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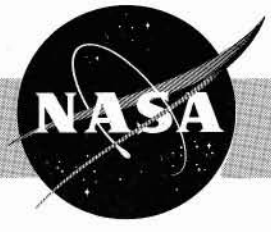
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GEORGE C. MARSHALL **SPACE FLIGHT CENTER**
HUNTSVILLE, ALABAMA

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**DIGEST OF
FY-62 FUNDED ADVANCED STUDIES
JULY 1966**

National Aeronautics and Space Administration



GEORGE C. MARSHALL SPACE FLIGHT CENTER

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FY-62 FUNDED ADVANCED STUDIES

JULY 1966

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INTRODUCTION

This publication is one of a planned series to summarize the MSFC 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 The purpose of these documents is to provide historical reference information which should be helpful in planning future study programs.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-62 funded studies are covered in this document. These investigations are covered under two major categories: Launch Vehicle Studies; and Lunar, Orbital, and Planetary Studies. The information presented on each study includes a brief description of the objectives 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 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 STUDIES

A. LAUNCH VEHICLE SIZE AND COST ANALYSIS

Objectives and Results

This effort was a continuation of previous studies which investigated the operational and economical parameters affecting the choice of the size of launch vehicles after Saturn. The contractor was to refine and update the previously developed cost methodology, perform an evaluation of large launch vehicle cost information obtained in previous studies, and refine the inherent reliability and reliability growth data previously generated. As a separate task assignment, the feasibility and cost of a large sea-launched booster system were also investigated.

The final reports listed below document the results of these studies:

1. "Reliability of U.S. Rockets, Final Report, Launch Vehicle Size and Cost Analysis, Phase III, Part I, Reliability Analysis", Contract No. NAS8-2599, Report No. 8659-6054-RS000, Space Technology Laboratories, Inc., November 1962, SECRET.
2. "Launch Vehicle Size and Cost Analysis, Phase III, Part II," Contract No. NAS8-2599, Report No. 8659-6055-RV000 and Space Technology Laboratories, Inc., December 1, 1962.
3. "Sea Launch Booster System, Feasibility and Cost Study", Contract No. NAS8-2599, Report No. LRP 297, Aerojet General (Subcontract to STL), February 12, 1963, UNCLASSIFIED.

Contract Information

1. Contractor: Space Technology Laboratories, Inc.
2. Contract No.: NAS8-2599
3. Period of Performance: March 62 - May 63
4. Contract Amount: \$366,529
5. Technical Supervisor: W. Huber

B. LARGE LAUNCH VEHICLES UTILIZING SOLID PROPELLANT (PHASE II)

Objectives and Results

This was a continuation of previous studies which determined that detailed investigations were desirable for Nova configurations. This task assignment was to result in preliminary design studies of Nova class solid systems with detailed design investigations of thrust vector control systems, vehicle staging, motor clustering, and facility requirements. In addition to these broad areas, a reliability analysis of the system was to be performed, a development and funding plan generated, and a detailed operations analysis performed including manufacturing and assembly methods, ground support equipment, testing plan, transportation analysis, and launch operations plan.

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

1. "Solid Boosted Nova Vehicle System Study," Contract No. NAS8-2438, Report No. D2-22431, Boeing Company, April 1963, CONFIDENTIAL.
2. "Study of Large Launch Vehicles Using Solid First Stages", Contract No. NAS8-2438 and Air Force Contract, Report No. SSD-TDR-62-144, Boeing Company, December 1962, CONFIDENTIAL

Contract Information

1. Contractor: Boeing Company
2. Contract No.: NAS8-2438
3. Period of Performance: March 62 - May 63
4. Contract Amount: \$441,236
5. Technical Supervisor: H. Koelle

C. APPLICATION OF SOLID PROPELLANT MOTORS TO FUTURE SATURN C-1 CLASS VEHICLES

Objectives and Results

This activity investigated the potential application of motors in the 120-inch diameter class for a solid propellant

booster stage, which could replace the first stage of the improved Saturn C-I. The study was to obtain data needed to determine if substantial gains could be attained in Saturn C-I performance, cost reduction, reliability, and operational considerations by replacing the S-I stage with a booster utilizing solid motors.

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

"Study of Application of Solid Propellant Motors to Future Saturn C-I Class Vehicles," Contract No. NAS8-5083, Lockheed Aircraft Corporation, January 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
2. Contract No.: NAS8-5083
3. Period of Performance: July 62 - February 63
4. Contract Amount: \$197,207
5. Technical Supervisor: S. Reinartz

D. SATURN D DESIGN (PHASE II)

Objectives and Results

This effort was a continuation of previous studies to perform preliminary design investigations of Saturn/nuclear stage vehicle configurations based on early nuclear propulsion systems which could logically evolve from the Rover project. The work was to cover the nuclear stage design, integrated engine/vehicle system, compatibility and mating of the nuclear stage with Saturn, vehicle performance, operating characteristics, hazard analysis, facility requirements, development schedule, and funding plan. The results were to provide a basis for making a decision to pursue the Saturn/nuclear vehicle or develop other possible space transportation systems.

The details of this phase of the study are documented in the following final reports:

1. "Saturn D Mission Study Final Report," Contract No. NAS8-1600, Report No. AE62-0667, General Dynamics, 31 August 1962, SECRET/RD.
2. "Saturn D (Nuclear Rocket Upper Stage) Mission Studies", Contract No. NAS8-1601, Report No. LMSC-B007036, Lockheed Aircraft Corporation, 31 August 1962, SECRET/RD.

Contract Information

1. Contractor: General Dynamics
 - a. Contract No.: NAS8-1600
 - b. Period of Performance: February 62 - September 62 (Phase II)
 - c. Contract Amount: \$100,000 (Approximate)
 - d. Technical Supervisor: W. Jordan

2. Contractor: Lockheed Aircraft Corporation
 - a. Contract No.: NAS8-1601
 - b. Period of Performance: February 62 - October 62 (Phase II)
 - c. Contract Amount: \$108,000 (approximate)
 - d. Technical Supervisor: W. Jordan

E. REUSABLE GROUND LAUNCH VEHICLES IN THE 50-100 TON ORBITAL PAYLOAD CLASS (PHASE I)

Objectives and Results

The objectives of this effort were to investigate possible successors to Saturn V and modified versions to be used as the primary cargo transport for mid-1970 support of Earth orbit operations and manned lunar explorations. The study was to determine conditions under which conversion to reusable configurations would be advantageous, and define the configurations best suited to succeed Saturn V. A plan was to be outlined for developing the techniques and attaining the technology required.

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

1. "Final Report - Conceptual Design Study of 50 to 100 Ton Reusable Orbital Carrier," Contract No. NAS8-5028, Report No. SID 63-87-1-2-3, North American Aviation, Inc., February 15, 1963, CONFIDENTIAL.

2. "Reusable Ground Launch Vehicle Study, 50 to 100 Ton Orbital Payload," Contract No. NAS8-5036, Report No. D2-22222, Boeing Company, December 1962, CONFIDENTIAL.

Contract Information

1. Contractor: North American Aviation, Inc.
 - a. Contract No.: NAS8-5028
 - b. Period of Performance: June 62 - February 63
 - c. Contract Amount: \$141,594
 - d. Technical Supervisor: M. Vaccaro

2. Contractor: Boeing Company
 - a. Contract No.: NAS8-5036
 - b. Period of Performance: June 62 - March 63 (Phase I)
 - c. Contract Amount: \$150,000 (Phase I)
 - d. Technical Supervisor: M. Vaccaro

F. REUSABLE 10-TON ORBITAL CARRIER VEHICLE (PHASE I)

Objectives and Results

The purpose of this study was to develop design approaches and operational concepts which are compatible with large scale transportation of cargo and personnel in support of manned space stations, lunar bases, and early manned planetary expeditions. One or more vehicles with a capability of carrying a two-man crew and 10 passengers to a rendezvous compatible 325-KM orbit and return were to be investigated. An alternative mode to be investigated was a 10-ton cargo capability to the same orbit. Optimization was to be based primarily on operational considerations, such as convenience, crew and passenger safety, high reusability rate, and launch site not necessarily limited to AMR. Both HTO and VTO rocket airplane concepts were investigated.

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

1. "Reusable 10-Ton Orbital Carrier Vehicle," Contract No. NAS8-2687, Report No. LR-16439, Lockheed Aircraft Corporation, 22 February 1963, CONFIDENTIAL.

2. "Final Report: Conceptual Design Study of Ten-Ton Reusable Orbital Carrier," Contract No. NAS8-5037, Report No. SID 63-158-1/2/3, North American Aviation, Inc., 22 February 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
 - a. Contract No.: NAS8-2687
 - b. Period of Performance: May 62 - March 63 (Phase I)
 - c. Contract Amount: \$78,011 (Phase I)
 - d. Technical Supervisor: D. Fellenz/L. Spears

2. Contractor: North American Aviation, Inc.
 - a. Contract No.: NAS8-5037
 - b. Period of Performance: June 62 - March 63 (Phase I)
 - c. Contract Amount: \$92,000 (Phase I)
 - d. Technical Supervisor: D. Fellenz/L. Spears

G. ADVANCED NOVA LAUNCH VEHICLE (TASKS I AND II)

Objectives and Results

The objectives of these investigations were to obtain data for 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). This effort (Tasks I and II) was concentrated on advanced conceptual designs for promising vehicles using chemical propulsion for Nova type missions. The results of these studies are documented in the following final reports:

1. "Phase I and II Post-Nova Launch Vehicle Study," Contract No. NAS8-5021, Report No. SM-42969, Douglas Aircraft Company, April 1963, CONFIDENTIAL.

2. "A Study of Post-Nova Launch Vehicles, Final Summary Report," Contract No. NAS8-5022, Report No. AOK 63-013, General Dynamics-Astronautics, April 1, 1963 CONFIDENTIAL.

3. "An Analysis of Future Large Launching Systems," Contract No. NAS8-5023, Report No. RM-3501, Rand Corporation March 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Douglas Aircraft Company
 - a. Contract No.: NAS8-5021
 - b. Period of Performance: June 62 - May 63 (Tasks I and II)
 - c. Contract Amount: \$166,401 (Tasks I and II)
 - d. Technical Supervisor: J. Sanders

2. Contractor: General Dynamics-Astronautics
 - a. Contract No.: NAS8-5022
 - b. Period of Performance: June 62 - May 63
(Tasks I and II)
 - c. Contract Amount: \$184,563 (Tasks I and II)
 - d. Technical Supervisor: J. Sanders

3. Contractor: Rand Corporation
 - a. Contract No.: NAS8-5023
 - b. Period of Performance: July 62 - March 63
 - c. Contract Amount: \$90,000
 - d. Technical Supervisor: J. Sanders

SECTION II. LUNAR, ORBITAL, AND PLANETARY STUDIES

A. EARTH-LUNAR TRANSPORTATION SYSTEM (PHASE II)

Objectives and Results

This was a continuation of a previous effort to obtain data needed to determine the optimum transportation mode for accomplishing a manned lunar landing and Earth return. Transportation modes, propulsion systems, and vehicles were to be analyzed. Conceptual designs were performed and pertinent areas of required research and development were defined.

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

"Study of Advanced Lunar Transportation Systems," Contract No. NAS8-1531, Report No. ER12742, Martin Company, December 1962, CONFIDENTIAL/RD.

Contract Information

1. Contractor: Martin Company
2. Contract No.: NAS8-1531
3. Period of Performance: September 61 - December 62 (Phase II)
4. Contract Amount: \$181,605 (Phase II)
5. Technical Supervisor: C. Earker/F. Williams

B. REUSABLE NUCLEAR LUNAR FERRY VEHICLE (PHASE I)

Objectives and Results

The purpose of this study was to investigate and compare two possible approaches for one or more attractive follow-on (advanced) lunar transportation system. One was to be expendable and the second a reusable system. The reusable concept was to utilize an orbit-launched nuclear vehicle, referred to as a nuclear ferry vehicle, and orbital operation techniques. This phase of the study (Phase I) required conceptual design of the vehicles involved in each phase of operation of the systems, excluding the Earth launch vehicle. A detailed operational analysis was required for a comparison of the two systems on a payload delivery cost basis.

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

1. "Advanced Lunar Transportation Study Final Report," Contract No. NAS8-5020, Report No. LMSC B00732-8-09-63-1, Lockheed Aircraft Corporation, 28 January 1963 CONFIDENTIAL/RD.
2. "Comparative Study of Advanced Lunar Transportation Systems," Contract No. NAS8-5027, Report No. 00.159, Chance Vought, 28 January 1963, CONFIDENTIAL/RD.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
 - a. Contract No.: NAS8-5020
 - b. Period of Performance: May 62 - March 63 (Phase I)
 - c. Contract Amount: \$144,596 (Phase I)
 - d. Technical Supervisor: W. Jordan/C. Rutland
2. Contractor: Chance Vought
 - a. Contract No.: NAS8-5027
 - b. Period of Performance: May 62 - March 63 (Phase I)
 - c. Contract Amount: \$144,897 (Phase I)
 - d. Technical Supervisor: W. Jordan/C. Rutland

C. ORBITAL AND LUNAR FLIGHT HANDBOOK (PHASE I)

Objectives and Results

The objective of this effort was to develop two handbooks needed by preliminary design engineers and mission planners in the area of flight mechanics and systems performance. One manual was to cover Earth orbital applications and the other was to cover lunar applications. Another study was to provide the same type data for planetary applications. These publications were to provide the necessary formulae, graphs, tables, and constants to plan missions around the Earth, to the Moon and to the planets.

The handbooks developed from this effort are listed below:

1. "Orbital Flight Handbook, Volume I and Lunar Flight Handbook, Volume II", Contract No. NAS8-5031, Martin Company, 1963, UNCLASSIFIED.

2. The above contractor publications were reissued as NASA Special Publications and also include the Planetary Handbook. These publications are numbered NASA SP-33, SP-34, and SP-35.

Contract Information

1. Contractor: Martin Company
2. Contract No.: NAS8-5031
3. Period of Performance: June 62 - April 63 (Phase I)
4. Contract Amount: \$171,221
5. Technical Supervisor: C. Swanson

D. LOW-ACCELERATION SPACE TRANSPORTATION SYSTEM

Objectives and Results

The contractor was to perform a study designed to predict, as realistically as possible, the desirable and attainable characteristics of low acceleration space vehicles in the period 1967-1980. The study was to determine propulsion systems requirements and characteristics, which necessitated study of a number of related aspects of the overall vehicles and their missions in order to form an adequate basis for conclusions. The effort included investigation of electric power sources, propulsion system design and programming, related design problems, and comparison of performance and costs. This included considerations of system reliability for low acceleration electric vehicles versus high acceleration vehicles.

The results of this investigation are documented in the final report listed below:

"A Consideration of the Problems Relating to Feasibility, Utility and Development of Electrical Propulsion Systems," Contract No. NAS8-2672, Report No. RM-3469, Rand Corporation, April 1963, CONFIDENTIAL.

Contract Information

1. Contractor: Rand Corporation
2. Contract No.: NAS8-2672
3. Period of Performance: May 62 - May 63
4. Contract Amount: \$78,150
5. Technical Supervisor: H. Ruppe

E. INTERPLANETARY TRANSPORTATION SYSTEMS (PHASE II)

Objectives and Results

Previous effort provided information in five areas of importance in the planning of manned interplanetary missions. These areas are: Nonstop round trips, stopover round trips, space missions launched normal to the ecliptic, precise calculations of guidance sensitivities, and nonstop trips passing both Mars and Venus. The intent of these studies were to fill the gap for the mission analyst and design engineer by providing technical information in the form of an easy to use manual. This part of the investigation (Phase II) was to provide information in the following areas:

1. Energy requirements for round trips and oneway trips to specified target planets, in particular Mercury, Venus and Mars, as a function of their launch dates and stay-times at the target planet.
2. Energy requirements for special mission profiles such as trajectories out of the exliptic, Hohmann, Crocco and Resonance round trips.
3. Optimum mission profiles for trajectories described above.
4. Launch window requirements, planetary capture maneuvers, midcourse maneuvers, accuracy requirements, tracking and position determining, entry through planetary atmospheres, orbital operations, and general astrophysical considerations.

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

"Final Report: A Study of Interplanetay Transportation Systems, Phase II," Contract No. NAS8-2469, Report No. 3-17-63-1, Lockheed Missles and Space Company, 2 April 1963, UNCLASSIFIED.

Contract Information

1. Contractor: Lockheed Missles and Space Company
2. Contract No.: NAS8-2469
3. Period of Performance: June 62 - June 63 (Phase II)
4. Contract Amount: \$85,500
5. Technical Supervisor: H. Thomae/H. Ruppe

F. EARLY MANNED PLANETARY MISSIONS (PHASE I)

Objectives and Results

These initial studies, usually referred to as EMPIRE, investigated the vehicles, systems and mission modes necessary to perform manned Mars and Venus flyby and orbiting missions. These early studies were to consider orbital techniques, number of men per ship, number of ships per mission, trajectory and guidance, life support and human engineering, rocket or aerodynamic braking for Earth return, possibility of use of Apollo capsule with a new mission module, and a funding and program plan for the early 1970's. From these early studies, it was determined that manned Mars and Venus missions appear feasible during the 1970's.

The details of this phase of this investigation are documented in the final reports listed below:

1. "Manned Interplanetary Mission Study," Contract No. NAS8-5024, Report No. 8-32-63-1, Lockheed Aircraft Corporation, March 1963, CONFIDENTIAL/RD.
2. "A Study of Early Manned Interplanetary Missions (EMPIRE)," Contract No. NAS8-5025, Report No. U-1951, Ford/Aeronutronics, 21 December 1963, UNCLASSIFIED.
3. "A Study of Early Manned Interplanetary Missions", Contract No. NAS8-5026, Report No. AOK 63-0001, General Dynamics-Astronautics, January 31, 1963, CONFIDENTIAL/RD.

Contract Information

1. Contractor: Lockheed Aircraft Corporation
 - a. Contract No.: NAS8-5024
 - b. Period of Performance: May 62 - May 63 (Phase I)
 - c. Contract Amount: \$73,998 (Phase I)
 - d. Technical Supervisor: H. Ruppe
2. Contractor: Ford/Aeronutronics
 - a. Contract No.: NAS8-5025
 - b. Period of Performance: May 62 - February 63
 - c. Contract Amount: \$84,050
 - d. Technical Supervisor: H. Ruppe
3. Contractor: General Dynamics-Astronautics
 - a. Contract No.: NAS8-5025
 - b. Period of Performance: May 62 - May 63 (Phase I)
 - c. Contract Amount: \$100,178 (Phase I)
 - d. Technical Supervisor: H. Ruppe