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Paper Session I-A - Launch Site Integration of Liquid Rocket Boosters

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LAUNCH SITE INTEGRATION OF LIQUID ROCKET BOOSTERS

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ABSTRACT

The impacts of introducing Liquid Rocket Boosters (LRB) into the STS/KSC launch environment are identified and evaluated. Proposed ground systems configurations are presented along with a launch site requirements summary. Pre-launch processing scenarios are described and the required facility modifications and new facility requirements are analyzed. Flight vehicle design recommendations to enhance launch processing are discussed. Processing approaches to integrate LRB with existing STS launch operations are evaluated. The key features and significance of launch site transition to a new STS configuration in parallel with on-going launch activities are enumerated.

INTRODUCTION

As a part of the overall STS program reassessment, Liquid Rocket Boosters (LRBs) are being evaluated as a replacement for the SRBs. The LRB could substantially improve STS payload capability, flight safety/reliability and could significantly streamline ground processing operations. NASA-MSFC initiated LRB design studies with General Dynamics and Martin Marietta. NASA-KSC conducted a companion study with Lockheed Space Operations Company (LSOC) to assess launch site integration of the LRB including impacts on facilities, operations and costs. Launch site recommendations were provided to the flight hardware design studies. In addition, NASA-JSC and their contractor, Lockheed Engineering and Sciences Company (LESC), have evaluated the ascent flight design of the LRB/STS and Level II integration issues. The three NASA center/contractor teams have established a technical working group network which was used to exchange LRB requirements and impact data. This level of coordination at the Phase A level of design has resulted in an operationally efficient design approach for the LRB flight system and the ground processing scenarios.

STUDY OBJECTIVES

The purpose of the LRB study was to assess the feasibility of replacing the STS Solid Rocket Boosters with Liquid Rocket Boosters. The KSC Integration Study Objectives are:

- o Define Facility/Operational Impacts
- o Develop Processing Scenarios/Transition Plans
- o Provide Booster Design Recommendations
- o Promote Operationally Efficient LRB System
- o Enhance the Ground Operations Cost Model
- o Formulate Launch Site Cost Assessments
- o Develop Preliminary LSE/GSE Designs
- o Create a Complete Launch Site Plan for LRB

The LRBI Study goal was to accommodate the Shuttle/LRB system with minimum impact to the STS/KSC ongoing ground processing operations.

LAUNCH SITE SCENARIO

After numerous trade studies, the LRBI Study Team assessment of the selected launch scenario resulted in the approach illustrated in Figure 1. This scenario begins with the delivery of the assembled boosters by barge to the turn basin near

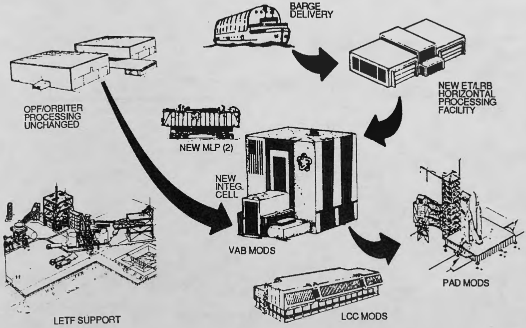


Figure 1. Preliminary LRB Scenario.

the VAB, followed by offload of the boosters via towed transporters. The boosters then enter the new Horizontal Processing Facility (HPF) where all standalone, checkout and flight certification activities are performed. The boosters begin the integrated part of ground processing by being towed (still on the delivery transporters) to the VAB. After all MLP preparations are completed the boosters are rotated and lifted into the new High Bay 4 integration cell where they are mated and aligned on the MLP holddown system. As noted in the figure the MLP is new and custom built for the LRBs. The remainder of VAB operations are similar to current procedures. The ET is mated to the boosters followed by closeout operations and preparations for Orbiter mate. Following Orbiter mate, the all-up Shuttle Integrated Test (SIT) is performed. Transfer to the Pad via the crawler/transporter is followed by standard SSV to Pad interface checks, payload operations and system readiness checks. The LRB fuel loading (if RP-1 is selected) can precede the countdown operations by several days. Existing LOX and LH2 (if selected) propellant facilities will be modified to provide adequate storage and transfer capabilities to support LRB requirements. Cryo-loading software and procedures will be updated to accommodate LRB. LOX/LH2 is the preferred propellant at the launch site.

The overall LRB scenario will incorporate planned testing support at the Launch Equipment Test Facility (LETF) and significant modification of application software and new firing room consoles in the Launch Control Center (LCC). The timeline for a typical LRB flow through this launch site scenario is presented in Figure 2 where a summary of the 130-item task processing schedule is illustrated. Flow time in work days is shown to total 58 days from receipt of booster hardware to launch. This same span for SRB is forecast to be 78 days in mid-90s time frame. Therefore, LRB operations should result in lowered de-

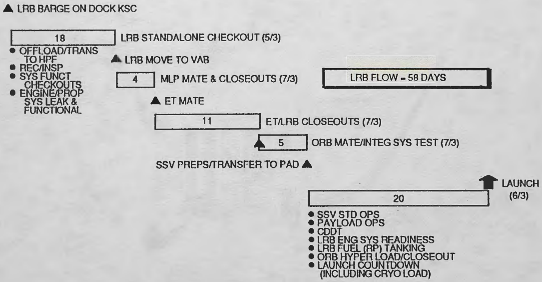


Figure 2. Generic LRB Process Flow.

mand on launch site resources for the same sustained flight rate or, alternately, the enhanced potential for increased launch rate capability. This is illustrated in Figure 3 where SRB and LRB flows are compared.

	WORK DAYS		%
	SRB	LRB	REDUCTION
VAB HB (INTEG CELL)	21	4	81%
MLP USE PER FLOW	55	40	27%
INTEG CRITICAL PATH (BOOSTER STACK TO ORB MATE)	32	15	53%
PAD FLOW	18	20	-11%
BOOSTER FLOW (PRE-LAUNCH)	78	58	25%

Figure 3. SRB/LRB Flow Comparison.

The implementation of effective LRB operations will require the following major provisions:

- o An activation management team to affect the facility activations, modification and verifications with minimum impacts to existing launch operations.
- o Dedicated manpower, trained and certified for LRB processing.
- o Effective planning for LRB launch rate buildup and integration with ongoing launch operations.
- o Advanced budget provisions (CoF and R&D).
- o Integrated planning with the flight hardware contractor using the assistance of a launch support services function.
- o Documentation of procedures and planned support functions.

- o Effective project management, timely analysis and decision making.

Using the overview of the launch site plan shown in Figure 4 the three basic phases of the project can be seen to span a period of approximately 16 years at the launch site. The transition phase from SRB to LRB launch operations (1996 through 2000) is the most critical phase. This will be true for any new large modification to the STS. The launch profile portion of the "life cycle" of the LRB program extends over 122 LRB missions. This profile was used by all LRB planners for life cycle cost evaluations.

LAUNCH SITE DESIGN RECOMMENDATIONS

LRB flight article design features which would enhance, simplify or streamline ground processing operations at the KSC launch site have been identified and provided to MSFC and the Phase-A contractors. Feedback on these recommendations was received and many features have been incorporated into the Phase-A designs. In addition, the KSC facility constraints have been identified and all proposed designs have been influenced by these STS constraints. Attempts have been made to minimize the magnitude of required launch site mods (i.e. the pad flame trench) due to the extended mod period required. Impacts to on-going launch operations can thus be reduced. Figure 5 summarizes the launch site LRB design recommendations.

Early in the LRB evaluation process the Study Team drafted a "KSC Requirements checklist for LRB". This document, after review and approval at KSC, was circulated to the Martin and General Dynamics Study Teams. The checklist is designed in the form of a questionnaire on ground processing requirements for LRB. Responses were received from both of the flight element contractors. The format of the checklist addressed both general groundrules and specific categories of requirements. During Phase-B preliminary design it is anticipated that the requirements checklist will be updated to be descriptive of the final selected LRB configuration.

FACILITY IMPACTS

HPF - The new Horizontal Processing Facility has been conceptually designed and sited to support processing of LRB and ET with provisions for two-flight surge storage. Shop areas are provided for LRB engines, battery, TPS and electronics/avionics activities. Areas for logistics, GSE and LRU storage are incorporated along with a mini-LPS control room for standalone testing. Horizontal access stands and platforms are to be provided for all off-line ET and LRB processing.

MLP - After evaluations of the feasibility for modifying existing MLPs for LRB, it was decided that an all new MLP design and construction would be required. The two key factors in this decision were: 1) removal of one of the three SRB/MLPs from service for an extended mod period would result in lost or delayed missions and 2) the feasibility of expanding the MLP flame holes and holddown system for LRB was found to be doubtful.

VAB - The conversion of VAB/High Bay 4 into a full STS integration cell for LRB will support initial LRB processing without disruption of on-going SRB/STS flight processing in HB-1 and HB-3. The resulting flight hardware flow path is illustrated in Figure 6, where HB-4 is for LRB only and HB-3 is converted for multiple use (SRB or LRB). This conversion is planned late in the transition when the SRB flight rate can be supported from HB-1 alone. Under this scenario the number of required lifting operations for an STS stack will be reduced for LRB from the current 14 to only 4 (a 70% reduction) and the LRB has no live propellant onboard (a significant safety feature).

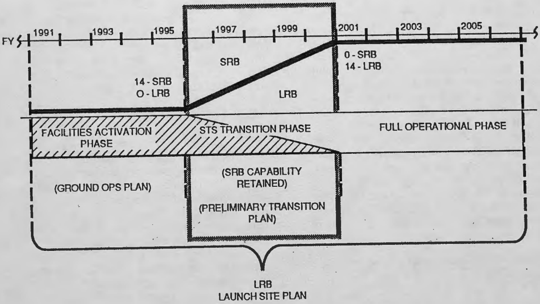
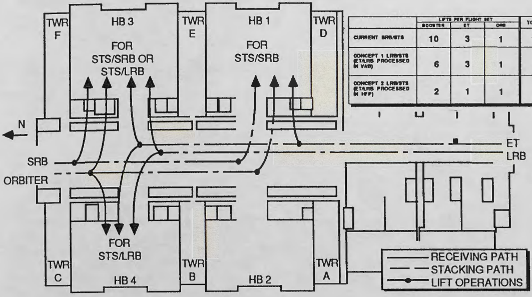


Figure 4. Launch Site Plan Overview.

DESIGN RECOMMENDATIONS	
• NO HYDRAULICS/NO HYDRAZINE	• USE SEPARATE BOOSTER DOWNLINK (RF)
• USE LIFT-OFF UMBILICALS- NO SWING ARMS OR LUT	• FACILITATE SEPARATE LRB STANDALONE TEST AND CHECKOUT
• MAXIMUM LRB DIAMETER LESS THAN 16 FEET	• ON BOARD LOX VENTS/NO BEANIE CAP
• LOCATE AVIONICS LRU's IN AFT SKIRT AREA	• HARD MOUNTED ENGINES (NOZZLE GIMBALS FOR TVC)
• FACILITATE ENGINE R/R IN VERTICAL ON MLP	• MINIMIZE ET MODS
• USE EXPENDABLE DESIGN	• ELIMINATE ENGINE PURGES, BLEEDS AND SPECIAL PREPS
• LOX/LH2 PROPELLANTS HAVE MINIMUM PAD IMPACTS	• CONSIDER EXTERNAL POD FOR AVIONICS AND BATTERIES TO FACILITATE ACCESS AND EASE OF SERVICE
• NO FLAME TRENCH (CONCRETE) MODS AT PAD	• AVOID ELEPHANT TRUNKS (TRAPS) IN PROPELLANT LINES THAT REQUIRE SPECIAL ATTENTION
• FACILITATE VERTICAL AND HORIZONTAL CHECKOUT	
• MAKE BOOSTER AUTONOMOUS WITH MINIMUM ORBITER INTERFACES	

Figure 5. KSC-LRB Design Recommendations.

VAB HIGH BAY 1, 3 AND 4 AS INTEGRATION CELLS
ET AND LRB PROCESSING AT HORIZONTAL FACILITY



	LIFTS PER FLIGHT SET			TOTAL
	BOOSTER	ET	ORB	
CURRENT SRB/STS	10	3	1	14
CONCEPT 1 LRB/STS (ET/LRB PROCESSED IN VAB)	6	3	1	10
CONCEPT 2 LRB/STS (ET/LRB PROCESSED IN HFP)	2	1	1	4

VAB FLOOR PLAN

Figure 6. VAB Recommended Concept.

The trade study results for lifting operations are illustrated in the table where two concepts are compared with the current SRB baseline. Concept 2 was selected for our final scenario.

PAD - Pad B has been selected for use on initial LRB launches due to the cycles of normal mods and update intervals which places Pad B in line for an upgrade at about the timeframe of LRB activations. Impacts with planned launches at Pad B during this mod period will be avoided by diverting certain SRB launches from Pad B to Pad A. Exclusive access for the modifications is needed for the last eight months leading up to Pad certification for LRB. The diversion of on-going launches to a single Pad poses one of the highest potential risks for STS launch impact or delay in the implementation of facilities for LRB. Mods for LRB are planned to retain existing MLP-to-Pad capability for SRB/STS launches after conversion.

Potential schedule impacts could occur at the Pad if required mods grow more significant. For example, flame deflector, vent arms and flame trench (concrete) mods are potential "hitters" due to the increasing diameter of some LRB configurations. In addition, any anomalies discovered during the planned LRB "Pathfinder" flow could delay LRB implementation placing more SRB launch schedule pressure on Pad A. Manpower and funding requirements are included in our activation plan.

New propellant requirements at the Pad have been defined and storage/pumping systems were conceptually designed for LOX, RP-1 and LH2. Major modifications to the side deflectors and main trench deflector were required to accommodate LRB designs.

OTHER FACILITY MODS - The Launch Equipment Test Facility (LETF) must support the development and verification testing of all MLP-mounted launch support equipment (LSE). The facility will be modified to support this testing and the manpower, schedule and funding have been identified. The Launch Control Center will be modified with new software and consoles for LRB processing and launch support.

By specifying a standalone mini-LPS at the HPF the existing control rooms will be relieved of the need to support standalone LRB operations. However, LRB integration in the VAB will require control room interfacing with LRB systems and, of course, all pad launch operations will require this monitoring and control interface.

Potential impacts to ongoing LCC operations can be anticipated with four firing rooms supporting SRB launches at a rate of 14 per year while part of the system is in mod to support software and console mods for LRB.

Careful scheduling of these LCC activities is required to avoid impacts. Implementation of the second generation LPS will be significant in easing the impacts of LRB activation.

CONCLUSIONS

The top level overall program finding is:

The Shuttle using liquid fueled boosters can, with proper planning and program execution, accomplish 122 launches from 1996 to 2006 at KSC.

The major conclusion: The sustained operation of the STS/LRB can potentially achieve 14 launches per year after a five-year transition starting in 1996. There are some major risks and program challenges during the early start-up years which could delay achieving the launch rate, or worse, degrade the ongoing operations launch rate. These challenges must be shared between the booster designers and the KSC ground processing design and planning community. Continued integration, study and planning is required.

Other significant study findings are shown in Figure 7.

Finding 1: The transition from STS/SRB operations to STS/LRB operations in a non-disruptive manner to the ongoing (phase down) STS/SRB operations presents an unprecedented NASA/KSC challenge. Transition has significant shcedule and cost risk. KSC needs a dedicated activation team for activation and transition planning. This team should follow through to implement the new booster operations.

Finding 2: New LRB facilities plus some modifications to existing facilities are required. These include 2 new Mobile Launcher Platforms (MLP), a new Horizontal Processing Facility (HPF) and modifications to the Launch Pads A and B.

Finding 3: Seventy percent of the LRB preliminary design requirements have significant ground systems implications and most design features drive ground systems designs (KSC non-recurring cost). Schedule risk and recurring costs are relatively insensitive to LRB design options, but LOX/LH2 is the KSC preferred propellant choice for LRB.

Finding 4: The LRB has a potentially significant and shorter integration timeline on the MLP in the VAB, compared to SRB. This potential reduces launch rate risk (providing the ability to increase launch rate).

Finding 5: Preliminary analysis has identified LRB launch pad clearance problems (metal to metal contact) during ascent. The extent of engineering required to achieve a solution and the magnitude of the solution is unknown.

Finding 6: Cost and launch schedules are sensitive to program planning factors and the degree of achieved booster processing friendliness. Reductions in cost estimates and schedule risks may be realized through the implementation of sweeping innovation (other than currently planned processing enhancements i.e., electronic shceduling LPS II).

Finding 7: The KSC LRB program costs are approximately $1 billion dollars non-recurring and $1 billion dollars recurring, for a total of $2 billion dollars over a ten-year life cycle (122 missions).

Figure 7. Study Findings.

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An extensive final report titled "Liquid Rocket Booster (LRB) Integration Study", NAS 10-11475, was produced and distributed in December of 1988. This report documented all study results and products. The Lockheed Study Team performed the work under the direction of the NASA/KSC Future Launch Systems Office (William J. Dickinson, KSC Study Manager). The Study Team was led by Gordon E. Artley, LSOC Study Manager.

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