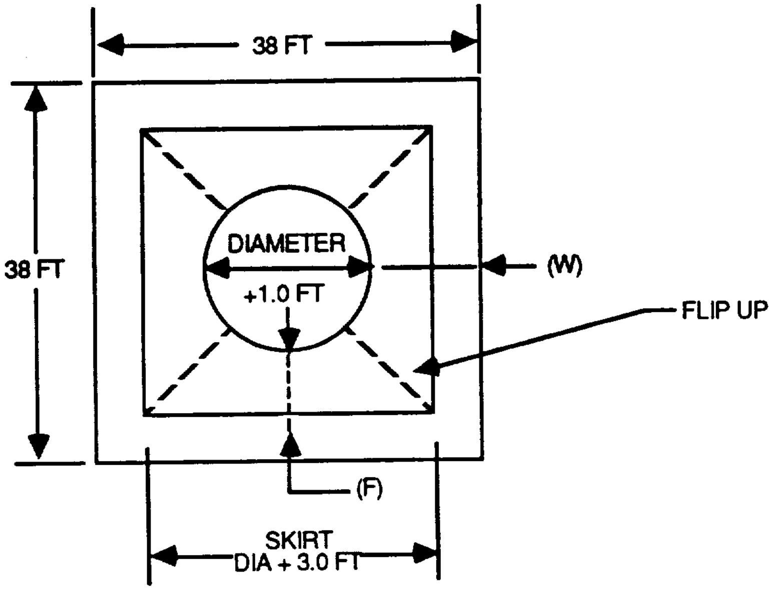

Figure 19.5.3. Available Work Space and Lift Clearance Around Each LRB

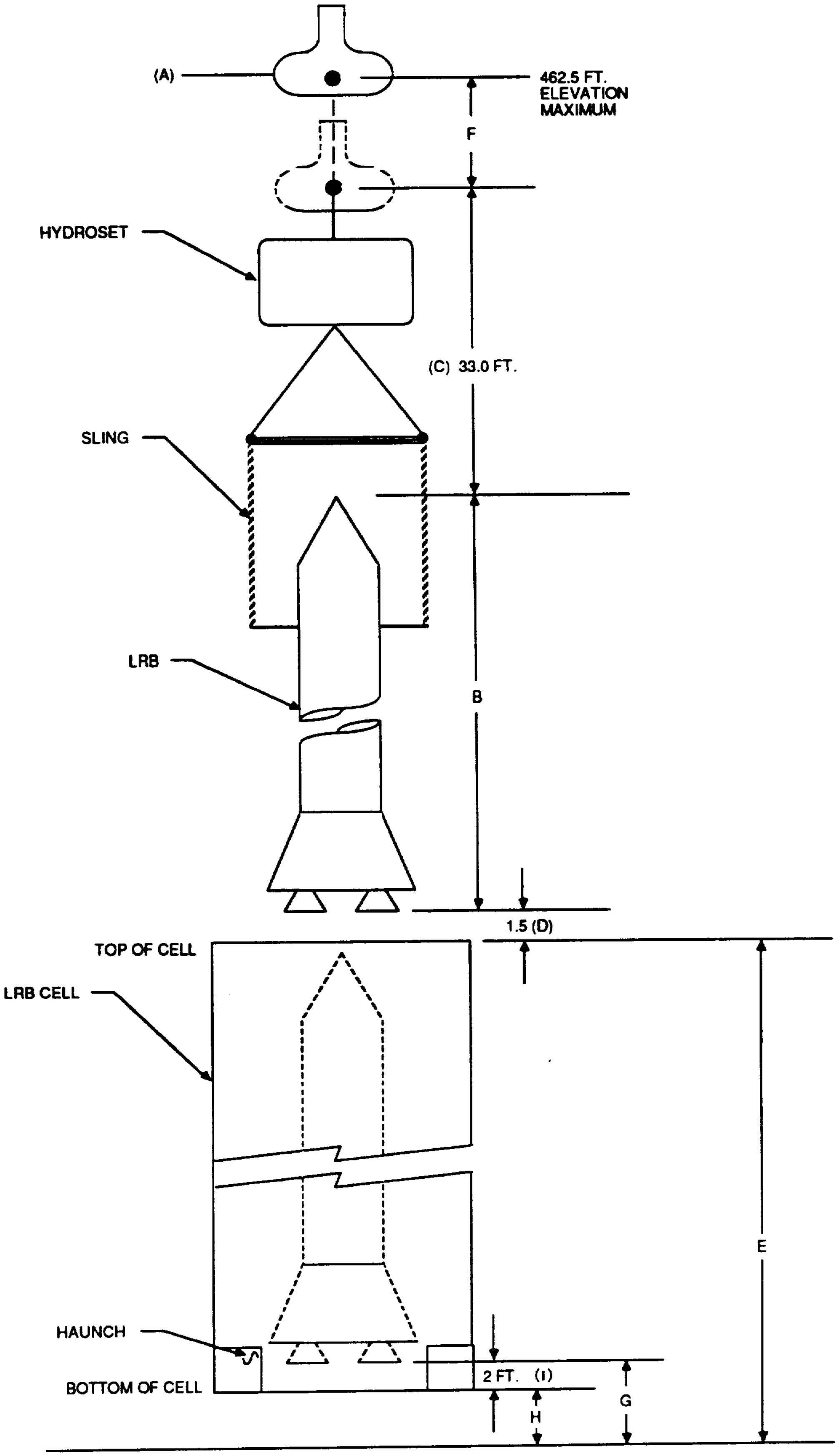

Figure 19.6.1-1 LRB Length and Crane Hook Height.

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|  |  | ET | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/CH4 | FSAA LOX/LH2 | GDSS LOX/LH2 "FATBIRD" |
|---|---|---|---|---|---|---|---|---|---|
| A | MAX CRANE HOOK ELEVATION | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 |
| B | LENGTH OF LRB/ET | 155.4 | 150.9 | 162.7 | 148.8 | 195.7 | 150.1 | 191.0 | 169.5 |
| C | SLING HEIGHT | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 |
| D | LIFT CLEARANCE | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| E | MAX HOOK LIFT MARGIN | 6.3 | 0.8 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 1.0 |
| F | MAX TOP OF CELL | 267.0 | 266.3 | 264.3 | 266.3 | 231.3 | 266.3 | 236.0 | 257.5 |
| G | BOTTOM OF ENGINE | N/A | 115.4 | 101.6 | 117.5 | 35.6 | 116.2 | 45.0 | 88 |
| H | DISTANCE BOTTOM OF ENGINE TO BOTTOM OF CELL | N/A | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| I | BOTTOM CELL STEEL | 115.0 | 113.4 | 99.6 | 115.5 | 33.6 | 114.2 | 43.0 | 86.0 |
|  | LENGHT OF ENGINE | N/A | 11.2 | 14.2 | 14.9 | 16.2 | 13.8 | 11.3 | 11.3 |
|  | CLEARANCE FOR ENGINE CHANGEOUT | N/A | 102.2 | 85.4 | 100.6 | 17.4 | 100.4 | 31.7 | 74.7 |
|  | DISTANCE FROM TOP OF HORIZ HB DOOR | N./A | 1.4 ABOVE | -12.4 BELOW | 3.5 ABOVE | -78.4 BELOW | 2.2 ABOVE | -69 BELOW | -26 BELOW |
|  | HB DOOR HEIGHT | 112.0 | 112.0 | 99.6 | 112.0 | 33.6 | 112.0 | 43.0 | 86.0 |

Figure 19.6.1-2. VAB High Bay Crane Elevation

### 19.6.3 VAB Crane Capacity For Lift

The VAB cranes have a capacity of 175 tons and 250 tons. To lift a horizontal booster, both cranes would be employed. The lifting operation to move an LRB from its transporter would involve lifting the booster with both cranes and rotating it so that the 250-ton crane would hold the booster vertically. Figure 19.6.3 shows the LRB weight in comparison to the crane capacity. The 250-ton crane has sufficient capacity to carry all the LRB configurations.

### 19.6.4 VAB Diaphragm Clearance

Once the booster is suspended vertically from the 250-ton crane, it must be lifted into the High Bay. The top of the steel elevation at the VAB Level 16 is 197 ft 7-1/4 in. As noted in Paragraph 19.6.1, the centerline elevation of the crane hook is 462.5 ft. The height of the opening for lifting into the High Bays is 264 ft 10-3/4 in. Figure 19.6.4 shows that sufficient clearance exists to lift all LRB configurations into the VAB High Bay vertically.

### 19.6.5 Concerns

For the cell locations available in front of the High Bay door in both High Bays, all configurations locate the holddown and engine bells below the top of the horizontal doors. The worst cases are the GDSS RP1 pressure pad, GDSS LH2, and GDSS Fat Bird LH2. For these three configurations, the clearances of 34.3 ft, 43.0 ft, and 86.5 ft, respectively, would eliminate the use of the High Bay door for ingress/egress of equipment.

## 19.7 FLIGHT HARDWARE FLOW PATH CONCEPTS

The present flow path of the SRBs and Orbiters will not be changed from the description presented in Paragraphs 19.2.1 and 19.2.2.

### 19.7.1 Concept 1

The conceptual flight hardware flow path uses VAB High Bays 1 and 3 as integration cells and VAB High Bays 2 and 4 as LRB/ET processing and storage areas. The ET processing will not be changed from the description presented in Paragraph 19.2.3. Phase 1 activation would be High Bays 3 and 4 to support first LRB flow.

| | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/CH4 | GDSS LOX/LH2 | GDSS LOX/LH2 "FATBIRD" |
|---|---|---|---|---|---|---|---|
| LRB DRY WEIGHT (LB) | 116665.0 | 199520.0 | 114000.0 | 228000.0 | 104000.0 | 108822.0 | 104339.0 |
| HORIZONTAL LIFT CAPACITY (250-TON AND 175-TON CRANE) (LB) | 850000.0 | 850000.0 | 850000.0 | 850000.0 | 850000.0 | 850000.0 | 850000.0 |
| VERTICAL LIFT CAPACITY (250-TON) (LB) | 500000.0 | 500000.0 | 500000.0 | 500000.0 | 500000.0 | 500000.0 | 500000.0 |
| VERTICAL LIFT MARGIN (LB) | 383335.0 | 300480.0 | 386000.0 | 272000.0 | 396000.0 | 391178.0 | 395661.0 |

Figure 19.6.3. LRB Weight Versus Crane Capacity.

| | MMC LOX/RP-1 PUMP-FED | MMC LOX/RP-1 PRESS-FED | GDSS LOX/RP-1 PUMP-FED | GDSS LOX/RP-1 PRESS-FED | GDSS LOX/CH4 | GDSS LOX/LH2 | GDSS LOX/LH2 "FATBIRD" |
|---|---|---|---|---|---|---|---|
| LEVEL 16 TOP OF STEEL (ELEVATION) | 197.6 | 197.6 | 197.6 | 197.6 | 197.6 | 197.6 | 197.6 |
| CENTER LINE OF CRANE HOOK (ELEV) | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 | 462.5 |
| CLEARANCE ABOVE LEVEL 16 (FT) | 264.9 | 264.9 | 264.9 | 264.9 | 264.9 | 264.9 | 264.9 |
| LENGTH OF LRB (FT) | 150.9 | 162.7 | 148.8 | 195.7 | 150.1 | 191.0 | 169.5 |
| SLING/HYDROSET | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 |
| LRB CLEARANCE OVER | 81.0 | 69.2 | 83.1 | 36.2 | 81.8 | 40.9 | 62.4 |

Figure 19.6.4. VAB Lift Into High Bay

The LRB processing would be accomplished as described in Paragraph 19.2. Figure 19.7.1 shows the flow path of all elements.

### 19.7.1.1 Impacts on Facility Activation

This concept would require activation of High Bays 2 and 4 as LRB processing areas to avoid diagonal transfer of LRBs from High Bay 4 to 1 or High Bay 2 to 3. Diagonal transfers would involve the use of an LRB transporter and additional lift operations. (See Paragraph 19.8.)

Activation of both High Bays 1 and 3 for integration of either LRBs/SSVs or SRBs/SSVs would be required. This would be required to achieve a launch rate of 14 LRBs/SSVs per year within 5 years.

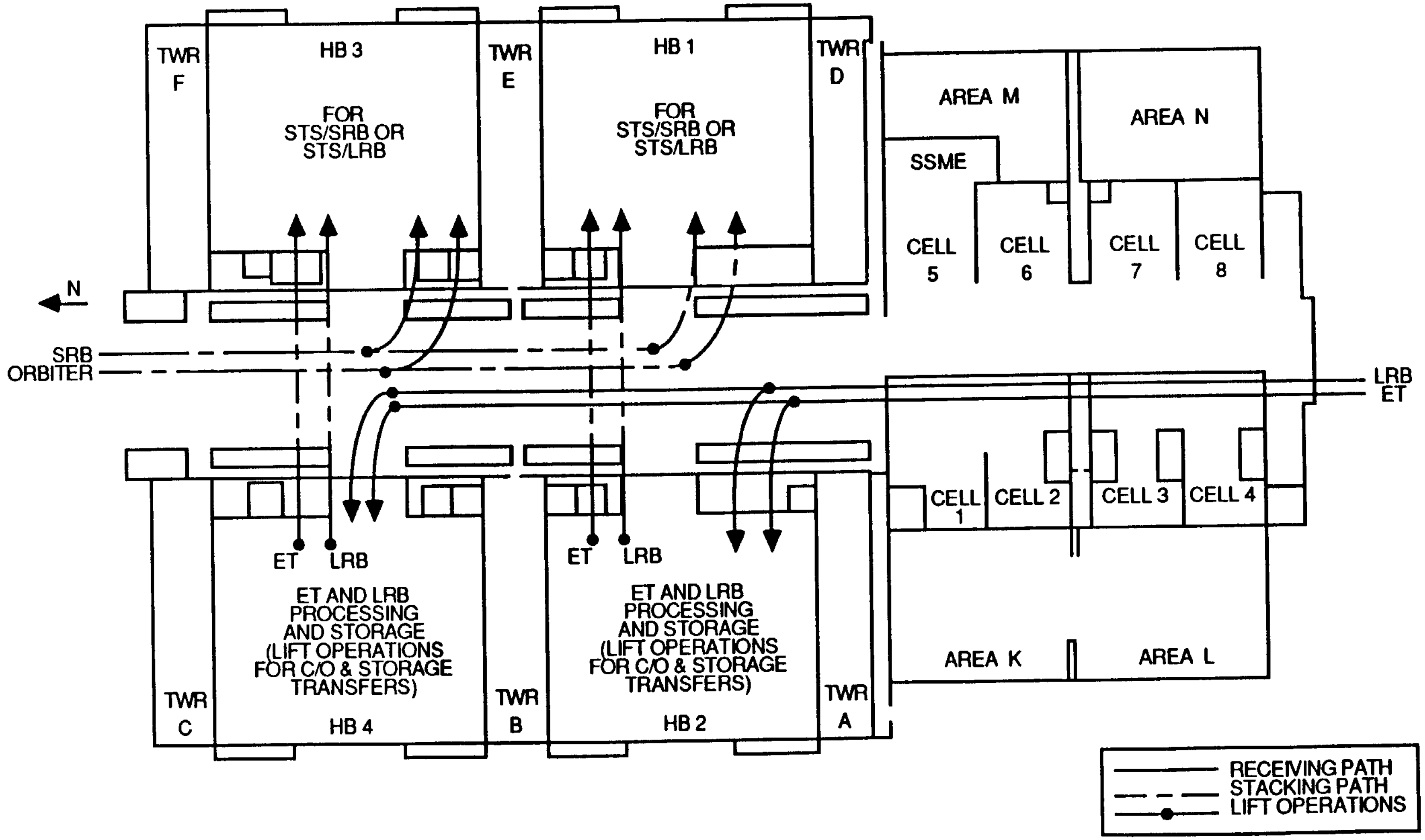
During phase l of construction, outages in the new LRB processing areas (High Bay 4) would occur when ETs are being processed and when SRBs are being stacked. During the construction/modification phase of the dual integration cell (High Bay 2), outages (periods of no work) would occur when the integration cell is utilized. In both these cases, construction time to achieve activation would be increased. An activation schedule is presented in Paragraph 19.9.

### 19.7.1.2 Impacts on Operational Activities

Hazardous operations in the VAB will provide scheduling challenges and outages depending on the operation being performed. The clear areas for various operations, as described in Paragraph 19.1.1.2, will be maintained for lifting operations, pressurization tests, and SRB stacking operations.

### 19.7.1.3 Future Expansion

This concept eliminates the VAB for future program requirements. High Bays 1 and 3 would be used to capacity for Shuttle I integration requirements, and High Bays 2 and 4 would be used to capacity for ET and LRB requirements.


FLIGHT ELEMENT FLOW PATH
VAB HIGH BAY 1 AND 3 AS INTEGRATION CELLS
HIGH BAY 2, 4 AS ET/LRB PROCESSING CELLS

VAB FLOOR PLAN

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Figure 19.7.1. Flight Hardware Flow Path - Concept 1.

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### 19.7.2 Concept 2

The conceptual flight hardware flow path would use VAB High Bay 1 as an integration cell for SRBs/SSVs; VAB High Bay 3 as an integration cell for either SRBs/SSVs or LRBs/SSVs; and activation of VAB High Bay 4 as an integration cell for LRBs/SSVs. LRBs would be processed in a new Horizontal Facility. The ET process described in Paragraph 19.2.3 would be changed to eliminate High Bay 4 as an ET processing area. Figure 19.7.2 shows the flow paths of all elements.

#### 19.7.2.1 Impacts to Facility Activation

This concept would require activation of High Bay 4 as an LRB integration cell. The SRB workstands currently located in High Bay 4 would have to be moved to High Bay 2 so that backup to the RPSF is maintained. The ET stands in High Bay 4 should be relocated to High Bay 2 so that the present processing and storage capacity for ETs is maintained at four.

Activation of High Bay 4 as an integration cell and modification of High Bay 2 to double the ET capacity would be impacted by outages. These outages would include lifting operations, SRB stackings, and ET processing hazardous tests (pressurization).

An advantage to activating High Bay 4 as an integration cell as a first phase activation would be the deferment of modifying High Bay 3 until the SRB flight rate is down so only High Bay 1 would be required.

#### 19.7.2.2 Impacts to Operational Activities

Hazardous operations in the VAB would provide scheduling challenges and outages depending on the operations being performed. The clear areas for various operations (see Paragraph 19.2.) would be maintained.

The diagonal transfer of ETs from High Bay 2 to High Bay 3 or 4 would involve additional crane operations and the transporter. (See Paragraph 19.8 for lifting concerns.)

FLIGHT ELEMENT FLOW PATH
VAB HIGH BAY 1, 3 AND 4 AS INTEGRATION CELLS
HIGH BAY 2 AS ET C/O CELL

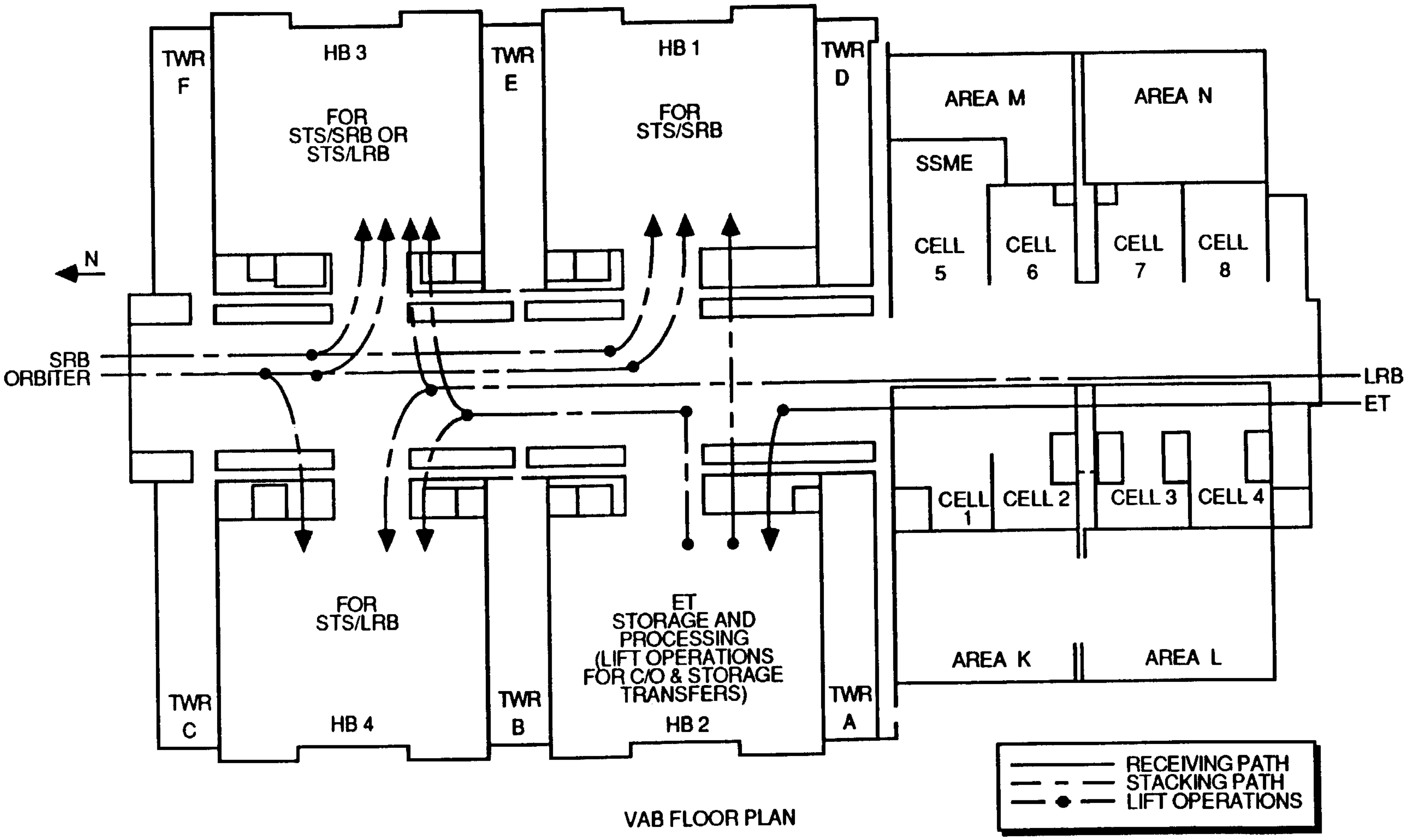

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Figure 19.7.2. Flight Hardware Flow Path - Concept 2.

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#### 19.7.2.3 Future Expansion

This concept would eliminate High Bay 2 from future program expansion, since the available space would be consumed by ET requirements. Providing High Bay 3 or 4 as an integration cell for LRB/SSV would allow High Bay 1 to be used for advanced future programs when SRBs are phased out. Use of an LRB Horizontal Facility would allow expansion of booster requirements for future programs.

### 19.7.3 Concept 3

This conceptual flight hardware flow path uses VAB High Bay 1 as an integration cell for SRB/SSV, VAB High Bay 3 as an integration cell for SRB/SSV or LRB/SSV, and High Bay 4 as an integration cell for LRB/SSV. High Bay 2 would be used for SRB workstand backup to the RPSF. Both LRB and ET processing and storage requirements would be performed in a Horizontal Facility. Figure 19.7.3 shows the flow path of all the elements.

#### 19.7.3.1 Impacts to Facility Activation

This concept requires activation of High Bay 4 as an LRB integration cell. The SRB workstands would be relocated to High Bay 2 (similar to concept 2).

Activation of High Bay 4 as an integration cell would be impacted by the "clear" requirements described in Paragraph 19.1.2 for SRB stacking and lifting. This would decrease the work stoppage time, providing large construction windows.

An advantage to activating High Bay 4 as a first phase activation task would be that modification of High Bay 3 could be deferred until the SRB flight rate is below seven. Another advantage is that impacts to ET processing requirements and schedules would be eliminated.

#### 19.7.3.2 Impacts to Operational Activities

Since ET and LRB processing and storage operations are not in the VAB, their operations would not be impacted by "clear" requirements. Also, lifting operations would be minimal.

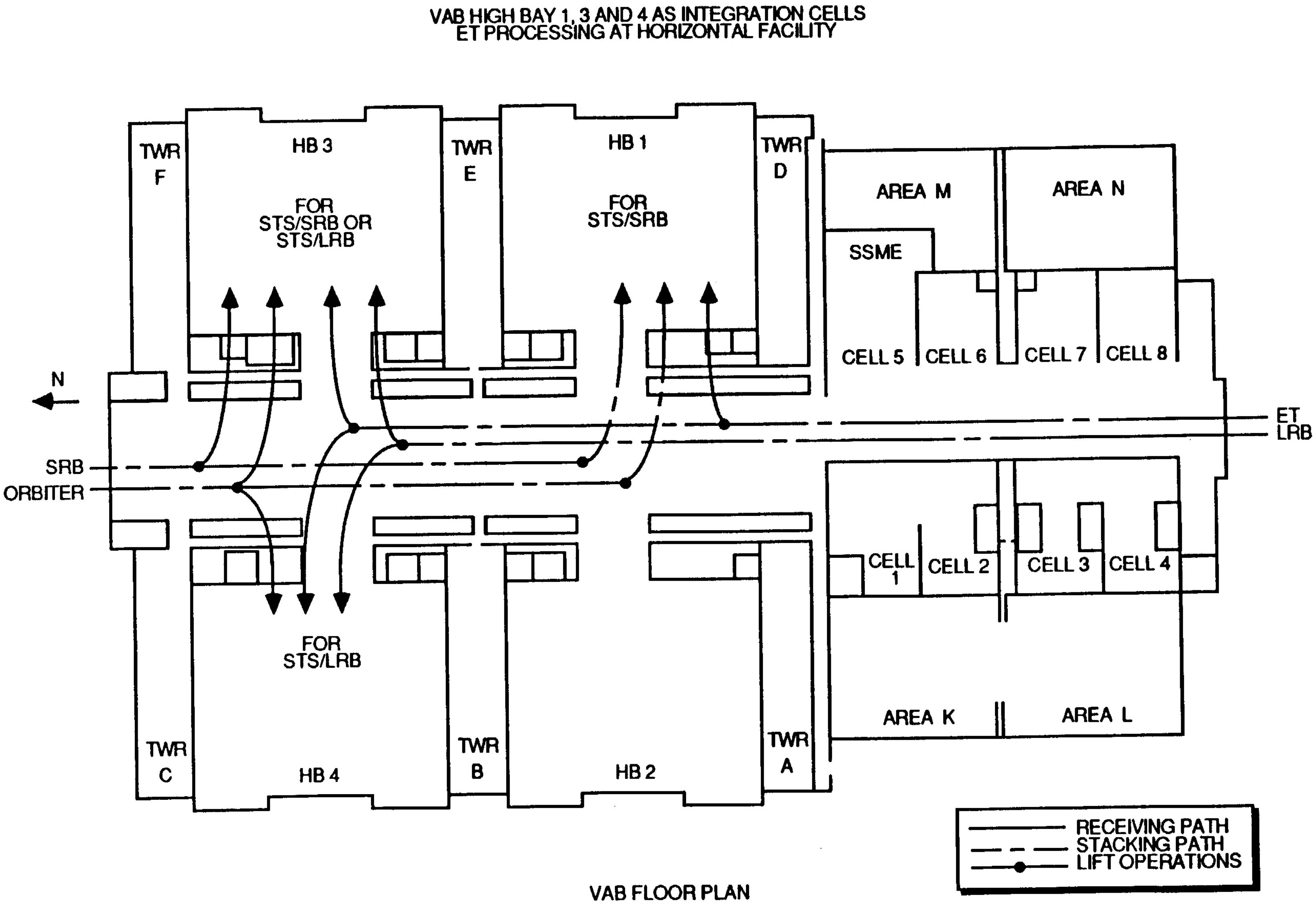

Figure 19.7.3. Flight Hardware Flow Path - Concept 3.

#### 19.7.3.3 Future Expansion

This concept would allow flexibility in meeting the needs of future programs. Utilizing High Bays 3 and 4 as LRB/SSV integration cells would allow High Bay 1 to be used for advanced programs when SRBs are phased out. Processing and storing ETs and LRBs at a Horizontal Facility would allow expansion of ET and booster requirements for future programs. VAB High Bay 2 would also be available for future needs of the program.

## 19.8 LIFTING OPERATIONS IMPACTS/EVALUATION

Each of the concepts presented in Paragraph 19.7 shows impacts to or enhancement of VAB crane utilization and lift requirements. (Since Orbiter and SRB lifts would not be changed by the introduction of LRBs to the Shuttle program, they are excluded from the analyses.)

Concept 1 would increase the number of lifts that would be required. Figure 19.8-1 shows that four lifting operations would be required to stack/mate an LRB/SSV (excluding the Orbiter) in either High Bay 1 or 3. The present requirement for ETs is three.

Concept 2 would require six lift operations to stack/mate an LRB/SSV (excluding the Orbiter) in High Bay 3 or 4. The ET mating requirement for High Bay 1 would remain unchanged at three, since LRBs are not integrated in High Bay l. See Figure 19.8-2.

Concept 3 would require three lift operations to stack/mate an LRB/SSV (excluding the Orbiter) in High Bay 3 or 4. An SRB/SSV stacking/mating operation would require one lift of an ET. This is a reduction of two lifts for an SRB/SSV integration. See Figure 19.8-3.

Since lifting flight hardware is a hazardous operation requiring clear areas, minimizing the number of lifts represents a significant enhancement of the entire program.

## 19.9 ACTIVATION IMPACT

The significant impact of processing LRBs in the VAB to meet a January 1996 launch date is that it would require activation of an integration cell and an LRB processing facility by January of 1995. The first LRB flow would occur between May of 1995 and launch day.

| LIFTS | ORBITER | ET | LRB (EACH) | SRB (EACH) | TOTAL |
|---|---|---|---|---|---|
| TRANSFER AISLE TO | | | | | |
| HB1 | 1 | | | 5(x2) | |
| HB2 | | 1 | 1(x2) | | |
| HB3 | 1 | | | 5(x2) | |
| HB4 | | 1 | 1(x2) | | |
| BETWEEN CELLS IN | | | | | |
| HB2 | | 1 | 1(x2) | | |
| HB4 | | 1 | 1(x2) | | |
| TRANSFERS BETWEEN | | | | | |
| HB2 TO HB1 | | 1 | 1(x2) | | |
| HB4 TO HB3 | | 1 | 1(x2) | | |
| TOTAL LIFTS FOR INTEGRATION IN | | | | | |
| HB1 | 1 | 3 | 3(x2) | 5(x2) | |
| HB3 | 1 | 3 | 3(x2) | 5(x2) | |
| TOTAL LIFTS TO HB1 | | | | | |
| FOR LRB/SSV | | | | | 10 |
| FOR SRB/SSV | | | | | 14 |
| TOTAL LIFTS TO HB3 | | | | | |
| FOR LRB/SSV | | | | | 10 |
| FOR SRB/SSV | | | | | 14 |

Figure 19.8-1. VAB Lift Operation Analysis- Concept 1.

| LIFTS | ORBITER | ET | LRB(EACH) | SRB(EACH) | TOTAL |
|---|---|---|---|---|---|
| TRANSFER AISLE TO | | | | | |
| HB1 | 1 | | | 5(x2) | |
| HB2 | | | | | |
| HB3 | 1 | 1 | 1(x2) | 5(x2) | |
| HB4 | 1 | | 1(x2) | | |
| BETWEEN CELLS | | | | | |
| HB2 | | 1 | | | |
| TRANSFERS BETWEEN | | | | | |
| HB2 TO HB1 | | 1 | | | |
| HB2 TO HB3 | | 2 | | | |
| HB2 TO HB4 | | 2 | | | |
| TOTAL LIFTS FOR INTEGRATION IN | | | | | |
| HB1 | 1 | 3 | | | |
| HB3 | 1 | 4 | 1(x2) | 5(x2) | |
| HB4 | 1 | 4 | 1(x2) | 5(x2) | |
| TOTAL LIFTS TO HB1 | | | | | |
| FOR LRB/SSV | | | | | 0 |
| FOR SRB/SSV | | | | | 14 |
| TOTAL LIFTS TO HB3 | | | | | |
| FOR LRB/SSV | | | | | 7 |
| FOR SRB/SSV | | | | | 15 |
| TOTAL LIFTS TO HB4 | | | | | |
| FOR LRB/SSV | | | | | 7 |
| FOR SRB/SSV | | | | | 0 |

Figure 19.8-2. VAB Lift Operation Analysis - Concept 2

| LIFTS | ORBITER | ET | LRB (EACH) | SRB (EACH) | TOTAL |
|---|---|---|---|---|---|
| TRANSFER AISLE TO | | | | | |
| HB1 | 1 | 1 | | 5(X2) | |
| HB3 | 1 | 1 | 1(X2) | 5(X2) | |
| HB4 | 1 | 1 | 1(X2) | | |
| TOTAL LIFTS FOR INTEGRATION IN | | | | | |
| HB1 | 1 | 1 | | 5(X2) | |
| HB3 | 1 | 1 | 1(X2) | 5(X2) | |
| HB4 | 1 | 1 | 1(X2) | | |
| TOTAL LIFTS TO HB1 | | | | | |
| FOR LRB/SSV | | | | | 0 |
| FOR SRB/SSV | | | | | 12 |
| TOTAL LIFTS TO HB3' | | | | | |
| FOR LRB/SSV | | | | | 4 |
| FOR SRB/SSV | | | | | 12 |
| TOTAL LIFTS TO HB4 | | | | | |
| FOR LRB/SSV | | | | | 4 |
| FOR SRB/SSV | | | | | 0 |

Figure 19.8-3. VAB Lift Operation Analysis - Concept 3.

### 19.9.1 Concept 1 Activation Impact

Activation of VAB High Bay 4 as an LRB processing facility and High Bay 3 as an integration facility would be required. It is estimated that conversion of VAB High Bay 3 from an SRB/SSV integration cell to a dual SRB/SSV and LRB/SSV integration cell would take 13 months of uninterrupted work time to accomplish the required modifications. The present conceptual facility utilization plan shows only 151 days of open work periods in High Bay 3 available from October 1991 to October 1994. Conversion of High Bay 3 in this time frame would require suspension of at least eight flights scheduled to be stacked/mated and integrated. Figure 19.9.1 presents an activation schedule.

It is estimated that activation of High Bay 4 as an LRB processing/storage facility would take 9 months. Requirements to clear for SRB stacking in High Bay 3 and ET pressurization in High Bay 4 would lengthen this estimate. Without suspending operations in High Bay 3 or 4, meeting a January 1995 deadline would be difficult.

### 19.9.2 Concept 2 Activation Impact

Activation of VAB High Bay 4 as an LRB integration facility and constructing a new LRB horizontal facility would be required. To maintain the existing flight rate schedule of 14 launches per year, the ET processing capacity of VAB High Bay 2 must be doubled.

It is estimated that activation of VAB High Bay 4 as an LRB integration facility would take 28 months. This estimate takes into account the "clear" orders associated with SRB stacking in High Bay 3. Activation of additional ET cells and moving SRB workstands in High Bay 2 is estimated to take 9 months. This estimate takes into account SRB stacking in High Bay 2 and increased work requirements in the existing High Bay 2 ET cells to meet flight requirements. During this activation period, besides construction of new ET cells, an increase in the number of ETs processed in High Bay 2 would occur. Unscheduled impacts may occur, which would result in construction time increases. The diagonal transfers of ETs from High Bay 2 to High Bay 3 would impact the integration schedule currently planned. Figure 19.9.2 depicts the activation schedule. It is estimated that activation of the LRB facility would take 25 months.

It would be possible to meet a January 1996 LRB first launch date. However, interruption of the existing conceptual SRB/SSV flight rate would be possible with unscheduled events during con-

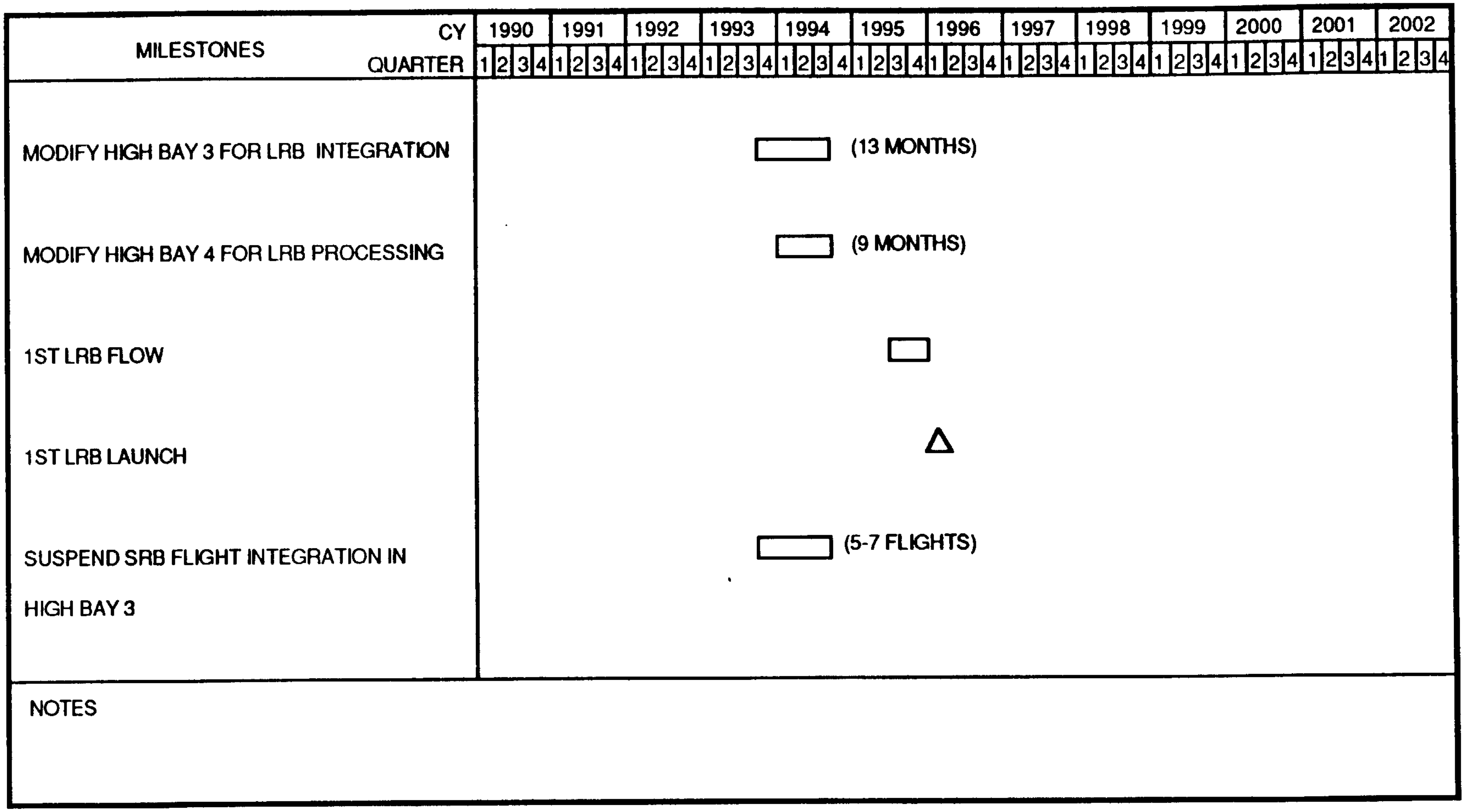

Figure 19.9.1. Activation Schedule - Concept 1.

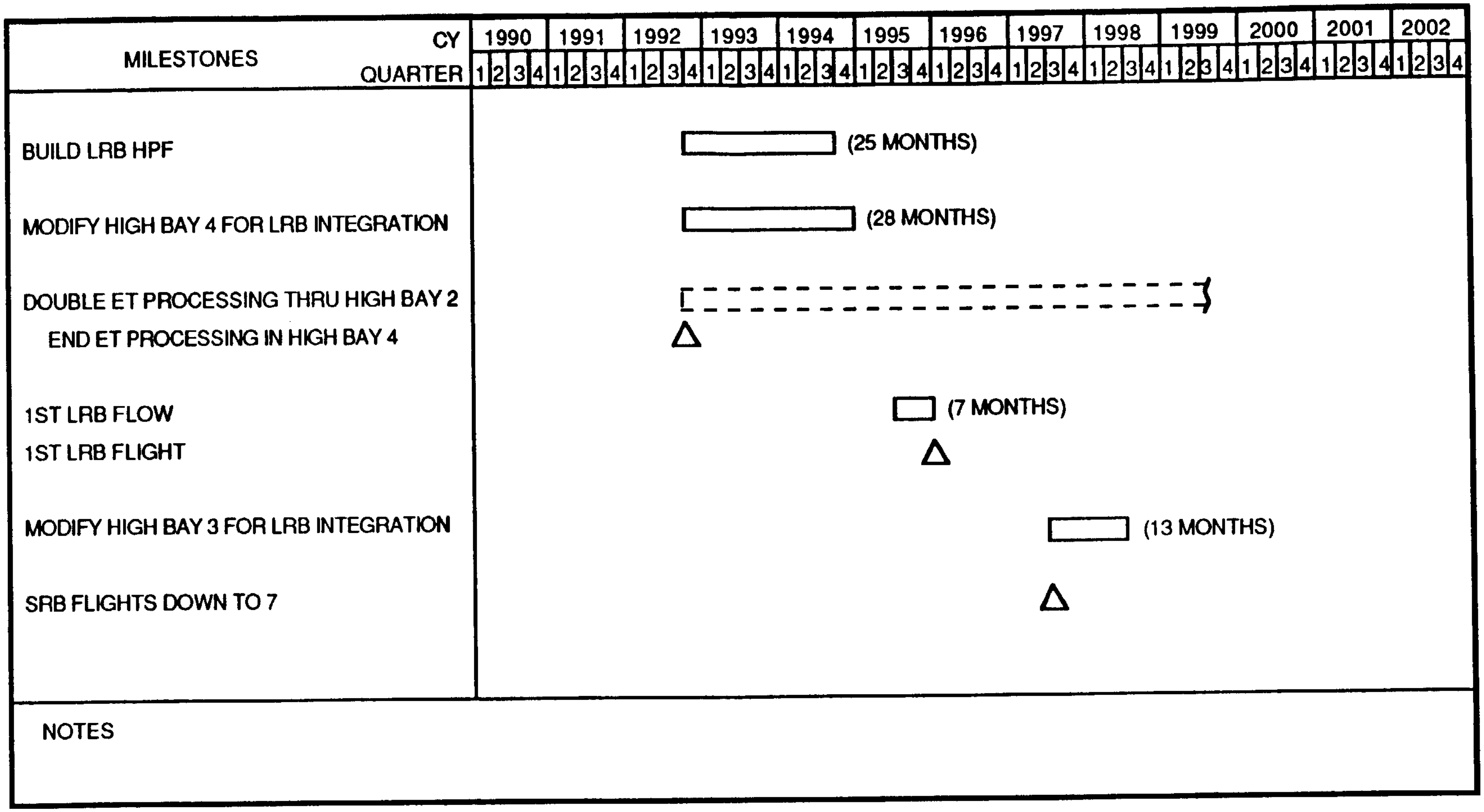

Figure 19.9.2. Activation Schedule - Concept 2.

struction/activation of LRB facilities. The reverse is also possible -- of SRB/SSV processing interrupting construction.

Activation of High Bay 3 as a dual SRB/LRB integration facility could be deferred to May of 1997 when SRB flights are seven per year.

### 19.9.3 Concept 3 Activation Impact

Activation of VAB High Bay 4 as an LRB integration facility and a new Horizontal Facility for ETs and LRBs would be required. Figure 19.9.3 depicts an activation schedule for the new ET facility, new LRB facility, and VAB High Bay 4. The estimated time required for activation of High Bay 4 is 28 months. This estimate takes into account the clearing time associated with LRB stacking in High Bay 3. Although unscheduled impacts on construction may occur from SRB operations, planning to do prefabrication will allow for no significant time delay.

This is the most promising concept, since changes to ET processing and the addition of LRB processing occur at a new construction site away from the VAB.

Activation of VAB High Bay 3 as a dual SRB/LRB integration facility could be deferred to May of 1997 when SRB flights are seven per year.

## 19.10 VAB QUANTITY/DISTANCE REQUIREMENTS

The proposed site for an ET/LRB Horizontal Facility is an area outside the VAB blast zone, which extends 1,310 ft around from the center of VAB Tower E. Although other considerations for siting are presented in Paragraph 3.1 of Section 3, Volume III consideration of processing ETs and LRBs outside the zone is recommended. The primary site shown in Figure 19.10 would provide access to the barge terminal and existing tow route with the least environmental impact. Paragraph 3.10 of Section 3, Volume III explained this concern in more detail.

## 19.11 LRB TEST/CHECKOUT CELL DESCRIPTION

The LRB test/checkout cells would have to be located in High Bays 2 and 4, as shown in Figures 19.5.1 and 19.5.2. The cells would be limited to a horizontal envelope of 38 by 38 ft. As shown in Figure 19.5.3, sufficient work area around the LRB would be available. This work space would be

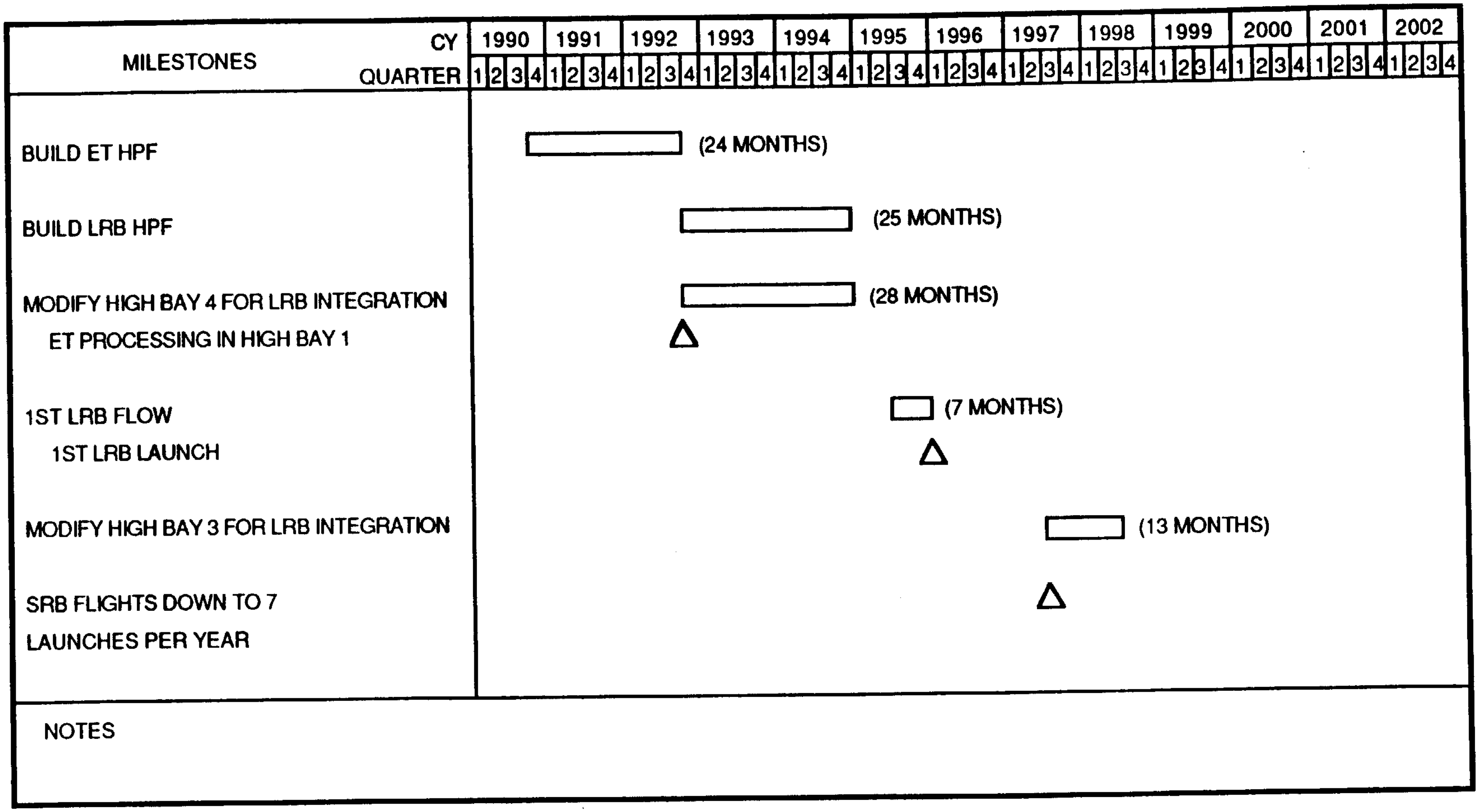

Figure 19.9.3. Activation Schedule - Concept 3.

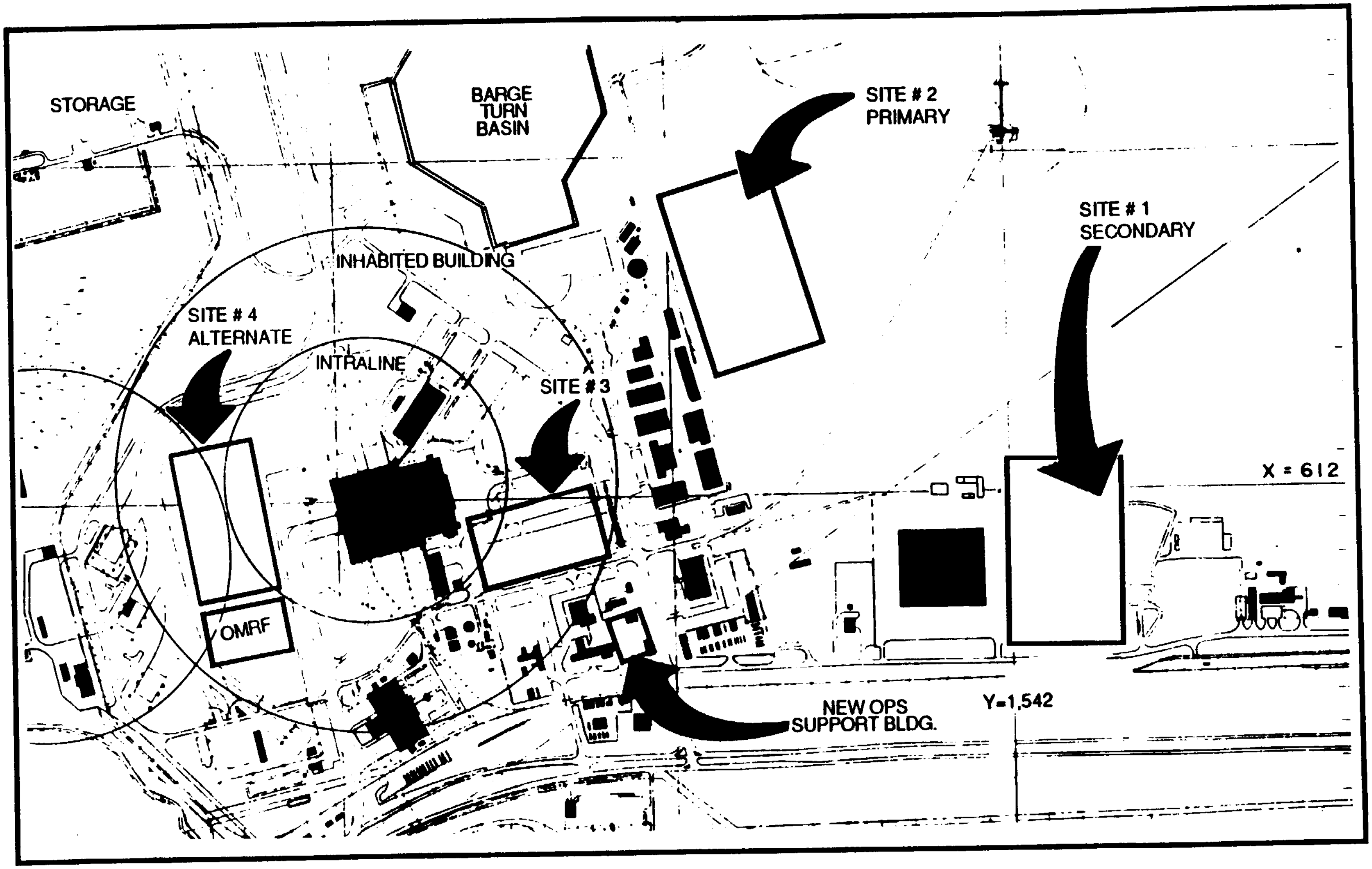

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Figure 19.10. Possible Site of Proposed LRB Processing Facility.

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as large as 11.5 ft for the GDSS RP1/LOX pump fed to as small as 9.6 ft for the GDSS LOX/LH2 "Fat Bird." Figure 19.6.1-1 and Figure 19.6.1-2 show the maximum and minimum elevations of the test cell due to crane lift capability. Holddown posts qualified at the LETF to support the LRBs would be located at the base of the test cell. These posts would be required to be tested and qualified in all aspects of certification except launch loads and would not have a release mechanism.

Flip-ups would be provided to insert and extract an LRB from the check out cell and clear the LRB skirt by 18 inches.

## 19.12 DESIGN CONSIDERATION FOR VAB ET/LRB PROCESSING NEW FACILITY

### 19.12.1 LRB Design Considerations

Utilizing the VAB for employment of LRBs would require operational tasks not needed if the LRB were to be processed horizontally. Lifting and rotating items into a processing cell would not be required. All processing, engine changeout, and storage would be done on the transporter. Figure 19.12.1 shows a comparison between vertical and horizontal LRB processing. The envelope in the VAB would be limited to 38 by 38 ft for each LRB, while in a new facility the envelope could be built to suit. Surge/storage capability is limited to two flight sets in the VAB in each High Bay (2 or 4) while a new facility could be built as required. The details are contained in Paragraph 3.1 of Volume III, Section 3.

### 19.12.2 ET Design Considerations

The present use of the VAB for ET processing requires operational tasks not needed if the ET is processed horizontally. Lifting operations would be reduced. All processing and storage would be done on the transporter. Figure 19.12.2 shows the comparison. Surge/storage capabilities are limited to two ETs in each VAB High Bay (2 or 4) while a new facility could be built with the possibility of storage/processing expansion. Paragraph 3.1 of Volume III, Section 3 contains the details.

|  | VERTICAL CONCEPT 1 | HORIZONTAL CONCEPT 3 |
|---|---|---|
| LIFT ROTATION | REQUIRED | NONE REQUIRED |
| STORAGE/PROCESSING | ON HOLD DOWN POSTS | ON TRANSPORTER |
| ENGINE CHANGEOUT | VERTICALLY | HORIZONTALLY |
| ENVELOPE | 38-FEET BY 76-FEET | UNLIMITED |

Figure 19.12.1. LRB Design Requirements - Horizontal versus Vertical

|  | VERTICAL CONCEPT 1 | HORIZONTAL CONCEPT 3 |
|---|---|---|
| LIFT ROTATION | REQUIRED | NONE REQUIRED |
| STORAGE/PROCESSING | IN CELL | ON TRANSPORTER |
| ENVELOPE | EXISTING | UNLIMITED |

Figure 19.12.2. ET Design Requirements - Horizontal versus Vertical

## 19.13 CONCLUSIONS FOR USE OF HIGH BAYS 2 AND 4 FOR LRB PROCESSING

The three concepts presented each have their own advantages and disadvantages. The use of High Bays 2 and 4 for processing LRBs, although feasible, has an implementation disadvantage. Without impacting the launch rate, High Bay 3 would be difficult to activate as an LRB/SSV integration facility. The number of lifting operations required to process LRBs is not the optimum desired for a new flight element. To minimize impacts to launch rate, a new integration facility (High Bay 4) and a new horizontal processing facility for LRBs are recommended.

The use of High Bay 2 for all ET processing increases significantly the number of lifts for ET mate in High Bay 3 and 4. This requirement for additional lifts is not recommended. To eliminate the need for additional ET lifts, a new horizontal ET facility is recommended. In both these concepts, expansion of High Bays 2 and 4 LRB and ET processing facilities for future programs is eliminated. Also, the limited storage capacity may impact the flight rate. Removing ETs from the VAB, locating LRBs outside the VAB blast area, and reducing lifting operations would enhance the safety of the existing program. Figure 19-13 illustrates the advantages and disadvantages of processing LRBs and ETs vertically vs horizontally.

## 19.14 REFERENCE DOCUMENTATION

The following drawings and documents are listed as references:

Vehicle Assembly Building Modification - 79K05424
Space Shuttle SRB Rotation Integration - 79K07022
(LC-39 Area KSC)
VAB High Bay - Architectural, Vol 14 - 203-100
Sling Set ET Forward - H78-3006

## 19.15 FINAL COMMENTS

The present operational philosophy and opinion is that the VAB is large and any new program requirement can be accomplished there. After reviewing this study a few conclusions stand out by the introduction of a mixed fleet and the addition of program requirements in the VAB.

| | HORIZONTAL PROCESSING | | VERTICAL PROCESSING | |
|---|---|---|---|---|
| | ADVANTAGES | DISADVANTAGES | ADVANTAGES | DISADVANTAGES |
| PROCESSING | ● MINIMAL LIFTS/ ROTATION OF LRB & ET<br>● ALLOW PATALLEL PROCESSING OF ALL FLIGHT ELEMENTS<br>● LEAST RECURRING COST<br>● OUT OF VAB BLAST AREA<br>● ENGINE REPLACEMENT HORIZONTALLY<br>● LOCAL LOGISTICS AREA LOCAL ENGINE SHOP<br>● LOCAL CONTROL ROOM<br>● ONE FACILITY FOR LRB PROCESSING/ STORAGE<br>● HORIZONTAL PROCESSING ON TRANSPORTER<br>● ONE FACILITY FOR ET PROCESSING/ STORAGE<br>● MAX SURGE CAPACITY<br>● MINIMAL INTERACTOIN OF FLIGHT ELEMENT PROCESSING | ● GREATEST NON-RECURRING COST<br>● SOME ET PROCESSING REQUIREMENT WILL BE DONE IN INTEGRATION CELL<br>● NEW ET OMI's REQUIRED | ● LEAST NON-RECURRING COST<br>● ALL ET PROCESSING REQUIREMENT DONE IN PROCESSING FACILITY<br>● EXISTING ET OMI's USED | ● EXTENSIVE LIFTS/ ROTATION OF LRB & ET<br>● SERIAL PROCESSING OF ALL FLIGHT ELEMENSTS<br>● GREATEST RECURRING COST<br>● IN VAB BLAST AREA<br>● ENGINE REPLACEMENT VERTICALLY<br>● REMOTE LOGISTICS AREA<br>● REMOTE ENGINE SHOP<br>● CONTROL ROOM IN LCC<br>● TWO HIGH BAYS FOR LRB PROCESSING/ STORAGE<br>● VERTICAL PROCESSING IN TEST CELL<br>● TWO HIGH BAYS FOR ET PROCESSING/ STORAGE<br>● MIN SURGE CAPACITY<br>● MAXIMUM INTERACTION OF FLIGHT ELEMENT PROCESSING |
| ACTIVATION | ● MINIMAL IMPACT TO FLIGHT RATE<br>● MINIMAL IMPACT TO FLIGHT RATE | | | ● POSSIBLE SUSPENSION OF SRB/SSV FLIGHTS<br>● EXTENSIVE IMPACTS TO ACTIVATION |
| FUTURE UTILIZATION | ● VAB HIGH BAY 2 AVAILABLE FOR FUTURE USE | | | ● VAB HIGH BAYS USED |

Figure 19.13. Comparison of Horizontal versus Vertical Processing of ET and LRB.

Utilization of only two integration cells means an impact to current launch operation plans, if an existing integration cell is modified. Presently external tank processing is performed during valuable work windows. These available work windows will become smaller when the launch rate of 12 to 14 is achieved, thereby impacting ET processing.

To achieve the capability of a mixed fleet without impacting the planned launch rate, new facilities (integration cell, processing facilities) will be required. Past experience shows SRB processing, both operational and safety wise, impacted the integration process. Due to these impacts the SRB Assembly and Refurbishment Facility (ARF), and Rotation Processing and Surge Facility (RPSF) where provided. It is envisioned that the same impacts will be encountered with the introduction of LRB or any other mixed fleet requirements.

The final conclusion is the VAB should be used as an integration facility and not a processing facility. This means removing ET processing from the facility.