CR-128665

Space Shuttle Program

MSC-03321

FINAL SUBMITTAL

(NASA-CR-128665) EXPENDABLE SECOND STAGE REUSABLE SPACE SHUTTLE BOOSTER. VOLUME 10: TECHNOLOGY REQUIREMENTS Final Report, Phase B (North American Rockwell Corp.) 25 Jun. 1971 12 p CSCL 22B

N73-14876

Unclas G3/31 50800

IBM

H HONEYWELL

Phase B Final Report
Expendable Second Stage
Reusable Space Shuttle Booster
Volume X. Technology Requirements

Contract NAS9-10960, Exhibit B
DRL MSFC-DRL-221, DRL Line Item 6
DRD MA-078-U2
SD 71-140-10
25 June 1971

Space Division • North American Rockwell 12214 Lakewood Boulevard, Downey, California 90241

SD 71-140-10
(MSC-03321)

25 June 1971

PHASE B FINAL REPORT
EXPENDABLE SECOND STAGE
REUSABLE SPACE SHUTTLE BOOSTER

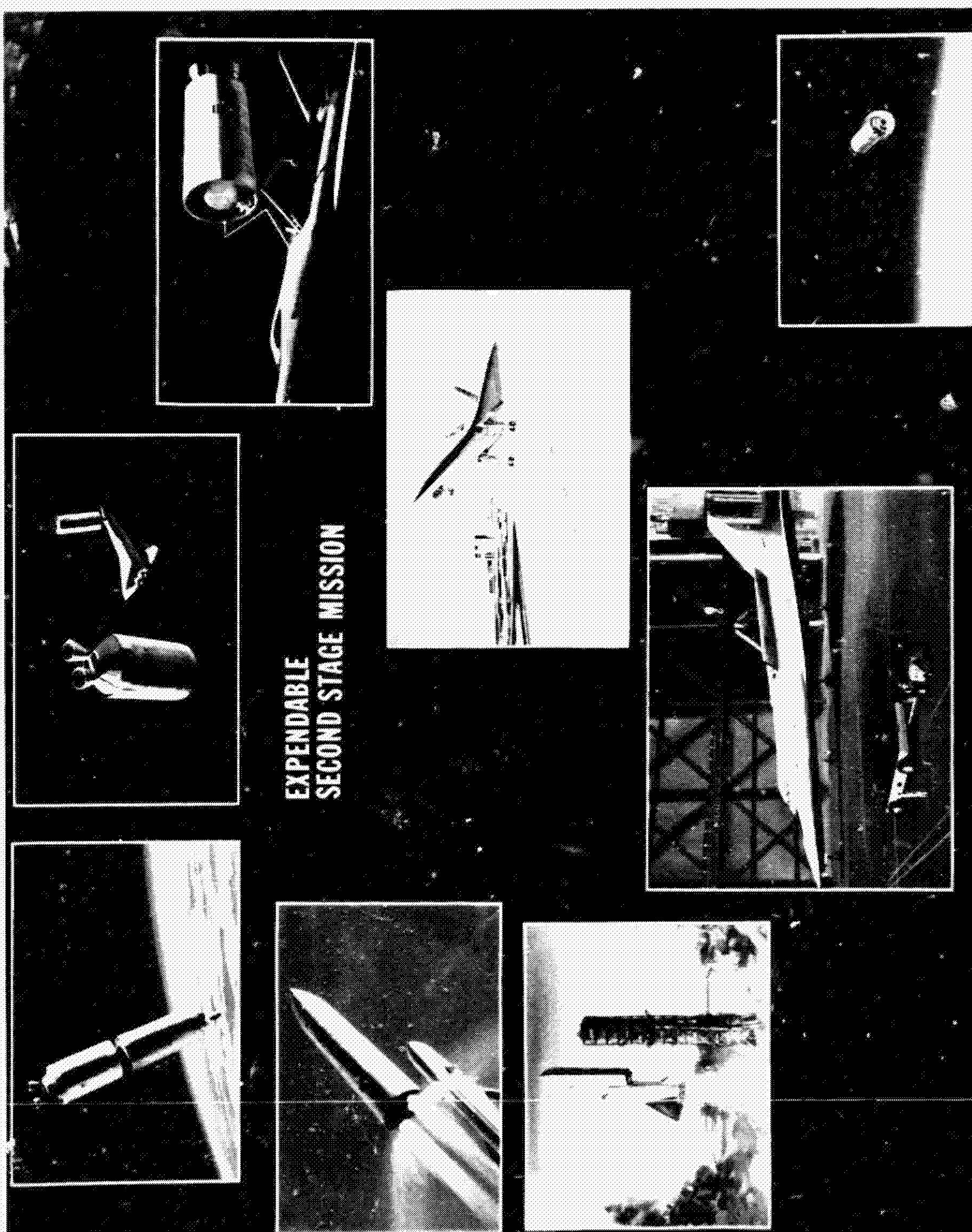
Volume X
Technology Requirements

Contract NAS9-10960, Exhibit B
DRL MSFC-DRL-221, DRL Line Item 6
DRD MA-078-U2

Approved by

R. B. Hello
Vice President and General Manager
Space Shuttle Program

Space Division • North American Rockwell 12214 LAKEWOOD BOULEVARD • DOWNEY, CALIFORNIA 90241


EXPENDABLE
SECOND STAGE MISSION

"PRECEDING PAGE BLANK NOT FILMED

FOREWORD

The Space Shuttle Phase B studies are directed toward the definition of an economical space transportation system. In addition to the missions which can be satisfied with the shuttle payload capability, the National Aeronautics and Space Administration has missions planned that require space vehicles to place payloads in excess of 100,000 pounds in earth orbit. To satisfy this requirement, a cost-effective multimission space shuttle system with large lift capability is needed. Such a system would utilize a reusable shuttle booster and an expendable second stage. The expendable second stage would be complementary to the space shuttle system and impose minimum impact on the reusable booster.

To assist the expendable second stage concept, a two-phase study was authorized by NASA. Phase A efforts, which ended in December 1970, concentrated on performance, configuration, and basic aerodynamic considerations. Basic trade studies were carried out on a relatively large number of configurations. At the conclusion of Phase A, the contractor proposed a single configuration. Phase B commenced on February 1, 1971 (per Technical Directive Number 503) based on the recommended system. Whereas a large number of payload configurations were considered in the initial phase, Phase B was begun with specific emphasis placed on three representative payload configurations. The entire Phase B activity has been directed toward handling the three representative payload configurations in the most acceptable manner. Results of this activity are reported in this 12-volume Phase B final report.

Volume I	Executive Summary	SD 71-140-1
Volume II	Technical Summary	SD 71-140-2
Volume III	Wind Tunnel Test Data	SD 71-140-3
Volume IV	Detail Mass Properties Data	SD 71-140-4
Volume V	Operations and Resources	SD 71-140-5
Volume VI	Interface Control Drawings	SD 71-140-6
Volume VII	Preliminary Design Drawings	SD 71-140-7
Volume VIII	Preliminary CEI Specification - Part 1	SD 71-140-8
Volume IX	Preliminary System Specification	SD 71-140-9
Volume X	Technology Requirements	SD 71-140-10
Volume XI	Cost and Schedule Estimates	SD 71-140-11
Volume XII	Design Data Book	SD 71-140-12

This document is Volume X, Technology Requirements, of the Phase B final report.

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

1.0 INTRODUCTION

The primary objective of the Expendable Second Stage (ESS) Program is to define a low-cost system for placing large payloads, such as the space station or reusable nuclear shuttle, into low earth orbit. The proposed concept is to utilize a modified Saturn V second stage (S-II) in conjunction with the space shuttle reusable booster. The ESS retains the major S-II structure, modified for attachment to the space shuttle booster, and incorporates both Saturn and shuttle developed propulsion and avionics hardware.

No major technology breakthroughs are required to develop this ESS system. Technology application and implementation efforts in selected areas, however, should be conducted in support of the ESS detail design and development phase.

The selected ESS system incorporates recovery of propulsion and avionics hardware by the shuttle orbiter for ESS reuse to minimize cost. Technology studies to (1) investigate methods of equipment design for recovery and (2) establish criteria to minimize refurbishment cost are recommended.

Additional studies to develop material and thermal properties for the modified S-II insulation system selected for the ESS application are proposed, together with continuing investigation of the pogo problem as it may apply to the ESS. Finally, a technology study involving shuttle integrated avionics system computer simulation is suggested.

In addition to the preceding identified technology requirements, maximum use will be made of the results from the technology studies being conducted under the Space Shuttle Program, reference SD 70-8A, "Space Shuttle Technology Requirements."

2.0 TECHNOLOGY REQUIREMENTS TASK SUMMARY

	Estimated Duration (Months)	Estimated Cost ($K)
1. Equipment recovery	18	100
2. Thermal protection system	21	455
3. Pogo analysis	24	395
4. IAS computer simulation	18	300
Total estimated costs		1250

3.0 TECHNOLOGY REQUIREMENTS DOCUMENTATION

3.1 EQUIPMENT RECOVERY TECHNIQUES

3.1.1 Objective

Develop the methodology for the design and the design verification of subsystems and components that have to be recovered from the ESS while it is in orbit.

3.1.2 Problem

To minimize total program cost, the recovery of high-value components is desirable. To achieve this recovery, however, several problems must be explored and resolved. The primary tasks are in the development of ordnance devices, mechanical release mechanisms, interfacing electrical connectors, and handling aids, and a complete environmental survey.

3.1.3 Technical Approach

A survey will be conducted of electromechanical and mechanical components suitable for recoverable packaging. A review of materials for application and environment will be conducted, and representative combinations will be selected. Packages will be built and subjected to identical environmental tests. The results will be analyzed and evaluated. (See Figure 1 for cost and schedule estimates.)

Tasks	Months 1 2 3 4 5 6 7 8 9 10 11 12 - 18	Est Cost ($K)
Ordnance survey		10
Connector survey		6
Mechanical survey		15
Select test combination		5
Fabricate prototypes		40
Perform tests		15
Evaluate results		10
	Total cost	$101

Figure 1. Equipment Recovery Techniques

3.2 THERMAL PROTECTION SYSTEM

3.2.1 Objective

Develop analysis and design TPS system for ESS.

3.2.2 Problem

The thermal protection system proposed for the ESS booster must be capable of withstanding acoustics, flutter, and shock wave impingement. Precise analyses for these design conditions are presently beyond the state-of-the-art.

3.2.3 Technical Approach

Wind tunnel and acoustic tests will be performed on representative test panels to verify the basic design concepts. The data from these tests will be evaluated and modifications made to the TPS design for both the acoustic and shock requirements. Aerodynamic flutter may require panel stiffening with the attendant weight increase. (See Figure 2 for cost and schedule estimates.)

Tasks	Months 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 - 24	Est Cost ($K)
Process variables		20
Design analysis		80
Influence coef tests		20
Flutter analysis		55
Eng drawings		100
Polyimide panel fabrication		20
Mech vibration		10
Flutter test		100
Acoustic test		20
Environmental test		10
Alt bleed-off test		10
Hard Spot development		10
	Total cost	455

Figure 2. Thermal Protection System

3.3 POGO ANALYSIS

3.3.1 Objective

Establish sensitivity of unsymmetric ESS configuration to pogo-type instability and determine most effective decoupling mechanism.

3.3.2 Problem

Pogo-type instabilities have been encountered on most large liquid propellant rocket powered boost vehicles. The ESS vehicle fits this category and, therefore, must be considered for the pogo phenomenon. The ESS/booster combination is further complicated by the lack of symmetry of the mated vehicles.

3.3.3 Technical Approach

Since the same basic pogo problem exists on the shuttle/booster combination, the data obtained from the Shuttle Program will be evaluated and applied to the ESS for the mated flight period. The pogo phenomenon during the ESS burn period will be evaluated as follows:

> It is planned to use the stiffness characteristics obtained from the static tests of the modified ESS thrust structure to partially verify the modeling used for that structure. The LO_2 feedline dynamics will be determined by analysis, using finite element techniques. The engine transfer function and pump termination impedance will be considered the responsibility of the engine contractor to be furnished by NASA. The above technique when coupled with the knowledge gained on the S-II Program is considered adequate for defining ESS pogo susceptibility. The static firings will be used to verify, in part, the structure/feedline/engine interaction. This will require adequate low-frequency, close-coupled instrumentation. Therefore, no special tests related to ESS pogo are planned other than those required by the engine contractor to define the engine transfer function and pump termination impedance.
>
> (See Figure 3 for cost and schedule estimates.)

Tasks	Months 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 - 24	Est Cost ($K)
Develop mathematical models of tanks, structure, payload, and overall vehicle		78
Obtain engine models		29
Perform stability and sensitivity analysis		46
Examine suppression devices		79
Recommendations for design		12
Detailed pogo analysis		150
	Total cost	395

Figure 3. Pogo

3.4 INTEGRATED AVIONICS SYSTEM COMPUTER SIMULATION

3.4.1 Objective

To support development and verification of expendable second stage computer program.

3.4.2 Problem

Adaptation of space shuttle modular software and the development of ESS on-board and ground computer software to provide compatibility for multifacility application require a simulation of the integrated avionics susbystem (IAS). Early verification of hardware design concepts requires support provided by an integrated IAS simulation.

3.4.3 Technical Approach

Systems engineering analysis of space shuttle IAS subsystem modular packages will be performed to determine applicability to ESS needs. Programs to satisfy delta demands will be identified, developed, and produced. Total flow diagrams for the ESS will be drawn, and a simulation model will be developed for the IBM 360 computer. The modular concept for the space shuttle will be utilized for the ESS and will provide elements for checkout, guidance, control, navigation, data bus, and redundancy management. The simulation will be used to verify software adaptation, confirm delta requirements, confirm computer memory and speed requirements, and support the development of ground and flight computer programs. (See Figure 4 for cost and schedule estimates.)

Task	Months 1 2 3 4 5 6 7 8 9 10 11 12 - 18	Est Cost ($K)
Systems analysis	1–3	20
Delta requirements	1–5	15
SIM requirements	2–8	15
Program development	3–18	250
	Total cost	00

Figure 4. Integrated Avionics System Computer Simulation