AEROSPACE REPORT NO.
ATR-72(7231)-1, VOL. I

Integrated Operations / Payloads / Fleet Analysis Final Report

Volume I: Summary, Study Overview

Prepared by ADVANCED VEHICLE SYSTEMS DIRECTORATE
Systems Planning Division

August 1971

Prepared for OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW-2129

Systems Engineering Operations
THE AEROSPACE CORPORATION

CAT. 30

Aerospace Report No.
ATR-72(7231)-1, Vol. I

INTEGRATED OPERATIONS/PAYLOADS/FLEET ANALYSIS FINAL REPORT

Volume I: Summary, Study Overview

Prepared by

Advanced Vehicle Systems Directorate
Systems Planning Division

August 1971

Systems Engineering Operations
THE AEROSPACE CORPORATION
El Segundo, California

Prepared for

OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW-2129

Aerospace Report No.
ATR-72(7231)-1, Vol. I

INTEGRATED OPERATIONS/PAYLOADS/FLEET ANALYSIS FINAL REPORT

Volume I: Summary, Study Overview

Prepared by Advanced Vehicle Systems Directorate

Approved

Ernest I. Pritchard

E. I. Pritchard
Study A Director
Advanced Vehicle Systems Directorate

L. R. Sitney

L. R. Sitney, Associate Group Director
Advanced Vehicle Systems Directorate
Systems Planning Division

Samuel M. Tennant

S. M. Tennant, Assistant General Manager
Systems Planning Division
Systems Engineering Operations

FOREWORD

The Integrated Operations/Payloads/Fleet Analysis was initiated in July 1970. In the course of the study one launch vehicle fleet analysis and two integrated operations/payloads/fleet analyses were accomplished. The first integrated analysis was completed in January 1971 and reported in the Mid-Term Report (Reference 1). The second analysis was completed in June 1971 and is reported here. Data from the Mid-Term Report, which are still valid, are used for this second analysis. As appropriate, reference is made to these Mid-Term Report data in this report.

This Final Report presents data based on input cut-off dates prior to the Integrated Operations/Payloads/Fleet analysis in March, April, and May 1971. The cut-off date for accepting new launch vehicle data was 23 March 1971. For assumptions, mission, and design data it was 1 April 1971. New low cost payload data were accepted from LMSC through 30 April 1971.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The Space Shuttle is a key element in NASA's plans for carrying out future national space programs. To generate the data necessary for cost-benefit analyses of this new space transportation system as contrasted to alternate launch system options, NASA is sponsoring an Economic Analysis Study. This study is composed of three contractor studies, as shown in Figure 1-1. The Aerospace Corporation Integrated Operations/Payloads/Fleet Analysis is summarized in this volume.

The Lockheed Missiles and Space Company (LMSC), Sunnyvale, California, is responsible for identification of payload cost reductions which may accrue either through utilization of the Space Shuttle payload capabilities or alternate low cost expendable transportation systems. The Aerospace Corporation is responsible for developing basic mission, payload, and launch vehicle technical and cost data, based on LMSC payload effects data and the mission and traffic models provided by NASA. Mathematica, Inc., Princeton, New Jersey, is responsible for the conduct of total program economic analyses, based upon program cost data provided by The Aerospace Corporation and NASA and DoD budget projections provided by NASA.

The Integrated Fleet Analysis examines NASA, DoD, and other U.S. space missions projected for the period of 1979-1990. Three launch vehicle fleets consisting of the current fleet, a low cost expendable fleet, and the Space Shuttle/Space Tug fleet are analyzed for deployment of payloads. Consideration of savings resulting from the ability to retrieve and reuse these payloads with the Space Shuttle/Space Tug and the relaxation of payload weight and volume constraints with the Shuttle or low cost expendable fleet are included in the analysis. The analysis consists of system cost estimating, mission modeling, definition of payload subsystems, launch vehicles and transfer stages, facilities, range safety, and launch rate limitations.

The results of this analysis indicate the principal cost drivers when comparing STS/Payload System costs with expendable launch/payload system costs are: payload refurbishment and maintenance costs for reusable payloads which replace the new expendable payload investment costs, the STS nonrecurring costs, and the reduced launch costs with the STS. Once the Space Shuttle is fully operational (60 flights per year), the total system costs are reduced with the STS fleet. In the years 1982 to 1988, the total STS/payload system costs vary from 1.8 to 2.8 billion dollars per year. Payload savings primarily arise from the retrieval, refurbishment or maintenance, and reuse of unmanned satellites. Cost reductions also occur due to the reduction in payload and launch vehicle losses, launch costs, and payload RDT&E costs.

This Final Report, Volume I, formally summarizes the results of The Aerospace Corporation analysis, the details of which are contained in the following volumes:

Volume II	-	Payloads
Volume III	-	System Costs
Volume IV	-	Launch Systems
Volume V	-	Mission, Capture and Operations Analysis
Volume VI	-	Classified Addendum

These documents are based upon mission and traffic models provided by NASA and upon payload effects data developed by LMSC.

The work reported herein has been conducted as Study A of NASA Contract NASw-2129. The NASA Study Director is Mr. William F. Moore, Space Shuttle Program Office, NASA Headquarters (Code MH).

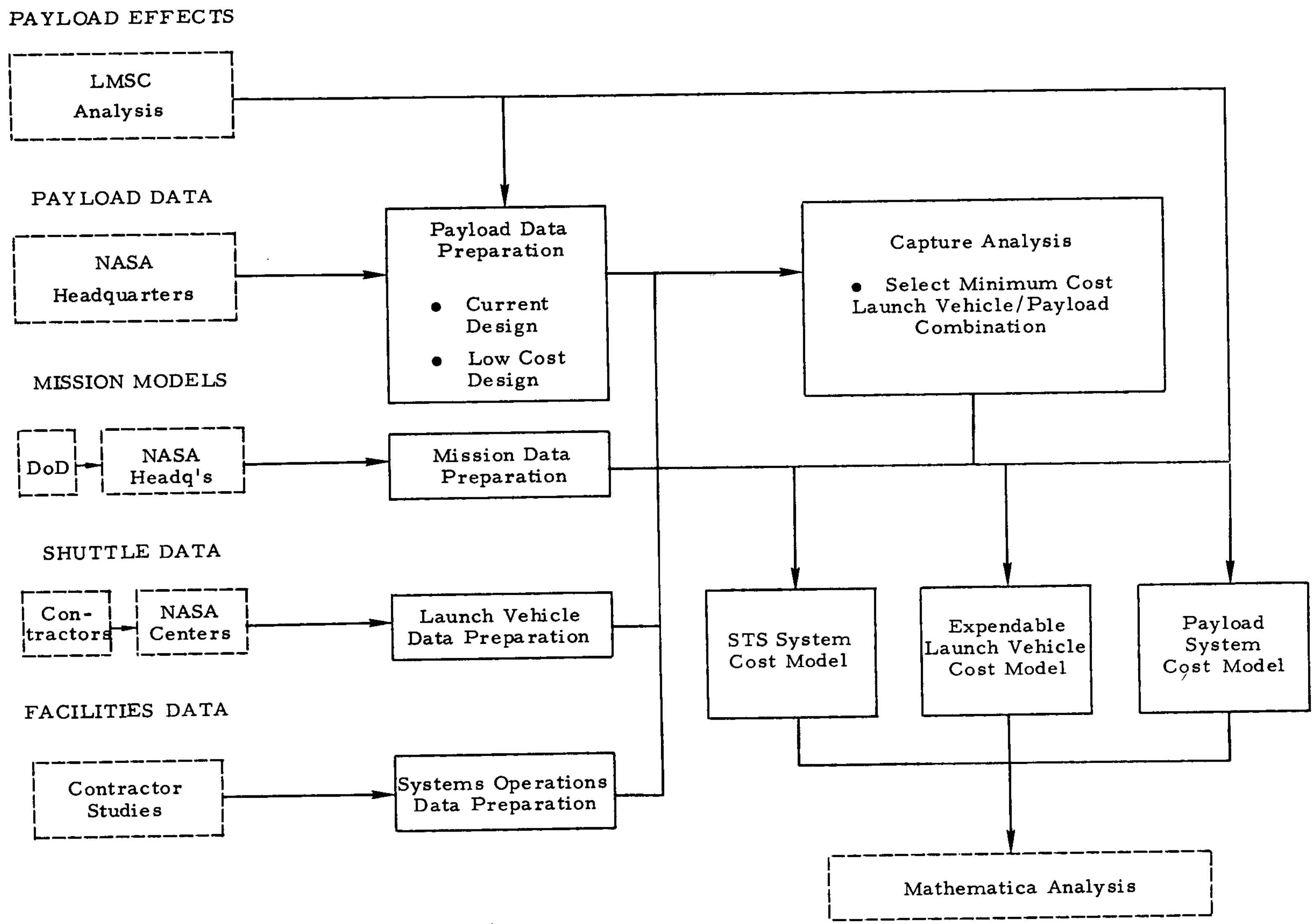


Figure 1-1. Data Flow

2. STUDY OBJECTIVE

The NASA Economic Analysis of Future Launch Vehicle Systems Study is aimed at providing an independent assessment of the following points:

(a) Is full-scale development of a new launch system to reduce the cost of payloads in orbit economically justifiable?

(b) Is the fully reusable concept economically justifiable when compared to new expendable or expendable/reusable concepts?

The task of conducting the necessary economic analyses and assessing them is assigned by NASA to Mathematica, Inc. The role of The Aerospace Corporation, the Integrated Operations/Payloads/Fleet Analysis contractor, is to act as the primary data source for input into the Mathematica economic analysis.

3. RELATIONSHIPS TO OTHER NASA EFFORTS

Figure 1-1 shows the relationship between the three contractor efforts as well as major inputs from NASA. Payload and mission data for the 1979-1990 time period were furnished by the NASA Study Director, Mr. William F. Moore. The output data are transmitted directly to the economic analysis contractor, Mathematica. The Aerospace Corporation Integrated Fleet Analysis receives NASA Phase B Space Shuttle data from Mr. William A. Huff of MSFC and Mr. Jerry E. Hoisington of MSC. Data from the NASA Phase A alternate configuration studies, the NASA Phase A Space Tug studies, and related payload studies such as the Large Stellar Telescope Study and the ITOS Study have also been made available by NASA.

Two other studies at The Aerospace Corporation sponsored by NASA Headquarters, Integrated Space Program and Vehicle System Analysis - Study B; and Development of Integrated Space Flight Program, Logistics Plan/Advanced Manned Missions Safety Studies - Study C, are related to the Integrated Fleet Analysis effort. Some study elements, such as acquisition of alternate configuration data and the study of Space Shuttle operations, are common to the studies, and use was made of data generated by these other two studies.

4. METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

The approach used in this study was to obtain input data from the various sources discussed in Section 3 and prepare it for use in the two principal analyses carried out by The Aerospace Corporation, namely, the Capture Analysis and Costing Analysis. The preparation of these input data represents a significant analytical effort and will be described along with the Capture and Cost Analyses later in this section.

Expendable launch vehicle data required for the current expendable fleet and new expendable fleet were obtained from NASA, SAMSO and Aerospace Program Offices. Saturn data came from NASA and Titan data from the Aerospace Titan-III Program Office.

4.1 GROUND RULES AND ASSUMPTIONS

The updated NASA Space Shuttle Payload and Traffic Model, April 1971, and the DoD Mission Model for Space Transportation System Mission Analysis, 1 March 1971, were furnished by NASA for this analysis.

Ground rules and assumptions used in the analyses reported in this Final Report are listed below.

(a) The Space Shuttle maximum flight rate is:

Calendar Year	1979	1980	1981
Maximum No. of Flights	14	36	50

(b) Launch Site Number 2 is activated for Shuttle one year after Launch Site Number 1.

(c) Space Station Laboratories and support costs are included, but costs for the Space Station hardware are excluded.

(d) Payload costs for DoD Support Missions are excluded.

(e) Two Space Tug availability dates are considered, 1979 and 1985.

(f) Agena and Centaur upper stages are used with the Space Shuttle until the Tug is available.

(g) The Space Shuttle development flights are launched from ETR.

(h) On-orbit maintenance is not desirable for expendable launch vehicle supported payloads.

(i) On-orbit assembly of payloads to stages and stages to stages is available as a developed operating technique and used as required to support the mission model.

(j) Payload refurbishment costs for payloads designed for refurbishment and maintenance are 32.5 to 39 percent of the payload unit cost.

(k) The Space Shuttle, Space Tug, and low cost expendable launch vehicle procurements are coordinated on a national basis.

(l) The current expendable launch vehicle operations are carried out as they are today.

(m) Space Shuttle vehicle elements are overhauled and reconditioned every 100 flights.

(n) The Space Tug vehicles are overhauled and reconditioned every 10 flights.

(o) The minimum investment in the Space Shuttle fleet is to be achieved (two complete vehicles at WTR and two boosters and three orbiters at ETR).

(p) Maximum payloads per Shuttle flight - three (3).

(q) Payloads can only be stacked end-to-end or side-by-side.

(r) The Shuttle ABE's are only removed when required.

(s) Passenger-carrying flights would have ABE's in.

4.2 DATA PREPARATION

The data preparation task consisted of formatting, extending, and correcting the input data to be compatible for use in the subsequent Capture and Cost Analyses. The input data from NASA and from the DoD Mission Model report are broken down only in terms of satellite gross weights. These data were processed by The Aerospace Corporation to develop subsystem weights for each satellite to allow their use in the subsequent Capture and Cost Analyses. In the process of preparing these subsystem data, it became apparent that some satellite gross weights needed to be adjusted up to 100 percent in order to be consistent with subsystem technologies.

Low cost payload design data and cost estimates were furnished to The Aerospace Corporation by LMSC based on their design and analysis of three typical NASA payloads. These data were intended to be representative of different classes of satellites and include the Orbiting Astronomical Observatory (OAO), representative of high cost payloads; the Synchronous Equatorial Orbiter (SEO), representative of medium cost payloads; and the Small Research Satellite (SRS), representative of a low cost payload. The Synchronous Equatorial Orbiter was derived by LMSC from the 850 lb Lunar Orbiter. Low cost payload lifetime was generally limited to two years maximum by the lifetime limitations estimated by LMSC for the low cost payload subsystems studied.

The Aerospace Corporation developed the weights for the satellites in the mission model from the LMSC data by using the following equation:

$$\text{Low Cost Satellite Weight} = \sum_{\text{Subsystems}} \text{Current Expend. Subsystem Wt.} \times \frac{\text{LMSC Low Cost Subsystem Wt.}}{\text{LMSC Historical Subsystem Wt.}}$$

The particular LMSC satellite (OAO, SEO, SRS) subsystem data were chosen to be most nearly compatible with the subsystem of the mission model satellite being considered. The volume data reported by LMSC were only for the total system and were not broken down by subsystem. Aerospace estimated the mission model satellite volumes by the following equation:

$$\text{Low Cost Satellite Volume} = \text{Current Satellite Volume} \times \frac{\text{LMSC Low Cost Satellite Volume}}{\text{LMSC Historical Satellite Volume}}$$

4.3 TRAFFIC MODELS AND BASIC PAYLOAD DATA

The baseline traffic model used in the analysis is the April 1971 NASA Space Shuttle Payload List and Traffic Model and Option B of the March 1971 DoD STS Mission Model. The activity level represented by the combined NASA and DoD payload traffic is shown graphically in Figure 4-1. The payload population on orbit represents the number of payloads actually functioning on orbit. The activity level is nearly constant with time. The average payload launch rate projected for the years 1982-1990 is slightly below the average U.S. historical launch rate for a comparable period in the 1960's. The average life of all payloads in orbit can be seen to be approximately 2-1/2 years; the average life of the unmanned payloads in the mission model is 3 years.

Basic payload data for NASA missions are from data sheets published in March 1971 in Volume II of the Aerospace Second Interim Report. These data evolved from NASA inputs which were expanded by Aerospace to meet the needs of this analysis and then coordinated by Aerospace with the NASA OSSA responsible engineers.

4.4 SPACE SHUTTLE AND SPACE TUG

The Space Shuttle configurations selected as typical for this analysis were the MDAC vehicle of March 1971 with a gross liftoff weight of 4.6 million pounds.

The reusable Space Tug selected for this analysis was 35 feet long and was based on an Aerospace configuration. The two NASA Phase A Tug designs were inappropriate for the mission models because of their size and design for space basing. Where required because of heavy payload weights, two Tugs in tandem were used to achieve payload retrieval from synchronous orbit. The modular reusable nuclear shuttle was used to support the lunar mission options reported on in the Mid-Term Report of this study.

4.5 NEW LOW COST EXPENDABLE LAUNCH VEHICLE FLEET

The new low cost expendable launch vehicle fleet selected for this analysis consists of the Titan III family with growth in payload capabilities to 100,000 lbs in an east launch to a 100 n mi altitude using a large diameter core vehicle. The vehicles and payload capabilities are given in Table 4-1. This fleet maximizes the use of low cost common vehicle elements. The Titan III family has relatively low accelerations during launch and accommodates large diameter, heavy payloads, thus supporting payload effects obtainable with large volume and weight concepts. The manned flights in the baseline mission model supporting the space station were carried out using the Big-Gemini (Big-G) reentry vehicle and an appropriate propulsive trailer.

4.6 CAPTURE ANALYSIS

The Capture Analysis was carried out using the data prepared as described in Sections 4.2 through 4.5 and according to the ground rules and assumptions listed in Section 4.1. For the new low cost expendable boosters, current design and new low cost design payloads were matched up with appropriate vehicles of the booster family to be consistent from a weight and volume standpoint. The cost of using these two options was considered for each traffic model entry. The LMSC data are for specific satellite lifetimes which do not exceed two years for the low cost designs, whereas some of the current design satellites have lifetimes of three to five years. The particular payload option selected was the one representing the least cost, including the RDT&E to redesign satellites. In the case of long duration missions, current designs proved to be more cost-effective. Multiple satellite launches were also considered by grouping mission model elements by destination and selecting boosters with compatible weight and volume capability. These were then compared from a cost standpoint with the other alternatives and the least costly approach selected.

For the Space Shuttle, a similar technique was used except that the retrieval-reusable aspect was factored in. This included two different approaches: (1) using a new, low cost, reusable payload design with a maximum life of two years and a refurbishment cost factor of 32.5 percent for satellites similar to OAO and 39 percent for satellites similar to the Synchronous Equatorial Orbiter (SEO); and (2) using a current technology payload design redesigned for reusability, but retaining or increasing the spacecraft current designed lifetime and a refurbishment factor of 39 percent. Refurbishments were accomplished after the satellite or spacecraft had operated for a period of one mean mission duration. Retrieval was generally effected on deployment flights to achieve maximum utilization of the Space Shuttle. Multiple satellite launches were considered in the same manner as the expendable booster case. In certain missions, the NASA model requires revisits to the satellites on a periodic basis. During these revisits, refurbishment was carried out periodically on orbit using satellite module, remove and replace maintenance techniques. The lifetime of the satellite on orbit was extended accordingly. All other refurbishment and satellite maintenance was carried on the ground following satellite retrieval.

4.7 COST ANALYSIS

The Space Shuttle and Space Tug costs were estimated using the Space Transportation System Cost Methodology, a computerized program using cost estimating relationships developed by The Aerospace Corporation. The costs of the payloads in the mission model for the current designs were arrived at on a subsystem basis using the weight data discussed in Section 4.2 and the cost estimating relationships (CER) of the SAMSO model. For the low cost designed payloads, the following equation was used:

$$\text{Cost of Low Cost Design Satellite} = \sum_{\text{Subsystem}} \text{SAMSO CER} \times \text{Current Subsystem Weight} \times \frac{\text{LMSC Low Cost Subsystem Cost}}{\text{LMSC Historical Subsystem Cost}}$$

The subsystem costs for the low cost design SEO and OAO satellite subsystems were applied to subsystems of current design satellites judged to be similar for either the one or two year payload designs. Factors for the SRS were not used, as the data were inapplicable to the mission model. The LMSC OAO and SEO subsystem cost data are presented respectively in Figures 4-1 and 4-2.

Table 4-1. New Low Cost Expendable Launch Vehicle Fleet

Launch Vehicle[1]	Payload, Lb (To 100 n mi East, ETR)	Configuration
5-Seg. SRM/Core II	7,900	Stage 1: One 5-Segment 120" SRM (New) Stage 2: Titan III 10' Diameter Liquid Core Stage II
Titan IIID	29,000	Stage 0: Two 5-Segment 120" SRM Core: Two Stage 10' Dia. Liquid Titan III
Titan IIID (7)	38,000	Stage 0: Two 7-Segment 120" SRM Core: Two Stage 10' Dia. Liquid Titan III
Titan IIIM	38,000	Titan IIID (7), Man-Rated
Titan III L-2 Titan III L-4	62,500 91,000	Stage 0: Two or Four 7-Segment 120" SRM Core: Two Stage 15' Dia. Liquid Titan III Growth (New)

(1)Agena, Centaur or kick stage available on any booster

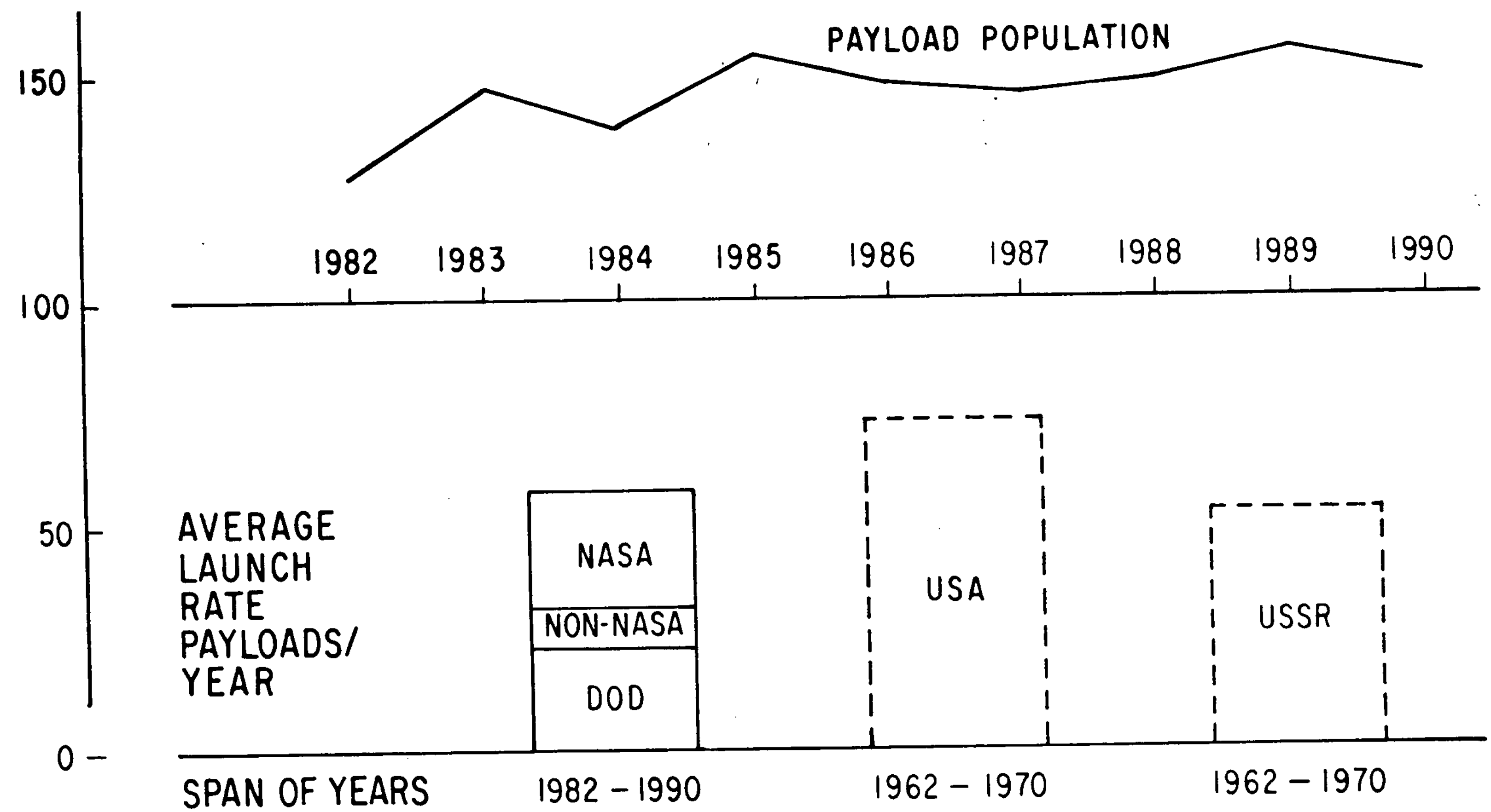
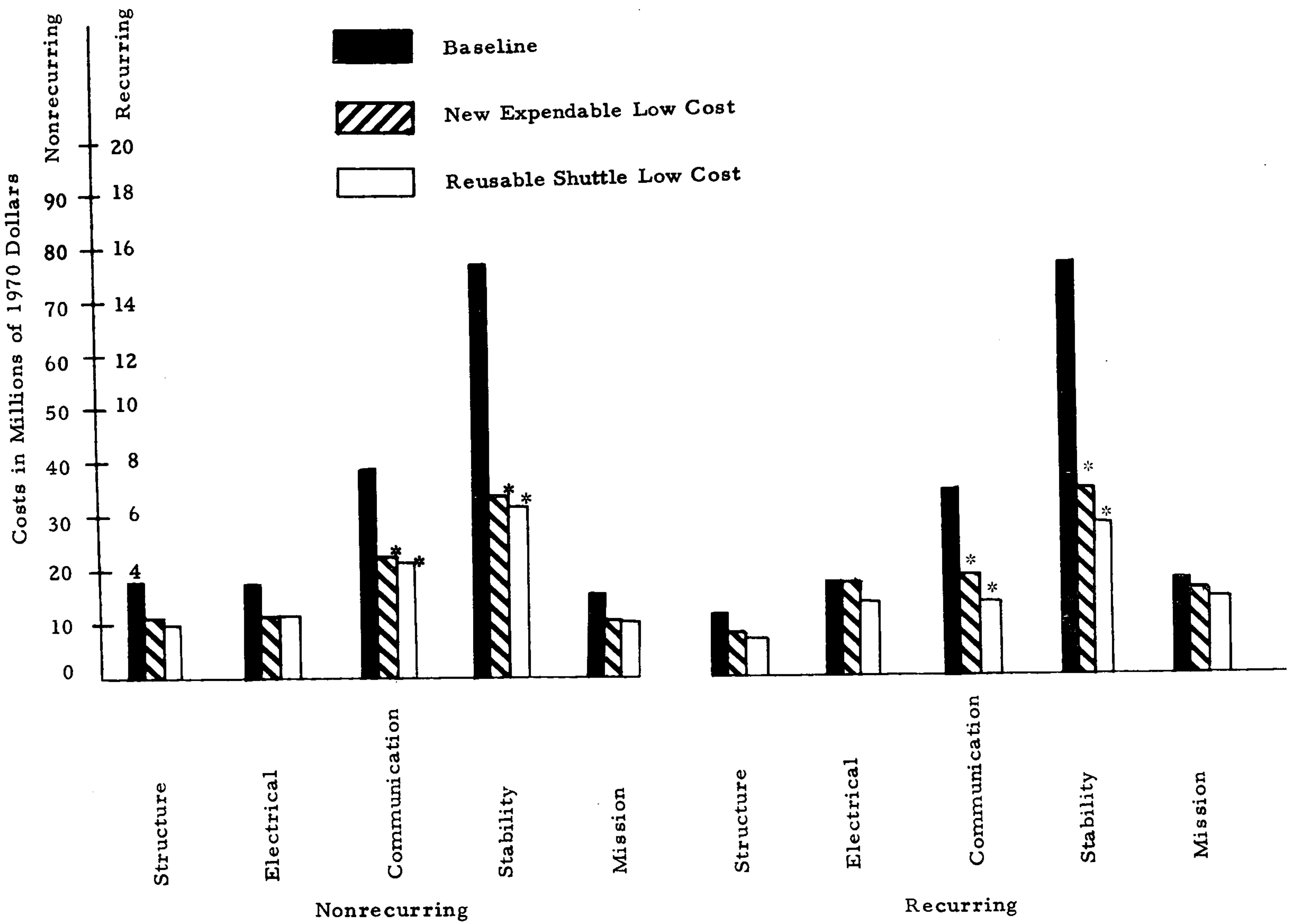


Figure 4-1. Mission Model Payload Activity Level



* Not Applied

Figure 4-2. LMSC Payload Cost Estimates, Orbiting Astronomical Observatory

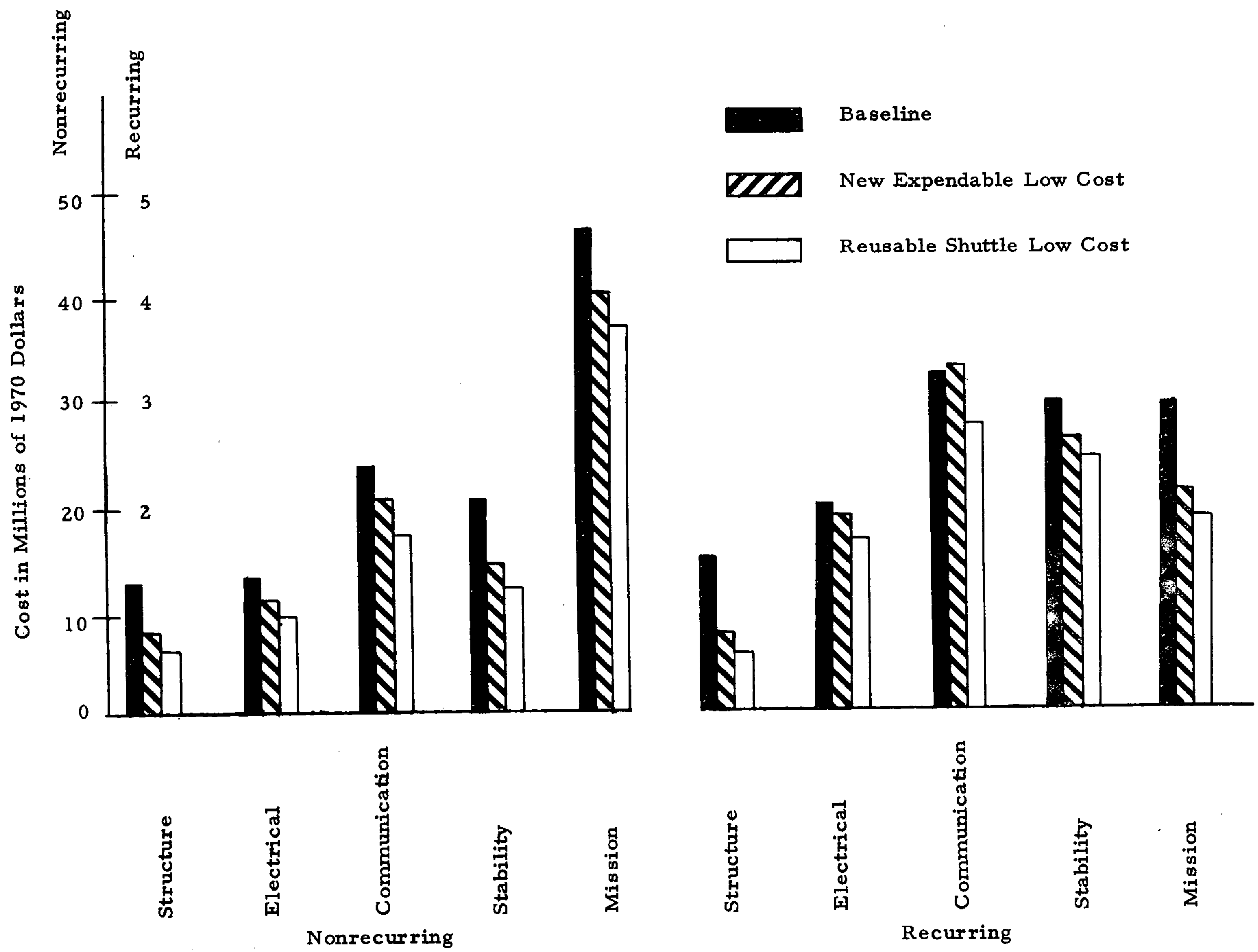


Figure 4-3. LMSC Payload Cost Estimates, Synchronous Equatorial Orbiter

5. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The results of the Aerospace analyses indicate a significant reduction (62 percent) in the required total number of new payload units with the Space Shuttle/Space Tug fleet. For both the current expendable and the new low cost expendable fleets, 632 new payload units were required, as contrasted to 240 for the Space Shuttle/Space Tug fleet. This reflects the retrieval capability of the Space Shuttle, which allows refurbishment of the payloads.

Another significant result is that 26 percent of the payloads for the new low cost expendable fleet and 26 percent for the Space Shuttle and Space Tug fleet are of low cost payload designs, as contrasted to 0 percent for the current expendable fleet. The primary factor favoring the current payload designs over low cost designs is their higher reliability and, therefore, longer lifetime before replacement.

The analysis indicated that early development of retrievable payloads and payloads designed for overhaul and repair are very desirable. There is an economic advantage in developing refurbishable payloads before the Shuttle becomes operational, deploying them from expendable launch vehicles, and then retrieving these payloads with the Space Shuttle and Space Tug when they become available.

The average yearly direct cost savings for the Space Shuttle era is predicted to be 1.4 billion dollars (see Table 5-1) for the space systems included in this analysis. Most of the savings are due to payload retrieval and reuse and lower launch costs (see Table 5-2).

After the Space Shuttle becomes fully operational, the direct costs for space systems included in this analysis totaled 2.0 billion dollars per year (see Table 5-1). The comparable cost for the Mid-Term analysis was 2.01 billion dollars. The Mid-Term analysis was based on a higher level of yearly payload launch activity than was the final analysis. The direct yearly costs appear to be relatively insensitive to space activity levels for the Space Shuttle era. Most of these direct costs arise from payload RDT&E and payload operations and refurbishment (see Table 5-3).

Table 5-1. Average Direct Cost Savings for the Fully Operational Space Shuttle Era, $B/Year

	NASA	Non-NASA	DoD(1)	Total
Current Expendable Launch Vehicle Systems	2.14	0.34	0.93	3.41
Fully Reusable STS	1.30	0.16	0.54	2.00
Cost Savings	0.84	0.18	0.39	1.41

Table 5-2. Space System Cost Reduction Areas

	% of Direct Cost Savings
Lower Launch Costs	43
Increased Launch Vehicle Reliability(1)	3
Payload Retrieval(1)(2) and Reuse	49
Low Cost Payload Design	5

Table 5-3. Average Direct Costs for Fully Operational Space Shuttle Era

	$ B/Year	%
Payload RDT&E	0.65	32
Payload Investment	0.34	17
Payload Operations & Refurbishment	0.71	36
Launch Costs	0.30	15
Total	2.00	100

Notes: All costs are in 1970 dollars for the baseline mission model

(1) Support mission payload costs not included
(2) Including payload infant mortality effects

6. STUDY LIMITATIONS

The scope of this cost analysis was limited by the following exclusions because of lack of data:

1. Space station (station crew, power, core, control and general purpose laboratory areas).

2. DoD support mission payloads.

3. NASA and DoD institutional activities, including ground station support of on-orbit payloads.

7. IMPLICATIONS FOR RESEARCH

This systems analysis indicates the desirability of demonstrating certain modes of operation such as payload retrieval, maintenance, repair and refurbishment and tandem Space Tug assembly on orbit. However, additional study will be required to define the implications for research, if any.

8. SUGGESTED ADDITIONAL EFFORT

The results of the systems analysis indicate that with the Space Shuttle capability for two-way transportation to space, new payload program options are made available which lead to significant payload program savings.

1. Satellite reuse
2. Reduction in payload losses due to launch failure or early payload failures
3. Reduction in the need for backup payloads
4. Reduction in the new satellite hardware used in the payload development (RDT&E) phase. The payload effects analysis showed that maintainable satellite hardware can be reused extensively for ground tests and flight.
5. Reduced sustaining engineering requirements for operational space systems
6. Reduced yearly maintenance for spacecraft with increased spacecraft component redundancy due to longer on-orbit periods between satellite replace and refurbish actions.
7. Payload services which the Shuttle orbiter might offer to potential users to effect reductions in payload program costs such as payload checkout, conditioning and power supply.

It is recommended that effort be applied towards better definition of the potential cost and operational advantages in the above areas through tradeoff analyses. It is further recommended that NASA initiate effort to implement these operational modes for the Shuttle era through appropriate changes in Space Shuttle and Space Shuttle payload design requirements. Studies defining the implications for research (see Section 7) are also recommended.

9. REFERENCES

1. "Integrated Operations/Payloads/Fleet Analysis Mid-Term Report," Consisting of:

   ATR-71(7231)-9, Vol. I, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume I: Summary," dated 31 March 1971 (Unclassified)

   ATR-71(7231)-9, Vol. II, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume II: Payloads," dated 24 March 1971 (Unclassified)

   ATR-71(7231)-9, Vol. III, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume III: System Costs," dated 31 March 1971 (Unclassified)

   ATR-71(7231)-9, Vol. IV, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume IV: Launch Systems," dated 19 March 1971 (Unclassified)

   ATR-71(7231)-9, Vol. V, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume V: Mission, Capture and Operations Analysis," dated 23 March 1971 (Unclassified)

   ATR-71(7231)-9, Vol. VI, "Integrated Operations/Payloads/ Fleet Analysis Mid-Term Report, Volume VI: Classified Addendum," dated 31 March 1971 (Secret)

DISTRIBUTION

Internal

E. Blond
R. M. Coulston
R. T. Dungan
G. M. Forslund
A. E. Goldstein
R. H. Herndon
R. E. Kendall
S. Lafazan (3)
H. J. Meyer
J. J. Minich
J. A. Plough
W. J. Portenier
E. I. Pritchard (5)
A. J. Shier
T. Shiokari
L. R. Sitney
S. M. Tennant
W. H. Wetmore
R. R. Wolfe
J. K. Yakura (2)
STSCF

External

NASA Headquarters
Washington, D.C. 20546
Attn: W. Fleming/AAD-3
T. Keegan/MTE
R. N. Lindley/M
J. Malaga/BR
W. F. Moore/MH (50)
C. T. Newman/BR
R. Wilson/SF

New Technology Representative
Headquarters Technology
Utilization Officer
NASA Headquarters, Code KT
Washington, D.C. 20546

NASA Scientific & Technical
Information Facility (3)*
P.O. Box 33
College Park, Maryland 20740

NASA Manned Spacecraft Center
Houston, Texas 77058
Attn: J. E. Hoisington/LA (2)

NASA Marshall Space Flight Center
Huntsville, Alabama 35802
Attn: W. A. Huff/PD-RV-1
J. O. Ballance/PD-MP-P

NASA Goddard Space Flight Center
Green Belt, Maryland 20771
Attn: G. Keller

NASA Langley Research Center
Hampton, Virginia 23365
Attn: R. H. Weinstein/APD
(Mail Stop 408)

National Aeronautics & Space Council
Executive Office of the President
Washington, D.C. 20502
Attn: Lester Fero

Mathematica, Incorporated
One Palmer Square
Princeton, New Jersey 08540
Attn: K. P. Heiss (5)

Lockheed Missiles and Space Company
Space Systems Division
P.O. Box 504
Sunnyvale, California 94088
Attn: R. M. Gray(3)

* One copy to serve as "reproducible"