NAS8-37136 DR-1

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Liquid Rocket Booster Study Plan (LRB) for the Space **Transportation System** (STS) Systems Study Marietta Aerospace (STS NAS LBB STS POS TEHS THE 0 161 S S **UTDO** 26 ANS PORT. ROCKET BOOSTER Bartin SYSTER CSCL 22B 63/16 Unclas 0125199 N89-14249 MARTIN MARIET ACE СНОUD AEROS Ρ н

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Liquid Rocket Booster (LRB) for the Space Transportation System (STS) Systems Study

Approved by:

Mobley mon

Thomas B. Mobley Study Manager

MARTIN MARIETTA MICHOUD AEROSPACE P.O. Box 29304 New Orleans, LA. 70189

Study Plan

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SECTION

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Introduction

Martin Marietta's study plan is submitted in accordance with DPD-696 (DR-1). The two major objectives of the plan are: to present our study approach, and to provide the standard for guiding the Liquid Rocket Booster (LRB) project.

The plan presents our full compliance with the Request for Proposal (RFP) and its scope includes: (1) concise task plans; (2) a study flow diagram (depicting task interrelationships); (3) a study schedule of control points; (4) time-phased manloading and skills by task; (5) major subcontractors (with their areas of responsibility/management relationships identified); and (6) a list of required government-provided documentation.

When approved by the Marshall Space Flight Center (MSFC), the study plan will serve as the primary study control document for the MSFC Technical Manager and the Martin Marietta Study Manager. There are no technical considerations or constraints that preclude Martin Marietta from successfully executing this study.

1. Task Plans

The task plans (Figure 1-1) provide a comprehensive description of the work to be performed. Each plan is presented on a foldout sheet that shows the task description, approach, timeframe, inputs/outputs, manloading, and management lead responsibility. The task plans form a basic element of the study management and control.

2. Study Flow Diagram

A logic network depicting tasks/subtasks, interrelationships, and time-phasing, is described in Figure 2-1.

3. Study Milestone Schedule

Figure 3-1 defines the milestones and timelines for all tasks and subtasks.

4. Time-Phased Man-Loading

The tasks and labor classifications/skills required for this study effort are listed in Figures 4-1 and -2.

5. Major Subcontractors

The subcontractors who will assist us on this project are: Aerojet Tech Systems, Co.; Honeywell, Inc., Space and Strategic Avionics Division; and Pioneer Systems, Inc., Aerospace Recovery Division. Their selection was based on their past and current experience and performance on similar programs. Each subcontractor is uniquely qualified in the areas they will support. All three subcontractors will report directly to the study manager, Mr. Thomas Mobley. Figure 5-1 provides the scope, task descriptions, and schedules for each subcontractor.

6. Documentation Required

Data are required from the following studies as described in the RFP: (1) Space Transportation Booster Engines (STBE); (2) Space Transportation Main Engines (STME); (3) in-depth analyses of the integration of candidate LRB concepts into the Space Transportation System (STS) flight system; and (4) the adaptation of LRBs into STS launch facilities and operations.

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1					Workload C (Manhours)			2317)4		
								م ص			Figure	17	Task Plans

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Task Description: TASK 1.0 (TASK A) LIQUID ROCKET BOOSTER Michoud Aerospace will perform trades and analyse the LRB concepts and supporting operations and fa the requirements for STS boosters. Basic character concept/systems will be identified and included in d

Task Approach

TASK 1.0 (TASK A) LIQUID ROCKET BOOSTER T

- Vehicle Requirements Based on Martin Mar ET/STS and our extensive database, develop requirements, including: 1) mission operatio mission analyses; 4) LRB/STS environments Level III, develop the requirements for: 1) str and hazardous gas detection system; 3) er 4) LRB separation; 5) LRB safing; 6) LRB or requirements documentation; and 8) test.
- 1.2 Preliminary Baseline Concepts Development contractual and IR&D studies will be augmen trades and analyses to develop preliminary c both pump-fed and pressure-fed booster sys
- Preliminary System Analyses Systems anlay concepts developed in Task 1.2 will provide | mechanics, and mass properties data in sup tasks.
- 1.4 Detail Trade Studies and Analyses Detail tra supporting analyses will be performed to opti pump-fed and pressure-fed systems develop performance (pound to orbit) and cost (develo operations) basis. Areas to be investigated in propellants; 2) propulsion system types; 3) (pressure-fed); 4) engine chamber pressure; performance/weights; 6) tank construction m construction (design/sizing); 8) avionics/elec generation" concepts-bite/autonomy); 9) reco posters (all or part); 10) recovery concepts; (control); 12) performance/trajectory shaping of the trades include structures, propulsion, th mechanics, materials, mass properties, avioni
- 1.5 Vehicle Trade and Analyses The preferred pressure-fed vehicle will be selected based (criteria developed in Task 1.6. The finalist co compared based on performance, STS impa a preferred configuration will be recommend for further definition in contract Task E.
- Configuration Evaluation Criteria Plan (DR-10 developed for NASA approval which will prov criteria for configuration evaluation and the s recommended configuration.
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	stems					Pressure-Fed Propulsion System Trades and Analyses Pressure-Fed Booster Configuration Trades and Analyses Technology/Advanced Development Requirements		Workload Distribution (Manhours)	
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Task Objective: TASK 2.0 (TASK B) PRESSURE-FED PROPULSION SYSTEM	Develop sufficient data to enable the selection of the preferred pressure-fed propulsion system for comparison with pump-fed and for further definition.		Task Outputs	Trades & Analyse (Task A) Program Planning (Task G) Recommended Pressure-Fed Vehicle	Recommended Pressure-Fed	Engine Performance Review Documentation - Final Report - Advance Development Requirements - Systems Definition (Task E) - Evolution/Growth Potential (Task C)			
SURE-F	nable th tem for		Task	11- Irades (Task A 2 - Prograr (Task G 3 - Recomi Vehicle	4 - Re Pre	а а а а а а а а а а а а а а а а а а а			
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Dbjectiv 2.0 (T	Develop sufficient data to pressure-fed propulsion s and for further definition.		Task Inputs	A - Project Planning (Task G) B - Prior LRB Study Results C - Trades and Analyses (Task A) D - Supporting	Studies & Coord (Task F)	Shuttle Ops Data Book (JSC-08934) Space Shuttle Flt & Grnd Sys Spec (JSC-07700, Vol X)			
Task (TASK	Devel press and fo		Ta	C B P			;		
	s design			sion	ail	e an ss and ation; 5) tank es - The ehicle advanced ss of			
TEM	fed engine/systems g, engine concept/design			SION SYSTEM selected pth to allow propulsion baseline booster or	and Analyses - Detail	led to determine an concept. Trades and thamber pressure; 2) tanl engine configuration; 5) IVC systems; 8) engine engine life and es and Analyses - The conceptual design of the by assessing vehicle ulrements - Based on the technology or advanced dvance the e the capabilities of			
SION SYSTEM	engine/ ngine cı			SION SYSTEM selected oth to allow prop baseline booste	Analys	ea to determine concept. Trade hamber pressu angine configura TVC systems; engine life and es and Analyse conceptual des by assessing ve ulrements - Bas technology or a dvance the e the capabilitie			
SIC	g, e			bat bat	and				

Task Description: TASK 2.0 (TASK B) PRESSURE-FED PROPULSI

Through subcontract(s) obtain data on pressure-fed which shall include parametric data vehicle sizing, e data, and planning information.

Task Approach

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TASK 2.0 (TASK B) PRESSURE-FED PROPULSK

Effective execution of the subtasks below by the sel subcontractor(s) will provide data in sufficient depth systems recommendations, with rationale for the ba concepts.

- 2.1 Pressure-Fed Propulsion System Trades and A trade studies and analyses will be performed to optimum pressure-fed propulsion system conce analyses will include at the minimum: 1) chamb pressure; 3) pressurization system; 4) engine propellant options; 6) feed systems; 7) TVC s thrust and ISP; 9) propellant ratios; 10) engine refurbishment; 11) cost and schedule.
- 2.2 Pressure-Fed Booster Configuration Trades subcontractor will provide support for the cor pressure-fed propulsion systems vehicle by a configuration options impacts on the propulsi
- 2.3 Technology/Advanced Development Require effort in Tasks 2.1 and 2.2 above identify tech development efforts that are required to adva state-of-the-art or to properly demonstrate th pressure-fed propulsion systems.

POLDOUT FRAME

DTENTIAL	Task Objective: TASK 3.0 (TASK C) EVOLI	I ask Objective: TASK 3.0 (TASK C) EVOLUTION/GROWTH POTENTIAL	AL	Responsibility	SF	STUDY MANAGER Thomas B. Mobley			
h or evolution in terms of s characteristics. for other planned or	Identify initial STS/LRB con evolution that will increase characteristics. Identify pot	Identify initial STS/LRB concepts areas that have potential growth or evolution that will increase booster capability and/or improved operations characteristics. Identify potential application of the LRB concepts for other	ntial growth or proved operations 3 concepts for other	SYSTEMS ENGINEERING AND INTEGRATION R. J. Dinjar		PROPULSION SYSTEM F. W. Houte		STRUCTUPAL AND MECHANICAL E.H. Phillips	
amine avionics systems bepts.	planned or potential launch capable of meeting evolvin	planned or potential launch vehicles. Identify avionics systems that are capable of meeting evolving/future launch vehicles requirements.	systems that are quirements.		PLANNING AND PROGRAMMATICS S.A. Martin		MANUFACTURING AND PROCESSING R.E. Jones	AND	
	Task Inputs	Task Outputs	O	Contract Month 0	۵ z	ш ->	Σ	۲ ۲	
DTENTIAL Ige of potential propulsion I be analyzed to determine	 A - STAS B - Prior Adv Launch Vehicle Studies C - Trades and 	 Trades & Analyses (Task A) ID of Growth Areas ID of Potential 	Significa	Significant Milestones Ori Stu	Orientation and Study Plan Update	ate	-		Preliminary Final Report Final Report
ssion requirements. These asks 3.2 and 3.3 below. e-fed and numn-fed	Analyses (Task A) D - Shuttle Ops Data Book (JSC-80934) F - Space Shuttle Elt	Application other Programs 4 - Advanced Development			Performance Review	Ince Performance Review	ance	ance	Performance Review
n subcontractor support to n, or if the systems evolve ease booster capability s.	۱.	ہ _	3.1 Trajectory Performance Analyses						
figuration and sizing will be th or evolution options	G - Supporting Studies & Coordination		3.2 Engine Growth Concepts	cepts A,B,D,E,F,G			- 2,5,7,8		
nd/or improve operations lenerated by Tasks 3.1 and	(Task F)	8 - Systems Definition (Task E)	3.3 Vehicle Concept Analyses		——— СО 		3,5,7,8		
stem will be examined for inned or potential future			3.4 Future Vehicle Application	cation		Ű-	4 45, 4 45, 4 55, 4 55, 4 55, 4 55, 4 55, 4 55, 4 55, 5 4, 55, 1 4, 55, 1 4	5,6,7	
avionics system selected ty to meet evolving/future identify avionics growth or sssary to meet the future			3.5 Future Vehicle Avionics	rics Analyses		□			
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			Workload Distribution		249 355	272 616	518		
			(Manhours)						

TASK 3.0 (TASK C) EVOLUTION/GROWTH POTE

Examine STS/LRB concepts for possible growth or increased capability and/or improved operations cha Determine the application of the LRB concepts for o potential future launch vehicles. In addition, examin capable of meeting evolving/future vehicle concepts

t

Task Approach

TASK 3.0 (TASK C) EVOLUTION/GROWTH POTEN

- 3.1 Trajectory Performance Analyses A range c and vehicle alternative configurations will be which will satisfy stated and potential mission data will establish the requirements for Tasks
- 3.2 Engine Growth Concepts Both pressure-fed propulsion systems will be analyzed with subc determine the amount of potential growth, or i into an advanced system that would increase l and/or improve operations characteristics.
- 3.3 Vehicle Concept Analyses Vehicle configura analyzed to determine the potential growth or available to increase booster capability and/or characteristics. In addition, the impacts genera 3.2 above will be assessed.
- 3.4 Future Vehicle Application The LRB system potential utilization on other currently planne launch vehicles.
- 3.5 Future Vehicle Avionics Analyses The avio will be analyzed to determine its capability to vehicle concepts requirements and also iden evolution requirements that may be necessa vehicle system requirements.

FOLDOUT FRAME

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	On selected LRB concepts, the data listed below will be provided to allow	On selected LRB concepts, the data listed below will be provided to allow		· famore roder	Thomas B. Mobley	ey .		
cle system, concentrating on	for a more detailed examination of LRB/ST a separate comparison effort. - Booster physical configuration data - Selected propellant and characteristics - Preliminary booster structural math model	a more detailed examination of LRB/STS integration that is planne eparate comparison effort. Booster physical configuration data Selected propellant and characteristics Preliminary booster structural math model (hittoff and boost) Preliminary booster structural math model to reflort and boost)		SYSTEMS ENGINEERING AND INTEGRATION R. J. Dinjar	PROPULSION SYSTEM F. W. Houte	(STEM	STRUCTURAL AND MECHANICAL E.H. Phillips	
	 Booster engine failure modes/probabilities Ground processing concepts 	stobabilities		PLANNING AND PROGRAMMATICS S.A. Martin	ND ATICS	MANUFACTURING AND PROCESSING R.E. Jones	AING AND	
	Tasl	l ä	Contrac	Contract Month O N		ы М	M V	L L
SIS OF STS INTEGRATION any lift-off, ascent, and reentry ants, reentry drag coefficients, and	· ·	÷ 1	Significant Milestones	Study Plan Update	-	4	Preliminary Report	
in ascent and reentry environments including base re will be determined.	System Specification (JSC-07700, Vol X) C - Trades and	 3 - Preliminary LHB Structure Math Model 4 - Preliminary MLP 			Performance Per Review Re	Performance Review	Performance	Performance Review
Note pains between Oroller, E1, , hold-down loads will be determined sequence and LRB engine shutdown 4.1. Loads and dynamics resulting be determined. In addition, we will the modal frequency and acoustics		Structure Math Model 5 - Booster Engine Failure Modes/Prob	4.1 Environment Definition	A,B,C,D-			-	>
p/prioritize dimensional constraints, clearances, facility and pacts.	́ц О	 6 - Ground Processing Concepts 7 - Performance Review 	4.2 Loads and Dynamics Analyses		A,B,C	C, F → C, E → C, C, E → C, E	→7 → 8,10	
HEVSOME start sequence, LHB ess the impact on vehicle loads, rmine resulting control requirements scent profiles analyses will be otal impulse and preliminary tal impulse and preliminary gimbal uirements at ETR/WTR.		Documentation 8 - Project Planning (Task G) 9 - Systems Definition	4.3 LRB/STS Dimensional Analyses	es		7,8,10		
based on the Task 4.1 separation s engine shutdown, and/or thrust n system. Conduct analyses of flight shutdown for launches out of		(Task E) 10 - Final Report	4.4 Mission Analyses	A,B,C,D			► 7,8,9,10	
thrust vs time, total impulse trol requirements to maintain vehicle control requirements due to shift in r aborts if nominal operations does			4.5 Propellant Loading Analyses		C F			
be studied, considering impacts to al capability with LRBs will be			4.6 Impacts Assessment	< }	A,B,D	+ 8 + 7	→ 1,2,3,4,5,6,8,10	<u>0</u>
configuration, develop propellant mmended LRB/STS configuration, e developed.						FOLDOUT	FRAMD	
			Workload Distribution (Manhours)	50 324	601 866 7	718 734	316	

TASK 4.0 (TASK D) PRELIMINARY ANALYSES

Perform preliminary analyses of LRB/STS integrexamine impacts to the current LRB/STS vehicle areas identified in the RFP.

Task Approach:

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4.0 (TASK D) PRELIMINARY ANALYSIS

- environments for the LRB. Aerodynamics a aerodynamic force and moment coefficient LRB running loads. Induced aerothermal a environments will be computed. Plume en heating and lift-off acoustics and pressure 4.1 Environment Definition-Develop preliminar
- LRB, and MLP. Vehicle loads, dynamics, hr resulting from LRB/SSME engine start seq sequence scenarios developed in Task 4.1 from vehicle control requirement will also be determine the implications of basic vehicle 4.2 Loads/Dynamics Analyses-Define static loa
- considering such constraints as interface cl transportation limitations aerodynamic impa 4.3 LRB/STS Dimensional Analyses-Develop/
- conducted to determine thrust vs time, total conducted to determine thrust vs time, total requirements to accomplish mission require 4.4 Mission Analyses-Analyses-Determine LRI shutdown/separation sequences, to assest dynamics, hold-down loads, and to determ and aerodynamics impacts. In addition, asc

Perform LRB separation impact analysis base scenario and effects of cg, aerodynamics eng changes: develop an optimum separation sys control requirements during LRB boost/shutd ETR/WTR. The analyses will investigate thrust requirements, gimbal requirements, control re trajectory within Orbiter/ET constraints, control cg over time and control requirements for abo not shut down engines.

Various LRB/SSME abort scenarios will be the current abort mode and any additional c identified in conjunction with Task 4.5.

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- 4.5 Propellant Loading Analyses-Based on col loading sequence and timelines.
- Impacts Assessment-Based on the recoming a secoming a seessments of impacts will be equalitative assessments of a second 4.6

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	Task Objective:			Management Responsibility:		STUDY MANAGER Thomas B. Mobley	\GER obley			
of the NASA approved LRB s in Task A. The system that performance, size,	TASK 5.0 (LASK E) SYSTEM DEFINITION Develop a system definition of the NASA approved LRB/STS concept(s). Provide documentation, including engineering drawings, detail weight statements: analysis results displayed in graphs. tables. charts. floor	In DEFINITION of the NASA approved LRE uding engineering drawings displayed in graphs. tables.	3/STS concept(s). , detail weight charts. floor	SYSTEMS ENGINEERING AND INTEGRATION R. J. Dinjar	GINEERING	PROPULSION SYSTEM F. W. Houte	V SYSTEM	STRUCTUR MECHANIC E.H. Phillips	STRUCTURAL AND MECHANICAL E.H. Phillips	
namanament, operations, ude at a minimum, where facilities, ground support	diagrams, and system/subsystems descriptions.	ystems descriptions.			PLANNING AND PROGRAMMATICS S.A. Martin	ATICS	MANUFACT PROCESSII R.E. Jones	MANUFACTURING AND PROCESSING R.E. Jones		
	Task inputs	Task Outputs	8	Contract Month	D N O	r C	. ⊻ ⊥	A	Σ	
n - Analyses and design wings and subsystem al systems, environmental electrical/avionics ttegration. As part of the y, and operations will be	 A - Trade Analyses (Task A) B - Pressure-Fed Propulsion System (Task B) C - Shuttle Operations Data Book (JSC-08934) D - Space Shuttle Flight 	 Basic Configuration Drawings Performance Review Documentation Project Planning Tasks (Task G) Preliminary Analyses of STS 	Significal	Significant Milestones	Up Up	T ew	Performance	Performance Review		reliminary inal eport Report Report Review
rses of the selected s, weights, mass mal environments will be se design/definition effort.		- 2 - 6 - 8 - 7	LRB/S Definit	ifiguration		A,B,C,D,E,F,		+ 3,4,8,12 F+2 F,H ↓ + 3,4,8		→2 →1,3,7, 11 ,3,6,11
t operations and flight refine flight operations lata for the selected ude ascent aerodynamics, mics. A six (6) ontrol study will be n stays within the	G - NSA Approved Baseline Configuration H - Project Planning (Task G)	Equipment Impacts 10- Hazards ID 11- Final Study Report 12- Supporting Studies and Coordination (Task F)	 5.2 Venicle System Analyses 5.3 Vehicle Mission Analyses 5.4 Performance Anomalies Analyses 	/ses /ses les Analyses		A,B,C,D,E,F,G A,B,C,D,E,F,G		+ H 448 1 + 23 1 + 23 1 + 1 1 + 1 +	╶┈╘┲┈╘╂╴	2,3,5,9,11
to uegree or needon the reusable LRB for his task will also include a e separation envelope of								1		
th orbiter and LRB to by system compared to the abort options from initial veloped for the LRB/STS ort STS system will be										
							\sim	non	1. 1 I. S.	
			Workload Distribution (Manhours)				483 1448	48 2014	2314 1	1265 -
					2			Figure		1-1 (Continued)

TASK 5.0 (TASK E) SYSTEM DEFINITION

Develop basic drawing and definition/analysis of the configuration(s) resulting from the trade analyses in T description is to be in sufficient detail and depth that weights, components, subsystems integration, maint etc., can be defined. The description should include appropriate, impacts of the total vehicle system, facili equipment, operations, hazards, etc.

Task Approach

TASK 5.0 (TASK E) SYSTEM DEFINITION

- 5.1 LRB/STS Vehicle Configuration Definition A efforts will provide basic engineering drawing definition, including structures, mechanical sy protection, propulsion and fluid systems, elec (including redundancy), and interfaces/integr overall definition, reliability, maintainability, an defined for the selected system.
- 5.2 Vehicle System Analyses System analyses concept including loads, dynamics, stress, we properties, acoustic loads, and base thermal performed in support of this overall vehicle de
- 5.3 Vehicle Mission Analyses Perform flight ope mechanics analyses will be performed to refir requirements and system performance data f concept. This definition/analysis will include a booster separation and reentry aerodynamics degree-of-freedom ascent stability and contro conducted to assue the LRB/STS system sta current STS constraints. A dynamics six (6) o reentry analysis will also be performed for the further recovery system development. This th booster separation analysis to assure the sep the LRB/STS system.
- 5.4 Performance Anomalies Analyses Definition capability will be developed including both or access performance impact to the LRB/STS is SRB/STS system. Coupled with this task, ab engine ignition through MECO will be develop system and those options over the current S defined.

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ID COORDINATION lies, that will provide s, one dealing with LRB of LRBs into STS launch on existing engine	TASK 6.0 (TASK F) SUPPC									
lies, that will provide s, one dealing with LRB of LRBs into STS launch on existing engine		TASK 6.0 (TASK F) SUPPORTING STUDIES AND COORDINATION		nespolisibility.		Thomas B. Mobley	bley			
on existing engine	Obtain existing, current, and new data as it is developed from previous, on-going and future studies on pump-fed and pressure-fed engines and LRBs that will enhance the quality and depth of this study.	d new data as it is develop. on pump-fed and pressure quality and depth of this st	ed from previous, -fed engines and udy.	SYSTEMS ENGINEERING AND INTEGRATION R. J. Dinjar		PROPULSION SYSTEM F. W. Houte	SYSTEM	STRU MECH	STRUCTURAL AND MECHANICAL E.H. Phillips	
				L L L L L L L L L L L L L L L L L L L	PLANNING AND PROGRAMMATICS S.A. Martin	S	MANUFACT PROCESSII R.E. Jones	MANUFACTURING AND PROCESSING R.E. Jones		
	Task Inputs	Task Outputs	ð	Contract Month			≥ ⊥	<	Σ	-
ID COORDINATION		1 - Trades and Analyses	Significar	Significant Milestones	Orientation and		-		Preliminary	
and evaluate existing ntial use as booster tudies will be conducted	C - F-1 Engine Data D - SSME Data F - Other Envine	(Task A) 2 - Pressure-Fed Promision System		Study Plan Update	lan				Ein	Final Report
to this LRB study. These appropriate.		(Task B) 3 - Evolution/Growth Potential		> ₽	Performance Review		Performance Review	Performance Review	nance Pe	Performance Review
oring - Monitor on-going Engines (STBE) and 1E) and review the data on esign which will be traded	F - Integration of Candidate LRB Concepts into STS	4 v	6.1 Past Studies and Programs	rams	> ⁽¹ / ₁	3,5,7	1,2,3,7	>		>
	G - Study of Adaptation of LRBs into STS		6.2 STBE and STME Data Review		<u>د</u> م الم	• • • • • • • • • • • • • • • • • • •	►5 _Γ ►3,4,7	<u>د</u>		- 9 2
ort-Monitor and Review - ate study to perform an ite LRB concepts into the	Launch Facilities & Operations H - Trade & Analyses	 b - Final Report 7 - Project Planning (Task G) 		9 V V				£	_	 -2 -2
ill be incorporated into the	(Task A) - System Definition		6.3 Integration Study Coordination and Support-Monitor and Review	rdination nd Review				-	- <u>-</u>	1
iation and Support - bosed separate study to	(I day L)		6.4 Launch Facilities and Operations	Dnerations			- 34 - 1,4	-12	<u>_</u>	-2-0-
to STS Launch Facilities Il be incorporated into the				oort G,H -		<u>⊥</u> _			• -	
						,,,,,				
									·····	
					<u>,</u>			TODOUT	r FRAME	E
			Workload Distribution	49 13	130 122	74	72 78	28	97	58
			(Manhours)							

TASK 6.0 (TASK F) SUPPORTING STUDIES AND C

Maintain coordination with current on-going studies, pump-fed engine data, and two proposed studies, or integration and the other dealing with adaption of LF facilities and operations. In addition, obtain data on systems for possible booster engines.

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Task Approach

TASK 6.0 (TASK F) SUPPORTING STUDIES AND C

- 6.1 Past Studies and Programs Collect data and designs, such as F-1 and SSME, for potential engines. Data search of applicable past studi and an assessment made for application to th data will be inputted to the other tasks as app
- 6.2 STBE and STME Data Review and Monitorin, studies of Space Transportation Booster Eng Space Transportation Main Engines (STME) & pump-fed engines of the proposed new desig in Task A.
- 6.3 Integration Study Coordination and Support-N Review the data from the proposed separate in-depth analysis or integration of candidate L STS flight system. The appropriate data will b other study tasks.
- 6.4 Launch Facilities and Operations Coordinatio Monitor and review the data from the propose perform a study for adaptation of LRBs into S² and Operations. The appropriate data will be other study tasks.

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	TASK 7.0 (TASK G) PROJECT PLANNING TASKS	ECT PLANNING TASKS		Responsibility:	STUDY MANAGER Thomas B. Mobley	VAGER Mobley			
orting 1 of	Provide NASA management level visibility of th Development (FSD) phase program which incl implementation approach, cost, and schedule.	Provide NASA management level visibility of the LRB Full Scale Development (FSD) phase program which includes requirements implementation approach, cost, and schedule.	ull Scale juirements	SYSTEMS ENGINEERING AND INTEGRATION R. J. Dinjar	G PROPULSION SYSTEM F. W. Houte	ON SYSTEM	STRUCTURAL/ MECHANICAL E.H. Phillips	URAL AND VICAL lips	
echnology requirements and rmance of an environmental s; and 9) development of t plan.				PLANNING PROGRAM S.A. Martin	PLANNING AND PROGRAMMATICS S.A. Martin	MANUFACT PROCESSII R.E. Jones	MANUFACTURING AND PROCESSING R.E. Jones	[]	
	Task Inputs	1 S	ð	Contract Month		₩ 	A	×	۔ ر
SKS	A - Trades and Analyses	1 - Preliminary Project Im-	Signific	Significant Milestones Orier	Orientation and		Prel	Preliminary	
ry Project in data for Phase C/D	(Task A) B - Systems			Study P Update	Study Plan Update		FIN	Final Heport Fin≉	ort Final Renort
supporting equipment, in accordance with		2 - Logic Network 3 - Project							
	C - NASA WBS Dictionary	4 - Supporting			Review Re	Review	Review		Review
ne for each major WBS	Comments D _ Preliminary	5 - Facilities		AIP					\mathbf{x}
nents. The plan shall include	•	Schedules 6 - Construction	7.1 Project Planning (DR-9)	6			1		
, iogistics, iogic riow, , subscale testing,	Integration	Costs		ТЦ ЧЦ ——————————————————————————————————				4 4	
ty, transportation, etc.	(Task D) E - New or	•	7.2 Schedules	_ t		J	4		
it plans, test requirements,		8 - Final WBS (DR-5)		Ч Ч Ч		►11 ► 5.6		►11.17	
t cost estimates are required edules for various phases	recrinology Requirements	9 - Preliminary WBS	7.3 Facility Requirements	<u></u>			4		
e included in the plan.	F - Pressure-Fed	טוכנוסחמוץ (שא-ס) 10 - Final WBS		4	A, F, U -	¶ 	ן 		
phased logic network to		Dictionary (DR-5)	7.4 Work Breakdown Structure (DR-5)		L ,	,		َ د	;
time increments and	Systems (Task B)	•		– – –				j t	11 1 17,21
denot. Develop an sluding primary activities,	G - NHB 8800.11		7.5 Project Cost Data (D	(DR-6)					22,23
supporting schedules	"Implementing	12 - 1ecnnology Development				A,D,F,I ¹ A,D,B,I ¹		'	24,25
such as design/development, perations. facilities. etc.	of The National		7.6 Technology Requirements						
mented in DR-4 "Final Report."	Environmental Policy Act"	13 - Environmental Impact		, , , , ,	4 ,	A,J,I f			(
lilities this project requires	H - Previous	(DR-7) 14 - Preliminarv	7.7 Environmental Analyses (DR-7)	ses (DR-7)	A D.G				
yor modification to existing chedules, and costs by fiscal year.	I - Evolution/Growth					11 11,14,15,26	5.26	م	-11,14,15
umented in DR-4 "Final Report" and the parallel study on I aunch Facility	Potential (Task C)	15 - System	7.8 System Safety	A,F,J			8		
	J - Supporting	Safety Criteria	7.0 Major Svetome Toet Boardinomoote		H 1 H 11,16		Ł.	20 • 11	1,16
Work Breakdown Structure (WBS)	Coordination	16 - Test Bequirements/	мајо					 	
al, in accordance with DR-5. The project, plans and schedules, and	(Iask F)			A,F-1					
		17 - Inputs to Final Report							
		- •							
		Analyses				→ EO	EOLDOUT	FRAME	
		(Task A) 19 - Pressure-Fed				}			
		Propulsion Svstems	Workload Distribution	212 765	5 1100 1318	1565 1729	29 1779	1812	1653
			(mannours)						

the preparation of development plans; 7) perform analysis; 8) conduct of a system safety analysis; a major systems test requirements and overall test pl including a summary time-phased logic network, p schedules; 3) identification of facility requirement 4) development of work breakdown structure and project and life cycle cost, 6) identification of tech TASK 7.0 (TASK G) PROJECT PLANNING TASK "Preliminary Project Implementation Plan"; 2) de Perform project planning tasks that include 1) the

Task Approach

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TASK 7.0 (TASK G) PROJECT PLANNING TASK

Project Planning - Develop a "Preliminary Implementation Plan," including planning of the recommended LRB concept and su facilities, manpower requirements, etc., in DR-9. 7.1

procurement, manufacturing, assembly, languation manufacturing sequence, breadboards, su software, GSE, GFE, and GFP requirement Program analyses/planning shall be done element and include hardware to the sub systems testing, system safety, reliability

to the subsystem level. Preliminary sched operation plans (ground and flight), and c of development and operations shall be ir Programmatics analysis of development

- critical paths for the entire project time per overall preliminary project schedule, inclu manufacturing processes, assembly, ope The result of this subtask shall be docume Schedules - Develop a summary time-phi the subsystem hardware level. Denote tin events, and decision points. Develop sup detailing the most important functions suc 7.2
- DR-6 "Cost Volume." Include data from the Facility Requirements - Describe all faciliti (new, old, and/or unique), including major facilities. Prepare construction plans, sch The results of this subtask shall be docun Integration by KSC. 7.3
- and WBS Dictionary with NASA approval, WBS shall be used for structuring the proj Work Breakdown Structure - Develop a M costs estimates. 7.4

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k Description:	Task Objective:			Management Responsibility:							
k Approach (Task G concl) Proiect Cost Data - Proiect cost estimates in accordance with DB 6	Task Inputs	Task Outputs	۵ –	Contract Month 0	z	a	ш Т	Σ	A	Σ	
region of each WBS element. Separate estimates in accordance with Dro- shall be made in FY87 dollars consistent with the depth of technical definition of each WBS element. Separate estimates shall be made for nonrecurring (DDTE), recurring production, and recurring operations costs. Describe the costing methodology; define the basis for the estimates (i.e., vendor quotes, parametric methods, etc.); and define all cost assumptions such as new or existing technology requirements, use off-the-shelf hardware, use of modification of existing designs, etc.		 20 - System Definition (Task E) 21 - Trade Studies Cost Estimate 22 - LCC of LRB 23 - DDT&E Costs 23 - DDT&E Costs 24 - Recurring 	Significa	Significant Milestones	-	-	-	-		-	-
Trade studies preliminary cost estimates shall be made to support the design. Cost comparison analyses shall be conducted as required to establish Life Cycle Costs (LCC), if applicable to the effort.		Operations Cost 25 - Program Cost Estimate Document									
Estimates of LCC with regard to size and thrust/weight ratio, cost per flight, development of critical technologies, and/or advanced development shall be made. Economic analysis shall be performed to support the rationale for concept selection. The results of these tasks shall be documented in DR-6 "Cost Volume."		(DR-6) 26 - Preliminary Analysis of STS Integration (Task D)					, <u>, , , , , , , , , , , , , , , , , , </u>				
Technology Requirements - Generate a technology development plan for each new or existing technology requirement found during the course of this study. Include task requirements, mode of accomplishment, schedules, objectives, task resources, operations timelines, and anticipated benefits. The results of this task shall be documented in DR-4 "Final Report." New technology needs shall be flagged to NASA's attention as soon as practical after determination of need.				<u>_</u>							
Environmental Analyses - Perform analysis of potential impacts to the environment this project may create. Satisfy points addressed in the subsequent "Environmental Assessment and Impact Statement" as discussed in NHB 8800.11, "Implementing the Provisions of the National Environmental Policy Act."											
Include comparative information on alternatives, brief discussions of the environmental impact of the proposed project and alternatives, and a listing of agencies and persons contacted. The results of this subtask shall be documented in accordance with DR-7 "Environmental Analysis."								ZFOI	Z Forman		****
System Safety - Perform 1) Preliminary Hazard Analysis; and develop 2) System Safety Criteria and Requirements; and 3) Technical Risk Management Summary.						<u>.</u>				FRAME	
Major System Test Requirements - Provide overall test planning for Phase C/D covering LRB and STS major systems from cradle to grave.		58	Workload Distribution (Manhours)								
FOLDOUT HEAME					₽ ₽	{			Figure	Ţ	-

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accomplishment, schedules, objectives, tas timelines, and anticipated benefits. The res documented in DR-4 "Final Report." New te be flagged to NASA's attention as soon as Trade studies preliminary cost estimates sh the design. Cost comparison analyses sha required to establish Life Cycle Costs (LCC Project Cost Data - Project cost estimates in shall be made in FY87 dollars consistent w definition of each WBS element. Separate Technology Requirements - Generate a ter plan for each new or existing technology re Environmental Analyses - Perform analysis the environment this project may create. So the subsequent "Environmental Assessme System Safety - Perform 1) Preliminary Ha develop 2) System Safety Criteria and Rec Technical Risk Management Summary. Major System Test Requirements - Provide development shall be made. Economic and to support the rationale for concept selective tasks shall be documented in DR-6 "Cost" Statement^{**} as discussed in NHB 8800.11, Provisions of the National Environmental F Include comparative information on alterna and a listing of agencies and persons conti for nonrecurring (DDTE), recurring produc operations costs. Describe the costing me basis for the estimates (i.e., vendor quotes etc.); and define all cost assumptions such technology requirements, use off-the-shelf per flight, development of critical technolog the course of this study. Include task requi the environmental impact of the proposed subtask shall be documented in accordanc Estimates of LCC with regard to size and t modification of existing designs, etc. "Environmental Analysis." Task Approach (Task G concl) determination of need. effort. 7.5 7.6 7.9 7.7 7.8

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Study Task Summaries

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Contract Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Мау	June	Juty
Orientation Significant Milestones	▼	J	L	I	⊨,=	<u> </u>	1	L	L	<u> </u>
Study Plan Upd DF		7						Prel Report I	0 R-4 🗸 F	inal 7
1.0 Liquid Rocket Booster Trade Analyses 1.1 Vehicle Requirements										
1.2 Vertiminary Baseline Concepts Development 1.3 Preliminary System Analyses 1.4 Detail Trade Studies and Analyses 1.5 Vehicle Trade and Analyses 1.6 Configuration Evaluation Criteria Plan (DR-10)			config Eval criteria Plan	(DR-10)						
2.0 Pressure-Fed Propulsion System 2.1 Pressure-Fed Propulsion System Trades and Analyses 2.2 Pressure-Fed Booster Configuration Trades and Analyses 2.3 Technology / Advanced Development Requirements										
3.0 Evolution / Growth Potential 3.1 Trajectory Performance Analyses 3.2 Engine Growth Concepts 3.3 Vehicle Concept Analyses 3.4 Future Vehicle Application 3.5 Future Vehicle Avionics Analyses										
4.0° Preliminary Analyses of STS Integration 4.1 Enviroment Definition 4.2 Loads / Dynamics Analyses 4.3 LRB / STS Dimensional Analyses 4.4 Mission Analyses 4.5 Propellant Loading Analyses 4.6 Impacts Assessment										
5.0 System Definition 5.1 Vehicle Configuration Definition 5.2 Vehicle System Analyses 5.3 Vehicle Mission Analyses 5.4 Performance Anomalies										
6.0 Supporting Studies and Coordination 6.1 Past Studies and Programs 6.2 STBE and STME Data Review and Monitoring 6.3 Integration Study Coordination aand Support - Monitor										
6.4 Launch Facilities and Operations Coordination and Support										
7.0 Project Planning Tasks 7.1 Project Planning (DR-9)							Prei Imp	Proj Plan DR-9	····	
7.1 Project Planning (DR-5) 7.2 Schedules 7.3 Facility Requirements 7.4 Work Breakdown Structure & WBS Dictionary (DR-5) 7.5 Project Cost Data (DR-5)			Prel WBS			WBS	¥	Fin DR	ai Dictionar) :-5 ⊽	 y
7.5 Project Coat Data (DR-5) 7.6 Technology Requirements 7.7 Enviromental Analysis (DR-7) 7.8 Systems Safety 7.9 Major System Test Requirements					Envir	/sis			Progi	ram DR-6
Performance Review Document Monthly Progress Report (DR-3) Computer-Aided-Design-Graphi		•	7 7		 ∇		7 7	7	7 7 7 7	<u> </u>

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ELEMENT CONTRACT MONTH	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	TOTAL
TASK 1 DENVER SUPPORT	-	275	275	275	-	-	-	-		-	825
TASK 1	854	2518	1865	888	787	510		-	-		7422
TASK 2	80	180	352	364	112	•	•	-	•		1088
TASK 3	-	128	361	349	696	476		-		-	2010
TASK 4		688	693	729	574	633	355	-	-	-	3672
TASK 5	-	•	÷	-	500	1930	2098	2530	466	-	7524
TASK 6	80	101	64	64	79	78	78	80	78	56	758
TASK 7	240	1003	1199	1635	1595	1463	1995	2029	1278	185	12622
OTS	144	43	43	43	43	43	43	43	43	160	648
AERQIET SUBCONTRACT	-	900	900	1119	1127	1000	1000	-		•	6046
HONEYWELL SUBCONTRACT	-	484	364	364	240	360	488	-		-	2300
PIONEER SUBCONTRACT	-	-	370	370	240	240	-	-	-	-	1220
CONTRACT MANHOURS	1398	6320	6486	6200	5993	6733	6057	4682	1865	401	46135
OVERHEAD MANHOURS	234	359	296	312	283	312	312	390	312	62	2872
TOTAL STUDY MANHOURS	1632	6679	6782	6512	6276	7045	6369	5072	2177	463	49007

Figure 4-1 Task Level/Time-Phased Manhour Allocations

	SR										TOTAL		TOTAL
	STAFF	GROUP	SR	PROG	EST &		PROD		PROD		CONT	O/H	STUDY
TASK	ENGR	ENGR	BNGR	ENGR	LCC	PLAN	OPS	PO&E	ASSUR	OTS	HOURS	MGMT	HOURS
1.0	558	1115	2498	2230	990	280	576	-	-	-	8247	553	8800
2.0	109	218	326	435	-	-	-	-	-	-	1088	104	1192
3.0	197	394	591	788	-	40	-		-	-	2010	283	2293
4.0	367	734	1102	1469	-	-	-	-	-	-	3672	338	4010
5.0	732	1464	2196	2928	-	-	204	-	-	-	7524	516	8040
6.0	75	149	224	298	-	-	-	12	-	-	758	175	933
7.0	46	92	138	184	2606	3814	2194	1248	2300		12622	700	13322
DOCUMENTATION	-	-	-	-	-	-	-	-	-	648	648	129	777
SUBCONTRACTS	-	-	-	-	-	-			-	-	9566	74	9640
TOTAL INDIRECT	-	-	•	-	-	-	•	-	-	-	-	2872	2872
TOTAL	2084	4166	7075	8332	3596	4134	2974	1260	2300	648	46135	2872	49007

Figure 4-2 Task Level Labor Classifications (Includes Denver IDOD)

Rev. 1

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SUBCON-		MONTHS AFTER ATP								
TRACT	TASK DESCRIPTION	1	2	3	4	5	6	7	8	
Aerojet (Subtask Support) 2.1	 Aerojet will perform five concurrent subtasks that define pressure-fed and pump-fed optimized propulsion system concepts. 1. Pressure-fed Propulsion System Trades, Analyses, and System Concept - Perform trade studies and analyses to determine an optimum pressure-fed propulsion system concept (i.e., chamber pressure, engine configuration, TVC]					
1,4, 1.5	systems, cost/schedule, etc.). 2. Pump-fed Propulsion System Concept - Define an optimum pump-fed propulsion concept based on contractor supplied tank study and analyses data and on Aerojet prior in-house studies and programs.]				
1.4, 1.5, 1.6, 2.2	3. Booster Vehicle Configuration - Provide support to Martin Marietta in the trade analyses and the conceptual design of booster vehicle using both pump and pressure-fed propulsion systems and in the development of the selection criteria and weighting definition.									
2.2, 2.3, 5.1, 5.2 7.1 thru	 Select Propulsion System Definition - Perform analyses and design efforts to define the selected propulsion system into the booster configuration and future growth concepts. Programmatics - Provide programmatic data on trade 									
7.9	studies and selected propulsion systems (i.e., schedules/costs, technology requirements, test requirements, etc.).						J			
Honeywell (Subtask Support) 1.4, 1.5 3.5, 4.5, 4.8, 4.9, 5.4	 Honeywell will perform four concurrent subtasks that define the LRB avionics and flight control systems concepts to be integrated into the booster vehicle configurations. Preliminary LRB/STS Flight Control /Dynamic Analyses - Support MMMA in detailed and vehicle trade analyses with preliminary flight control definition and dynamic analyses. Assess impacts of MMMA supplied LRB configurations on existing STS flight controls and determine the extent of modifications required and identify any enabling technology. Flight Controls Integration into LRB/STS Selected Configurations - Perform the preliminary integration tasks to incorporate the modified and/or new elements of the STS flight controls and malfunctioning flights (engine-out). Prepare and outline flight control and avionics concepts suitable for LRB/STS growth and/or future vehicle application. 									
5.1 7.1 thru	 Flight Controls/Avionics System Definition - Develop for the selected configuration, avionics systems definition including drawings and supporting analyses. Programmatics - Provide programmatic data on trade 		<u>.</u>							
7.6, 7.7, 7.8, 7.9	studies and selected flight control/avionics system (i.e., schedule/cost, technology requirements, test requirements, etc.).	l								
Pioneer (Subtask Support) 1.4, 1.5	 Pioneer will perform three subtasks that define the LRB system to be integrated into the booster vehicle configurations. 1. Recovery System Trades - Perform analyses and trade studies to identify recovery concepts to recover all or part of the LRB. 									
5.1	 Trades will also identify cost/schedule and enabling technologies for each concept. Recovery System Definition - Perform design and analyses to define the selected concept from Task 1 which will include component definition, volume, weight installation requirements, etc. Support MMMA with integration of the system into the LRB vehicle design. 				C]		
7.1 thru 7.6, 7.7, 7.8, 7.9	3. Programmatics - Provide programmatic data on trade studies and selected recovery system (i.e., schedule/cost, technology requirements, test requirements, etc.).			Γ]		