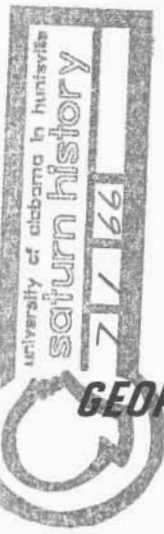


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DIGEST OF FY-63 FUNDED ADVANCED STUDIES JULY 1966

National Aeronautics and Space Administration



GEORGE C. MARSHALL SPACE FLIGHT CENTER

DIGEST OF
FY-63 FUNDED ADVANCED STUDIES

JULY 1966

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RESOURCES MANAGEMENT OFFICE
ADVANCED SYSTEMS OFFICE

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
SECTION I. LAUNCH VEHICLE AND SUPPORTING STUDIES	2
A. Investigation of Vehicle-Integrated Rocket Power Plants with Air Augmentation	2
B. Nova Vehicle Systems (Parts I and II)	2
C. Conceptual Study of Reusable Ten Passenger Orbital Carrier Vehicle (Phase II).	3
D. Study of Reusable Launch Vehicles in the 100-Ton Orbital Payload Class Based on Advanced Saturn Hardware (Phase II)	4
E. Post-Nova Chemo-Nuclear Launch Vehicle (Task III)	5
F. Applications Study of Large Solid Motors	6
G. Launch Vehicle Cost Model	7
H. Cost Element Research	7
I. Cost/Reliability Relationships	8
SECTION II. ORBITAL AND LUNAR STUDIES	9
A. Advanced Orbital Launch Operations	9
B. Orbital and Lunar Flight Handbook (Phase II).	9
C. Advanced Lunar Transportation System-Operations Analysis	10
D. Preliminary Design of a Reusable Nuclear Ferry Vehicle (Phase II).	11
SECTION III. PLANETARY STUDIES	12
A. Nuclear Pulse Space Vehicle	12
B. Advanced Nuclear System Design Parameters	12
C. Planetary Transportation Systems Model	13
D. Interplanetary Flight Handbook (Phase III).	14
E. Early Manned Planetary Mission Study (EMPIRE) (Phase II).	15
F. Low Acceleration Space Transportation System (Phase II).	15
G. Manned Mars Exploration in the Unfavorable (1975-1985) Time Period	16

INTRODUCTION

This publication is one of a planned series to summarize the advanced study program for each fiscal year beginning with FY-61. A separate report will cover the study program for each fiscal year. The purpose of these documents is to provide historical reference information which should be helpful in planning future study programs.

The FY-63 funded studies are covered in this document. These investigations are covered under three categories: Launch Vehicle and Supporting Studies; Orbital and Lunar Studies; and Planetary Studies. The information presented on each study includes a brief description of the objective and results and pertinent contract data.

In order to keep this report small and easy to use, no attempt was made to include conclusions based on the study results; however, the final reports documenting the investigations are referenced. If these reports are needed for permanent retention and are not available from the Technical Supervisor or the MSFC Library (MS-IPL), submit requests for the documents to the Scientific and Technical Information Facility, Attention: NASA Representative, P. O. Box 33, College Park, Maryland 20740.

SECTION I. LAUNCH VEHICLE AND SUPPORTING STUDIES

A. INVESTIGATION OF VEHICLE-INTEGRATED ROCKET POWER PLANTS WITH AIR AUGMENTATION

Objectives and Results

The primary objective of this study was to assess the feasibility and the desirability of improving launch vehicle performance by using air breathing rocket propulsion systems. Existing rocket technology coupled with known principles of gaseous mixing and combustion were to be employed to the maximum extent possible to attain this objective. The study was entirely analytical in nature and covered a broad area in a parametric fashion.

The results are documented in the following final report:

"Investigation of Vehicle-Integrated Rocket Powerplants with Air Augmentation", Contract No. NAS8-11017, Report No. D2-23217, Boeing Company, June 15, 1964, CONFIDENTIAL.

Contract Information

1. Contractor: Boeing Company
2. Contract No: NAS8-11017
3. Period of Performance: June 63 - June 64
4. Contract Amount: \$84,108
5. Technical Supervisor: D. Thompson/W. Escher

B. NOVA VEHICLE SYSTEMS (PARTS I AND II)

Objectives and Results

The major objective was to define various vehicle concepts and to make systems comparisons to determine the most desirable concepts for a Post-Saturn vehicle. At the time this part of the study was initiated, an early manned Mars mission was of interest; therefore, the majority of the effort was expended on configurations that offered early availability. Based on the results of these investigations and several mission studies, it was concluded that early (mid-1970's) planetary missions using new launch vehicles were impractical because expected resources did not permit the required development work. Thus, the follow-on studies concentrated on more advanced concepts that were more compatible with the expected resources.

Results of these investigations are documented in the following final reports:

1. "Nova Vehicle Systems Study, Part I," Contract No. NAS8-5135, Report No. 12590, Martin Company, April 3, 1963, CONFIDENTIAL.
2. "Nova Vehicle Systems Study, Part I," Contract NAS8-5136, Report No. AE63-0096, General Dynamics-Astronautics, April 1, 1963, CONFIDENTIAL.
3. "Vehicle Systems Study, Part II, Final Report (NOVA)," Contract No. NAS8-5135, Report No. 12589, Martin Company, September 1963, CONFIDENTIAL.
4. "Nova Vehicle Systems Study Final Report, Part II, Conceptual Design Studies," Contract No. NAS8-5136, Report No. GDA 63-0844, General Dynamics-Astronautics, September 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Martin Company
 - a. Contract No.: NAS8-5135
 - b. Period of Performance: August 62 - September 63 (Parts I and II)
 - c. Contract Amount: \$1,600,000 (Parts I and II)
 - d. Technical Supervisor: F. Williams/W. Huber
2. Contractor: General Dynamics-Astronautics
 - a. Contract No.: NAS8-5136
 - b. Period of Performance: August 62 - September 63 (Parts I and II)
 - c. Contract Amount: \$1,598,000 (Parts I and II)
 - d. Technical Supervisor: F. Williams/W. Huber

C. CONCEPTUAL STUDY OF REUSABLE TEN PASSENGER ORBITAL CARRIER VEHICLE (PHASE II)

Objectives and Results

The overall objective of this study was to define a launch vehicle system suitable for transportation of non-astronaut passengers between Earth surface and Earth orbit, with cargo capability as a secondary function. The conceptual design phase (Phase I) of the study, which had been completed, explored rocket airplane concepts for horizontal (HTO) and vertical (VTO) take-off to determine features and modes compatible with the study objective. The objective of this phase

(Phase II, Preliminary Design) was to investigate one of the promising concepts resulting from Phase I of the study. This concept is a two-stage rocket airplane type vehicle designed for repeated re-use of most, or all, elements of hardware.

The results of this phase of the study are contained in the following final reports:

1. "Reusable Ten Passenger Orbital Carrier Vehicle, Phase II," Contract No. NAS8-2687, Report No. LR-17087, Lockheed Aircraft Corporation, 16 March 1964, CONFIDENTIAL.
2. "The Study of Ten Passenger Reusable Orbital Carrier, Phase II," Contract No. NAS8-5037, Report No. SID 64-144, North American Aviation, Inc., March 19, 1964, CONFIDENTIAL.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
 - a. Contract No.: NAS8-2687
 - b. Period of Performance: February 63 - March 64 (Phase II)
 - c. Contract Amount: \$349,390 (Phase II)
 - d. Technical Supervisor: D. Fellenz/L. Spears
2. Contractor: North American Aviation, Inc.
 - a. Contract No.: NAS8-5037
 - b. Period of Performance: March 63 - March 64 (Phase II)
 - c. Contract Amount: \$250,000 (Phase II)
 - d. Technical Supervisor: D. Fellenz/L. Spears

D. STUDY OF REUSABLE LAUNCH VEHICLES IN THE 100 TON ORBITAL PAYLOAD CLASS BASED ON ADVANCED SATURN PROGRAM HARDWARE (PHASE II)

Objectives and Results

The objective of this study was to investigate possible successors to the Saturn V and modified versions to be used as the primary cargo transport for mid-1970 support of Earth orbit operations and manned lunar transportation. Phase I of this effort was a conceptual design study of possible recoverable and reusable Saturn V configurations. The prime objective of this phase of the study (Phase II) was to extend the investigations conducted in Phase I in order to obtain preliminary designs and supporting data for reusable first stage Saturn V configurations to establish a firm base point for comparison with other candidate vehicles.

The results of this phase of the study are documented in the following final report:

"Reusable Ground Launch Vehicle Study-100-Ton Orbital Payload," Contract No. NAS8-5036, Report No. D2-22804, Boeing Company, December 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Boeing Company
2. Contract No.: NAS8-5036
3. Period of Performance: March 63 - March 64 (Phase II)
4. Contract Amount: \$199,920 (Phase II)
5. Technical Supervisor: M. Vaccaro

E. POST-NOVA CHEMO-NUCLEAR LAUNCH VEHICLE (TASK III)

Objectives and Results

The objective of this study was to contribute to the selection and definition of a Nova-class vehicle, and to explore advanced concepts capable of improving efficiency of operation in launching very large payloads (one million pound class). Tasks I and II, which were previously completed, concentrated on advanced conceptual designs for promising vehicles using chemical propulsion for Nova type missions. The primary objective of this portion of the study (Task III) was to review the state of the art for very large launch vehicles, using nuclear propelled stages in conjunction with a chemical boost stage, with an availability of 1975 or later. Secondary objectives were to provide selection criteria for promising concepts, prepare conceptual designs, and investigate their compatibility with the Nova first stage.

The results of this phase of the study are contained in the following final reports:

1. "Post-Saturn Class III and IV Launch Vehicle Study (Phase III)," Contract No. NAS8-5021, Report No. SM-45804, Douglas Aircraft Company, March 1964, CONFIDENTIAL.
2. "Post-Saturn Launch Vehicles Study, Phase III, Class IV Vehicles," Contract No. NAS8-5022, Report No. GD/A-AOK-64-009, General Dynamics-Astronautics, March 11, 1964, UNCLASSIFIED.

G. LAUNCH VEHICLE COST MODEL

Objectives and Results

The objective of this study was to develop a detailed mathematical cost model which would yield complete R & D and operational program cost estimates of present and proposed launch vehicle systems. It was intended that this cost model would be used in conjunction with an IBM 7094 computer to provide rapid cost estimates for a wide range of launch vehicles of various sizes and technologies.

The results of the study are contained in the following final reports:

1. "Launch Vehicle Systems Cost Model," Contract No. NAS8-11006, Report NO. FZM-4154, General Dynamics-Ft. Worth, June 15, 1964, UNCLASSIFIED.
2. "Launch Vehicle System Cost Model," Contract No. NAS8-11008, Report No. LR-17825/27/28, Lockheed California Company, June 15, 1964, UNCLASSIFIED.

Contract Information

1. Contractor: General Dynamics - Ft. Worth
 - a. Contract No.: NAS8-11006
 - b. Period of Performance: June 63 - June 64
 - c. Contract Amount: \$118,886
 - d. Technical Supervisor: T. Sharpe
2. Contractor: Lockheed California Company
 - a. Contract No.: NAS8-11008
 - b. Period of Performance: June 63 - June 64
 - c. Contract Amount: \$90,000
 - d. Technical Supervisor: T. Sharpe

H. COST ELEMENT RESEARCH

Objectives and Results

The objective of this study was to analyze, in detail, the cost histories of past and present missile and space systems in order to obtain a better understanding of factors that influence program costs of a complete launch vehicle system. These data and relationships were to be used to support the development of a mathematical model to predict launch vehicle costs.

The results of the study are contained in the following final report:

"Cost Analysis of Launch Vehicle Systems," Contract No. NAS8-11082, Report No AR-152, Rand Corporation, September 1964
CONFIDENTIAL.

Contract Information

1. Contractor: Rand Corporation
2. Contract No.: NAS8-11082
3. Period of Performance: June 63 - June 64
4. Contract Amount: \$45,230
5. Technical Supervisor: W. Porter

I. COST/RELIABILITY RELATIONSHIPS

Objectives and Results

During the past few years, considerable data in the areas of cost and reliability have been collected in an effort to establish a technique for predicting launch vehicle reliability and cost trends. The objectives of this investigation were to update this information; develop a model to predict the reliability growth of any launch vehicle; and develop detailed relationships between reliability and cost.

The information resulting from this investigation is contained in the following final report:

"Final Report on Investigation of Cost/Reliability Relationships," Contract No. NAS8-11037, Report No. 8499-6019-RU000 and 8499-6018-RZ000, Space Technology Laboratories, Inc., May 18, 1964, SECRET.

Contract Information

1. Contractor: Space Technology Laboratories, Inc.
2. Contract No.: NAS8-11037
3. Period of Performance: June 63 - June 64
4. Contract Amount: \$97,876
5. Technical Supervisor: W. Huber

SECTION II. ORBITAL AND LUNAR STUDIES

A. ADVANCED ORBITAL LAUNCH OPERATIONS

Objectives and Results

An initial study (Phase I), under contracts NAS8-852 and NAS8-853, investigated the problems associated with Orbital Launch Operations (OLO) and the requirements for supporting systems with emphasis on early applications during the late 1960's. The second phase (current effort) was to further refine the procedures and techniques by which both chemical and nuclear vehicles can be launched from an Earth orbit, primarily for planetary missions with emphasis in the 1970 time period. Also, a comprehensive mathematical model of the elements comprising orbital operations was to be developed.

The results of this effort are documented in the following final report:

"Final Report, Advanced Orbital Launch Operations," Contract No. NAS8-5344, Report No. 00.368, Ling-Temco-Vought, May 4, 1964, CONFIDENTIAL.

Contract Information

1. Contractor: Ling-Temco-Vought
2. Contract No.: NAS8-5344
3. Period of Performance: April 63 - April 64
4. Contract Amount: \$349,800
5. Technical Supervisor: L. Ball

B. ORBITAL AND LUNAR FLIGHT HANDBOOK (PHASE II)

Objectives and Results

The overall objective of this effort was to develop two handbooks (Earth-orbital and lunar applications) needed by preliminary design engineers and mission planning engineers in the area of flight mechanics and systems performance. Together with a handbook developed under another contract (NAS8-2469, Planetary Trajectory Manual), these publications were to provide the necessary formulae, graphs, tables, and constants to plan missions around the Earth, Moon, and to the planets. The objective of this follow-on effort was to prepare for up-dating and adding to the data presented in the first edition of the handbooks.

The results of this effort are contained in the following document (See the "Digest of FY-62 Advanced Studies" for titles and identification of the Handbooks)."

"Extension of Effort for Lunar Flight Handbook," Contract No. NAS8-5031, Report No. ER-13550-I/II/III, Martin Company, December 1964, UNCLASSIFIED.

Contract Information

1. Contractor: Martin Company
2. Contract No.: NAS8-5031
3. Period of Performance: May 63 - January 64 (Phase II)
4. Contract Amount: \$30,000 (Phase II)
5. Technical Supervisor: C. Swanson

C. ADVANCED LUNAR TRANSPORTATION SYSTEM-OPERATIONS ANALYSIS

Objectives and Results

This study was a continuation of earlier conceptual studies of advanced systems which show promise of offering more economical transportation systems for the Post-Apollo time period. The emphasis of this study was on the development of methods and procedures that would allow an analysis and valid comparison of lunar transportation systems under varying assumptions. The procedures used for operations analysis of the systems studied earlier were to be refined. These procedures were to provide the means of selecting an optimum system or combinations thereof, and show a logical evolution of these systems to operational application over several decades.

The results of this effort are documented in the following final report:

"Operations Analysis of Advanced Lunar Transportation Systems," Contract No. NAS8-5027, Report No. 00.389, Chance-Vought, February 29, 1964, CONFIDENTIAL.

Contract Information

1. Contractor: Chance-Vought/Astronautics
2. Contract No.: NAS8-5027
3. Period of Performance: March 63 - February 64 (Phase II)
4. Contract Amount: \$213,470 (Phase II)
5. Technical Supervisor: C. Rutland

D. PRELIMINARY DESIGN OF A REUSABLE NUCLEAR FERRY
VEHICLE (PHASE II)

Objectives and Results

This study was a continuation of earlier exploratory studies with emphasis on the preliminary design of a reusable nuclear ferry vehicle, which is a key element of advanced lunar transportation systems. The objective was to determine the most desirable approaches to be taken, the operational problems to be expected, operational cost effectiveness, and to derive detailed criteria and specifications for such a vehicle.

The results of the effort are documented in the following final report:

"Reusable Nuclear Ferry Vehicle Preliminary Design Study,"
Contract No. NAS8-5020, Report No. LMSC-B007429 (8-09-64-2)
Lockheed Missiles and Space Company, February 28, 1964,
CONFIDENTIAL/RD.

Contract Information

1. Contractor: Lockheed Missiles and Space Company
2. Contract No.: NAS8-5020
3. Period of Performance: June 63 - February 64
4. Contract Amount: \$174,600
5. Technical Supervisor: C. Rutland

SECTION III. PLANETARY STUDIES

A. NUCLEAR PULSE SPACE VEHICLE

Objectives and Results

The primary objective of this study was to determine the mission potential of nuclear pulse space vehicles for lunar and planetary missions during the period between 1975 and 1995. A variety of mission profiles and operational systems were investigated. This effort was to define expected operational system characteristics, operational problems, and investigate possible solutions to these problems. Typical development programs geared to reach major planetary mission capability in the 1975 to 1995 time period were to be established.

The results of the study are outlined in the following final reports:

1. "Nuclear Pulse Space Vehicle Study," Contract No. NAS8-11053, Report No. GA-5009, General Dynamics-General Atomic, September 19, 1964, SECRET.
2. "Nuclear Pulse Space Vehicle Study-Mission Velocity Requirements and Systems Comparison," Contract No. NAS8-11053, Report No. GA-5009, General Dynamics-General Atomic, February 28, 1966, UNCLASSIFIED.

Contract Information

1. Contractor: General Dynamics-General Atomic
2. Contract No.: NAS8-11053
3. Period of Performance: June 63 - March 64
4. Contract Amount: \$98,300
5. Technical Supervisor: G. Whiton/V. Gradecak

B. ADVANCED NUCLEAR SYSTEM DESIGN PARAMETERS

Objectives and Results

The primary objective of this effort was to produce the necessary data to permit identification and definition of essential design requirements for an operational nuclear space propulsion system with availability in the 1970 - 1980 period. The study was to define Class I (1,500 - 5,000 MW) and Class II (5,000 - 15,000 MW) engine configurations and system parameters required for: (1) Delivery of passengers and/or cargo into lunar orbit; (2) representative unmanned

planetary and solar probes; and (3) stages for manned interplanetary vehicles. In addition, Class II engine requirements were to be investigated for representative manned planetary missions.

The results of this effort, and the FY-64 follow-on funded effort, are documented in the following final report:

"Mission Oriented Advanced Nuclear System Parameters Study,"
Contract NO. NAS8-5371, Report No. 8423-6007-RU000, TRW
Space Technology Laboratories, March 1965.

Contract Information

1. Contractor: TRW Space Technology Laboratories
2. Contract No.: NAS8-5371
3. Period of Performance: April 63 - May 64
4. Contract Amount: \$149,930
5. Technical Supervisor: W. Jordan

C. PLANETARY TRANSPORTATION SYSTEMS MODEL

Objectives and Results

The objective of this effort was to provide a reliable, flexible, and comprehensive automated matrix model of planetary transportation systems that would give quantitative results in terms of significant figures of merit for the evaluation of advanced propulsion systems in connection with potential mission requirements. A synthetic evaluation method incorporating the information of related previous studies was to be used. This initial model was to be capable of further growth by making provisions for incorporating additional significant system parameters in order to improve its predictive accuracy.

The results of this work, and follow-on efforts, are documented in the following final reports:

1. "Space Technology Analysis and Mission Planning (STAMP) Detailed Technical Report," Contract No. NAS8-11057, Report No. CR-64-16, Martin-Denver, January 1965, UNCLASSIFIED.
2. "STAMP Space Technology Analysis and Mission Planning," Contract No. NAS8-11084, Report No. GD/A AOK 65-001/-1/-2/-3/-4, General Dynamics-Astronautics, 1965, UNCLASSIFIED.

Contract Information

1. Contractor: Martin-Denver
 - a. Contract No.: NAS8-11057
 - b. Period of Performance: June 63 - May 64
 - c. Contract Amount: \$74,841
 - d. Technical Supervisor: V. Gradecak
2. Contractor: General Dynamics-Astronautics
 - a. Contract No.: NAS8-11084
 - b. Period of Performance: June 63 - May 64
 - c. Contract Amount: \$72,987
 - d. Technical Supervisor: V. Gradecak

D. INTERPLANETARY FLIGHT HANDBOOK (PHASE III)

Objectives and Results

Past effort provided a manual with information on high thrust planetary trajectories and other information associated with the design of manned planetary space vehicles for use by mission analysts and design engineers. The prime objectives of this effort were to: (1) Refine the existing material for maximum benefit to the user; (2) continue theoretical studies and include usable results in the manual; and (3) define problem areas related to low thrust planetary trajectories.

The resulting manual is one of a series covering orbital, lunar, and planetary trajectories. The handbooks are listed below:

1. "Space Flight Handbooks, Volume I, Orbital Flight Handbook," NASA SP-33, 1963, UNCLASSIFIED.
2. "Space Flight Handbooks, Volume II, Lunar Flight Handbook," NASA SP-34, 1963, UNCLASSIFIED.
3. "Space Flight Handbooks, Volume III, Planetary Flight Handbook," NASA SP-35, 1963, UNCLASSIFIED.

Contract Information

1. Contractor: Lockheed Missiles and Space Company
2. Contract No.: NAS8-2469
3. Period of Performance: June 63 - March 64 (Phase III)
4. Contract Amount: \$69,869 (Phase III)
5. Technical Supervisor: H. Thomae/H. Ruppe

E. EARLY MANNED PLANETARY MISSION STUDY (EMPIRE)
(PHASE II)

Objectives and Results

The first phase of this study concentrated on the selection of attractive mission profiles for manned exploration of the planets in the early 1970's, and conceptual design of suitable space vehicle systems for each of the mission profiles selected. The objectives of this phase of the study were to: (1) Define in detail the mission profile for a fast trip to Mars in the 1975 time period; (2) perform a preliminary design of a space vehicle system for this mission profile including requirements for Earth launch, orbital operations, nuclear engines, scientific missions, and Earth atmospheric re-entry; and (3) perform a compatibility study of this vehicle system for other missions of the national space program.

The results of this phase of the study are documented in the final reports listed below:

1. "Manned Planetary Mission, Follow-on Study Final Report," Contract No. NAS8-5024, Report No. 8-32-64, Lockheed Aircraft Corporation, February 28, 1964, CONFIDENTIAL/RD.
2. "A Study of Manned Interplanetary Missions," Contract No. NAS8-5026, Report No. GD/A-AOK 64-006, General Dynamics-Astronautics, July 1, 1964, UNCLASSIFIED.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
 - a. Contract No: NAS8-5024
 - b. Period of Performance: May 63 - March 64 (Phase II)
 - c. Contract Amount: \$100,000 (Phase II)
 - d. Technical Supervisor: H. Ruppe
2. Contractor: General Dynamics-Astronautics
 - a. Contract No.: NAS8-5026
 - b. Period of Performance: June 63 - March 64 (Phase II)
 - c. Contract Amount: \$99,058 (Phase II)
 - d. Technical Supervisor: H. Ruppe

F. LOW ACCELERATION SPACE TRANSPORTATION SYSTEMS (PHASE II)

Objectives and Results

The major emphasis in Phase I of this study was to conduct a preliminary survey and analysis of major elements and related problems

of electric propulsion. Phase II was to place the major emphasis on the role of electric propulsion for planetary missions, especially the manned Mars mission. Thus, the prime objective of this effort was to investigate the use of electric propulsion, relative to chemical and nuclear, or combinations of both, in manned and deep space unmanned planetary missions. Comparisons were to be based upon economic considerations incorporating other criteria such as probability of mission success and crew survival.

The results of this phase of the study are contained in the following final report:

"Electrical Propulsion in Space: Mission Comparisons, Development Costs, Reliability, and their duplications for Planning," Contract No. NAS8-11081, Report No. RM-4056, Rand Corporation, August 1964, UNCLASSIFIED.

Contract Information

1. Contractor: Rand Corporation
2. Contract No.: NAS8-11081
3. Period of Performance: June 63 - April 64 (Phase II)
4. Contract Amount: \$90,000
5. Technical Supervisor: H. Ruppe

G. MANNED MARS EXPLORATION IN THE UNFAVORABLE (1975-1985)
TIME PERIOD

Objectives and Results

The primary objective of this study was to survey all attractive profiles for manned Mars missions during the 1975-1985 time period and select mission profiles of primary interest. The main criterion of optimization was to minimize initial mass in Earth orbit. Also, this study was to define problem areas that could be solved and, if solved, would improve mission capability considerably during the 1975-1985 time period.

The results of the study are presented in the following final reports:

1. "A Study of Manned Mars Exploration in the Unfavorable Time Period (1975-1985)," Contract No. NAS8-11004, Report No. FZM-4039, General Dynamics-Ft. Worth, 15 February 1964, CONFIDENTIAL/RD.

2. "Manned Mars Exploration in the Unfavorable (1975-1985) Time Period," Contract No. NAS8-11005, Report No. SM-45575-45586, Douglas Aircraft Company, February 1964, UNCLASSIFIED.

Contract Information

1. Contractor: General Dynamics - Ft. Worth
 - a. Contract No.: NAS8-11004
 - b. Period of Performance: June 63-March 64
 - c. Contract Amount: \$86,000
 - d. Technical Supervisor: J. Smith
2. Contractor: Douglas Aircraft Company
 - a. Contract No.: NAS8-11005
 - b. Period of Performance: June 63 - March 64
 - c. Contract Amount: \$91,901
 - d. Technical Supervisor: J. Smith