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APOLLO

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PRELIMINARY

PROJECT DEVELOPMENT PLAN

AUGUST 9, 1961

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PROJECT DEVELOPMENT PLAN

FOR

PROJECT APOLLO SPACECRAFT

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Part 1:
PROJECT SUMMARY

[redacted]

PRELIMINARY PROJECT DEVELOPMENT PLAN

PROJECT APOLLO SPACECRAFT SYSTEM

I. Summary

A manned lunar landing has been stated to be a goal of the United States space exploration program. In Project Apollo, a versatile spacecraft system will be developed which will ultimately be capable of such a mission.

The over-all Apollo spacecraft development program will include a number of projects as follows:

A. Advanced missions with Mercury-type spacecraft, including prolonged manned orbital flights, rendezvous experiments, and life sciences missions.

B. Parabolic reentry tests with Atlas-Agena launch vehicles.

C. Apollo spacecraft and onboard propulsion system development.

Items A and B above will provide information essential to the design and development of the Apollo spacecraft. However, these projects will be treated separately and each will have a development plan. The present plan considers only Item C.

[redacted]

[redacted]

The Project Apollo spacecraft system will be developed in three separate but related mission concepts:

1. Phase "A". A manned spacecraft to be placed in orbit around the earth at 300 nautical mile altitude for a two-week duration for the purpose of developing space flight technology, including rendezvous, and for conducting scientific experimentation. The scheduling aspects of the present plan cover only phase "A".

2. Phase "B". A manned spacecraft for circumlunar and orbital flight around the moon at an appropriate height and duration to permit the development of flight operations in deep space and provide an assessment of the system for the lunar landing mission.

3. Phase "C". A manned spacecraft to be soft landed on the surface of the moon and returned to earth.

It is contemplated that the spacecraft for each of these three phases of Project Apollo will consist of separate modules as follows:

A Command Module which will serve as a control center for spacecraft and launch vehicle operations, as crew quarters for the lunar mission, and as the entry and landing

[redacted]

vehicle for both nominal and emergency mission phases. To the greatest extent possible, the same Command Module will be used for all three phases cited in paragraphs 1, 2 and 3 above.

A Service Module which will house support systems and components and will contain propulsion systems, as required, for emergency aborts, returning from earth orbit, mid-course corrections, lunar orbit and de-orbit, and lunar take-off. It is contemplated that separate contracts will be issued for some of these propulsion systems.

An Orbiting Laboratory Module for use in earth orbiting missions, as a laboratory for technological or scientific experiments and measurements.

A Propulsion Module to be added for the lunar landing mission, for the purpose of landing the Command and Service Modules on the moon's surface.

Procurement action for the Apollo spacecraft system was initiated on July 28, 1961. A target date of December 29, 1961, has been set for award of a letter contract to the spacecraft prime contractor.

Total Space Task Group manpower requirements for conduct of

Part II:
JUSTIFICATION

Part III: HISTORY AND RELATED WORK

[redacted]

the Project Apollo spacecraft development and missions will reach 2,700 at the end of FY 1963.

New facilities costing $74,300,000 and a total expenditure of about 2.8 billion dollars will be required through FY 1965 for conduct of the Project Apollo spacecraft development and missions.

II. <u>Justification</u>

A manned lunar landing has been stated to be a goal of the United States space exploration program. The Apollo spacecraft system will ultimately be capable of such a mission. Necessary intermediate steps leading to the landing mission will include multimanned earth-orbital and circumlunar flights.

III. <u>History and Related Work</u>

In March 1960, tentative guidelines for the Project Apollo circumlunar mission were formulated by the Office of Space Flight Programs and Space Task Group. These guidelines were discussed in detail with all of the NASA Centers in the March to May 1960 period, and a number of research programs, directed toward the Apollo missions were initiated by the NASA Research Centers.

In July and August 1960 the Apollo guidelines were presented to industry and in September 1960, proposals for a design

[redacted]

feasibility study of the Apollo mission were solicited from industry. The Apollo mission, at that time, and the feasibility studies were directed primarily toward the circumlunar mission. However, as parts of the studies, the modifications or additions that would be required to adapt the circumlunar spacecraft to a lunar landing were to be investigated.

On October 10, 1960, 14 proposals were received from industry and on November 15, 1960, after a detailed technical evaluation, contracts were signed with General Electric, Convair Astronautics, and the Martin Company for six-month studies of the Apollo mission.

Concurrent with the industry studies, inhouse NASA studies were undertaken and the aid of all the NASA Centers in monitoring and evaluating the studies, through Apollo Technical Liaison Groups, was organized.

The results of the studies, references 1, 2, and 3, and concurrent research investigations indicate that the Apollo circumlunar mission is marginally feasible with the Saturn C-2 escape velocity launch capability of 15,000 pounds, and, that to provide the desired abort and lunar orbit capability, the escape launch capability should be increased to about 25,000 pounds. The studies showed several feasible approaches to the Apollo mission and indicated that the Apollo circumlunar spacecraft could be adapted to the lunar landing mission with the addition of a suitable landing system and the provision of adequate launch vehicle capability.

In April and May 1961, the Ad Hoc group headed by Mr. William Fleming considered an accelerated lunar landing plan. The program outlined in this development plan is consistent with the conclusions of that study, reference 4.

The over-all Apollo spacecraft development program will include a number of projects as follows:

A. Advanced missions with Mercury-type spacecraft, including prolonged manned orbital flights, rendezvous experiments, and life sciences missions.

B. Parabolic reentry tests with Atlas-Agena launch vehicles.

C. Apollo spacecraft and onboard propulsion system development.

Items A and B above will provide information essential to the design and development of the Apollo spacecraft. However, these projects will be treated separately and each will have a development plan. The present plan considers only Item C.

Part IV:
TECHNICAL PLAN

[redacted]

IV. Technical Plan

A. Description

Project Apollo will be developed in three separate but related mission concepts:

1. Phase "A". A manned spacecraft to be placed in orbit around the earth at 300 nautical mile altitude for a two-week duration for the purpose of developing space flight technology, including rendezvous, and for conducting scientific experimentation. The scheduling aspects of the present plan cover only phase "A".

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It is contemplated that the spacecraft for each of these three phases of Project Apollo will consist of separate modules as follows:

A Command Module which will serve as a control center for

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spacecraft and launch vehicle operations, as crew quarters for the lunar mission, and as the entry and landing vehicle for both nominal and emergency mission phases. To the greatest extent possible, the same Command Module will be used for all three phases cited in paragraphs 1, 2 and 3 above.

A Service Module which will house support systems and components and will contain propulsion systems, as required, for emergency aborts, returning from earth orbit, mid-course corrections, lunar orbit and de-orbit, and lunar take-off. It is contemplated that separate contracts will be issued for some of these propulsion systems.

An Orbiting Laboratory Module for use in earth orbiting missions, as a laboratory for technological or scientific experiments and measurements.

A Propulsion Module to be added for the lunar landing mission, for the purpose of landing the Command and Service Modules on the moon's surface.

The Command Module will be a lifting body type vehicle having a hypersonic L/D capability of about 1/2. Flight control will be either by center of gravity offset and roll or by conventional type control surfaces. The Command Module will house the crew throughout the circumlunar flight. That is, auxiliary living space will not be provided. A typical configuration meeting the preceding requirements is shown in figure 1.

The Service Module will carry those parts of the equipment that are essential to the mission, but that need not be carried during earth reentry and which can safely and conveniently be carried external to the Command Module. The Service Module may be nearly identical for all missions; however, different propulsion systems will be carried in this module for the earth-orbital, circumlunar and lunar landing phases. For some earth-orbital missions, a special Orbiting Laboratory Module may be carried in the spacecraft-to-launch-vehicle adapter.

The abort and lunar launch propulsion system, incorporated within the Service Module, will be required to provide a velocity increment of about 10,000 feet per second for lunar launch. For critical abort on the circumlunar mission, a velocity increment of about 5,000 to 6,000 feet per second is needed. It is planned that a vernier hypergolic liquid system be used to provide approximately 30 per cent of the total impulse required for lunar take-off. The remainder of the impulse required for lunar take-off will be supplied by a number of identical solid rockets. For other missions the vernier liquid system with fewer solid rockets would be used. A backup development effort for a high-energy all-liquid system will likely be undertaken also.

The lunar landing propulsion module will use hydrogen-oxygen propellants. Landing will almost certainly be done from lunar orbit and the terminal phase may be either tangential, as shown in figure 2, or vertical.

B. Approach

Basic questions affecting the approach to be followed in implementing the Apollo spacecraft program include the effects of prolonged weightlessness on man and the biological hazards of radiation.

Weightlessness

The Apollo spacecraft development effort will be based on the assumption that artificial gravity is not required.

There are already indications that this assumption may well be a reasonable one. Shepard and Grissom's five-minute flights, Gagarin's ninety-minute flight and Titov's 24-hour flight have demonstrated that flights up to one day duration have no deleterious physiological effects. Titov's flight also demonstrated that man is able to sleep, eat, and perform essential body functions under weightless conditions.

Programs are under study to establish the effects on man of prolonged weightlessness. These include 14-day primate and four to seven day manned flights in modified Mercury-type capsules in the 1963 time period. It can be anticipated that gross results from long-duration Russian manned flights will also be available during the next 18 months.

Data from all of these flights will establish whether or not the assumption to proceed without artificial gravity is valid. Should artificial gravity be found to be necessary, extensive experiments in earth orbit will be required to define acceptable rates of rotation and acceptable "g" levels. These experiments would be carried out under the Orbiting Laboratory phase of Apollo "A."

[redacted]

Radiation Shielding

Present data and calculations indicate that solar flares present the major radiation hazard to manned lunar flight. The spacecraft structure and equipment inherently provide adequate shielding against most solar flares. However, in order to limit dosage to the emergency limit of 100 rem for the more intense flares, a moderate amount of shielding must be added to that afforded by the basic spacecraft. Depending on the spacecraft configuration, the shielding weight could either be built into the walls of the vehicle or fitted about the individual crew members in the form of quick-don water filled garments. Based on present knowledge, several hundred pounds of added shielding would be adequate for all but the so-called giant flares. For these "giant" events, the low probability of occurrence and the fact that with the amount of shielding provided, a giant flare would not result in a lethal dosage to the crew, appear to make the risks associated with even giant flares acceptably low.

Spacecraft Systems

Aside from the basic weightlessness and radiation questions, the entire spacecraft development for the circumlunar mission appears to be within projected state-of-the-art. The following

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approaches are likely to be followed for various aspects of the development:

Reentry heat protection	Ablation type using nylon-phenolic or epoxy resin and silica
Attitude control	Bipropellant jet
Landing system	Parachute (Steerable parachutes and "flexwings" are also under consideration.)
Power supply	Fuel Cells
	Batteries
Environmental control system	Two-gas, liquid and gaseous storage system
Guidance and navigation	Combination of onboard inertial and star tracking system with onboard computer
	Ground based tracking and computing to be used as backup
Spacecraft propulsion	Storable hypergolic plus solids for abort and lunar launch
	High energy (O_2-H_2) for lunar landing

Of all the preceding systems, the guidance and navigation and spacecraft propulsion are considered to present the greatest development problems.

[redacted]

Certainly a crucial task in the entire spacecraft design and development for the ultimate lunar landing mission will be to devise a vastly simplified and reliable launch system for departure from the lunar surface. It will be required that the system be self-contained within the spacecraft and be readily operated by three men on a precise schedule. It is considered that a lunar simulation chamber on earth which can contain the entire spacecraft and expose it to simulated lunar conditions will be an essential tool in the development of this system. It should be possible for the crew to work outside the spacecraft, enter, countdown, and possibly light-off the lunar launch propulsion system in the simulator chamber. Only by so doing can the necessary high reliability of this system be attained prior to flight.

Uncertainties in the design assumptions for reentry heating at parabolic velocity will be covered by allowing adequate weight margin for ablation heat shielding and structure. Design studies for typical Apollo reentry vehicles have determined that on the basis of the best theoretical analyses today, a heat shield weight of about 20 to 25 per cent of the reentry vehicle weight is required. The greatest uncertainty in this estimate is due to the unknown degree of nonequilibrium radiation heat flux. The design study of reference 1 has concluded that in the worst case the percentage of heat shield weight might increase to 30 or 35 per cent of reentry weight. Adequate margin will be provided in the spacecraft design to cover this extreme case. In addition, the reentry vehicle development program will be phased such that the critical heating data from large-scale flight experiments will be available prior to the need for final specification of the heat shield design for reentry at parabolic velocity. During the orbital phase of the Apollo program, a heat shield, which is analytically capable of reentry at parabolic velocity and which is known from experience to be satisfactory for reentry from orbit, will be fitted to the spacecraft. If necessary, the heat shield can subsequently be changed prior to higher velocity flights with the production Apollo spacecraft.

Test Program

An extensive program of ground and flight testing will be essential in developing the Apollo spacecraft system. The following categories of spacecraft development and qualification tests must be included in preparation for the ultimate lunar landing mission:

Component and subsystem development tests

Part V:
MANAGEMENT PLAN

Component and subsystem reliability tests

Component and subsystem environmental tests

Spacecraft simulated missions tests

Aircraft drop tests

Conceptual flight tests of the launch escape propulsion system

Conceptual flight tests using Little Joe Senior launch vehicles

Spacecraft-launch vehicle compatibility flight tests using prototype of test spacecraft and Saturn C-1 launch vehicles

Full-scale reentry flight tests at superorbital velocity of Apollo prototype spacecraft on Saturn C-1 launch vehicles

Unmanned and manned orbital flight tests of Apollo spacecraft on Saturn C-1 launch vehicles

Reentry qualification flights of Apollo spacecraft on Saturn C-3 launch vehicles

Manned elliptical orbit, circumlunar and lunar orbit flights

Simulated lunar landing and take-off flights

A proposed schedule for the orbital phase of Project Apollo is included as figure 4 of this plan.

V. Management Plan

A. Approach

In order to effectively manage a major national effort of the magnitude of Project Apollo, NASA will be required to apply maximum resources to plan, technically direct, and monitor the work of related government and contractor personnel. The relationships between NASA Headquarters, the Space Task Group, the Marshall Center, the Goddard Center, and the various associated contractors and major subcontractors must be defined. The over-all organization of the key organizational elements of NASA has not as yet been determined. Consequently, only the role of the Space Task Group is discussed in this plan.

Responsibilities of the Space Task Group

The Space Task Group is responsible for the design, development and procurement of the spacecraft required for the Apollo project. Specifically, the Space Task Group is responsible for:

1. Developing basic design concepts for the Apollo spacecraft and related subsystems.

2. Handling all spacecraft operations for each mission including preflight operations, landing and recovery operations, and provision of crews for actual flight operation.

3. Providing technical direction to the spacecraft contractors on all phases of their work.

4. Reviewing and evaluating the effectiveness of the Apollo contractors and subcontractors in carrying out their contractual responsibilities.

5. Reviewing proposed systems and subsystems engineering plans for subsystems and major vehicle components to assure that systems are soundly engineered and compatible.

For each phase of Project Apollo spacecraft development, a project manager will be designated on the staff of the Space Task Group; this man will act as the central point of decision-making and will be responsible for the control and coordination of all work including coordination between contractors and between elements of NASA.

B. Schedule

Shown in figure 3 is a broad schedule of activity for implementing the Apollo phase "A" spacecraft development. Significant initial milestones in this program are listed below:

Guidance and navigation contract award	8/61
Prime contract awarded	1/62
Mock-up	10/62
First test spacecraft delivered	4/63
First Apollo spacecraft delivered	4/64

Part VI: PROCUREMENT ARRANGEMENTS

[redacted]

Proposed milestones for other phases of the program will be indicated in a detailed Project Development Plan.

The proposed flight schedule for Apollo phase "A" is shown in figure 4. The Apollo spacecraft development schedule and the Saturn development schedules are, of course, intimately related. The schedule shown reflects the present Saturn C-1 schedule for vehicles 1 through 10, and assumes Saturn availability to meet the subsequent spacecraft requirements.

VI. Procurement Management Arrangements

A. Approach

It is intended, under the over-all procurement program, to award several contracts for each separate phase or subphase of the Apollo Project spacecraft specifically as follows:

1. A contract to a principal contractor for the following elements of the project:

   a. A Command Module and Service Module to serve all flight missions,

   b. A Propulsion Module for the earth-orbiting mission, if needed.

   c. Responsibility for systems engineering and system integration for all elements being developed by other contractors associated with Project Apollo spacecraft

[redacted]

[redacted]

systems. It is intended that the same principal contractor will be retained for all three phases; however, the government will retain the option of selecting a new principal contractor for phases "B" and "C" if it is considered desirable to do so.

2. An associate contract for the development of an Orbiting Laboratory Module and vehicle adapter for the earth-orbiting mission.
3. An associate contract for the development of a Lunar Landing Module.
4. An associate contract for the development of the Apollo guidance and navigation system. A letter contract was awarded to the MIT Instrumentation Laboratory for this phase of the program on August 10, 1961.

Responsibilities of Contractors

The responsibilities of each of the associated contractors participating in Project Apollo will be developed and defined separately as each contract is negotiated and written. General types of responsibility, however, can be summarized as follows:

1. <u>Command Module and Service Module Contractor</u>. (Principal Contractor)

The contractor assigned responsibility for the development of the Command Module and Service Module will also be responsible

[redacted]

[redacted]

for systems integration and systems engineering for all missions. The Principal Contractor will serve in the role of principal integrator of all modules of the spacecraft to assure compatibility and timely and complete execution of all requirements of each mission. The contractor will also serve as the principal point of coordination with the launch vehicle developer to assure effective solution of interface problems between launch vehicle and spacecraft components, and with ground support developers to meet all of their requirements.

2. Space Laboratory Module and Propulsion Module Contractors

The contractors assigned responsibility for the development of phase "A" Space Laboratory Module or phase "C" Lunar Landing Module will be expected to complete all aspects of their subsystem and to work under the general technical direction of the principal contractor to assure the full and timely completion of the integrated spacecraft system and its integration with the launch vehicle and related ground support facilities.

Type of Contract Administration

It is intended that a cost-plus-fixed-fee type of contract will be used initially in the procurement of the spacecraft.

In view of the magnitude, complexity, and substantial dollar value

[redacted]

of the Apollo spacecraft, a principal contractor and associate prime contractor method of procurement is recommended. The spacecraft principal contractor will be contractually assigned responsibility and authority for the design of the system and the integration of the performance specifications for all subsystems and components to assure that they fit into a compatible, efficient system, and to manage the day-to-day development and production. The Space Task Group will retain authority to make major decisions, resolve conflicts between the spacecraft principal contractor and the associated contractors; review and/or approve decisions made by the principal contractor; approve the make-or-buy policies. In addition, the Space Task Group will control concentration of principal contractor "in-house" effort; assure competition in the selection of subcontractors by requiring the spacecraft principal contractor to take full advantage of the facilities and capabilities of existing subsystem manufacturers by subcontracting or the placement of systems direct by NASA with associated contractors.

Requests for proposals will require that companies will furnish a description of the proposed organization and management plan for the spacecraft project including names of personnel to be assigned to key positions within such organizations. Prior to commencement of negotiations, NASA will develop a contract clause which will assure

NASA control over the selection and retention of the contractor's key personnel assigned to the project.

NASA will reserve the right to issue a separate contract to a qualified organization to assess systems reliability. If it is subsequently determined that such a contract is to be issued, this will be done at about the same time as the principal contractor is selected. Similar reliability assessment contracts may be placed for associated systems, as required.

Contract Negotiation and Award

It is the intention of the government to select, initially, a contractor qualified to perform all the tasks set forth under paragraph VI. A. 1. above and to award a contract broad enough in scope to provide, with subsequent amendment, for the accomplishment of the total tasks required toward the completion of the Project Apollo Spacecraft Program. The initial contract will specifically cover the engineering study, detail design, development of manufacturing techniques, fabrication of breadboards, test hardware, laboratory models, test spacecraft, certain long lead items, and a detailed engineering mock-up of the Apollo spacecraft.

The Administrator may determine that negotiations will be conducted with several companies. If such negotiations are directed, the names of the companies selected for negotiations will not be announced. Following completion of such negotiations, the Source Evaluation Board will again report to the Administrator the results of the negotiations at which time he will determine that company with which to negotiate a contract if satisfactory terms can be arranged. Announcement of such selection will then be made in accordance with NASA regulations. Negotiations will be conducted by the Space Task Group procurement and technical staffs, with supplemental assistance from Headquarters management and technical staffs. The contract will be negotiated to spell out as extensively as possible all facets of contractor organization, management, technical performance and cost control to achieve the maximum assurance of protection of the interests of the government, consonant with the urgency of the work of the Project.

Schedule of Procurement Action

July 28, 1961	Request for proposals mailed and bidders invited to conference
August 14-15, 1961	Bidders' conference
October 9, 1961	Proposals due
December 1, 1961	Evaluation of proposals completed
December 28, 1961	Selection of contractor
December 29, 1961	Letter contract (if desirable)
April 30, 1962	Definitive contract

PART VII: RESOURCE REQUIREMENTS

Contract Management

A project manager will be designated on the staff of the Space Task Group to act as the central point of decision-making, control and coordination of all work of the contract including coordination between contractors and between elements of NASA.

VII. Resource Requirements

A. Manpower

Estimates of total manpower requirements for the first two years of the Manned Space Flight Program and for Apollo are tabulated below:

FY	Total End of Year Complement: Pro.	Tech.	Adm.	Total Man Years	Man Year Total Apollo and Related Programs	Man Year Total Mercury
1962	600	600	440	1204	400	804
1963	1050	1050	600	2100	1880	220

Estimates for subsequent years and a detailing of the manpower effort will be provided in the Detailed Project Development Plan.

B. Facilities

The following facilities are required in the conduct of Project Apollo:

Facility	Completion Time	Cost
Manned Space Flight Laboratory		
Flight Project Facility	18 mos.	$12,133,000
Equipment Evaluation Laboratory and Support Facility	26 "	13,245,000
Flight Operations Facility	24 "	3,600,000
Environmental Testing Laboratory	48 "	26,482,000
Site Development and Utility Installations	18 "	4,540,000
Launch Site Facilities		
Preflight Operation Facilities		9,100,000
Crew Preparation Facility		1,200,000
Composite Spacecraft Preflight Test Facility		4,000,000
TOTAL FACILITIES		$74,300,000

A detailed description of the preceding facilities is presented in the Amended FY 1962 Budget Estimates Book.

Part VIII:
OPERATIONS PLAN

Part IX:
PROJECT RESULTS

[redacted]

C. Funds

Estimated R&D funding requirements for the Apollo and certain related projects through FY 1965 are tabulated in figure 5. A total expenditure of about $1.6 billion in that time period is estimated to be required for the Apollo spacecraft development and fabrication. Costs of related projects and launch vehicle procurement bring the total R&D and C of F estimated cost to about $2.8 billion through FY 1965.

VIII. Coordinated Operations Plan

It is conceived that the operational phase of Project Apollo will be organized in a manner similar to Project Mercury. The overall operations direction will be by the Space Task Group, with support from the Marshall and Goddard Space Flight Centers, DOD, U. S. Weather Bureau and contractors.

IX. Project Results

Project results will be processed by Space Task Group through direction and coordination of contractor, GSFC, MSFC, and DOD efforts. The processed results will be reported in the form of public releases, technical reports, technical conferences, motion pictures, and speeches before technical societies. All such information will be coordinated with and approved by NASA Headquarters prior to general release.

[redacted]

R E F E R E N C E S

1. Apollo Feasibility Study, Final Report, May 15, 1961. Convair Astronautics Division, General Dynamics Corporation.

2. Apollo Feasibility Study, Final Report, May 15, 1961. General Electric Missiles and Space Vehicles Department

3. Apollo Feasibility Study, Final Report, May 15, 1961. The Martin Company.

4. Fleming Committee Report, June 16, 1961. "A Feasible Approach for an Early Manned Lunar Landing"

ATTACHMENTS

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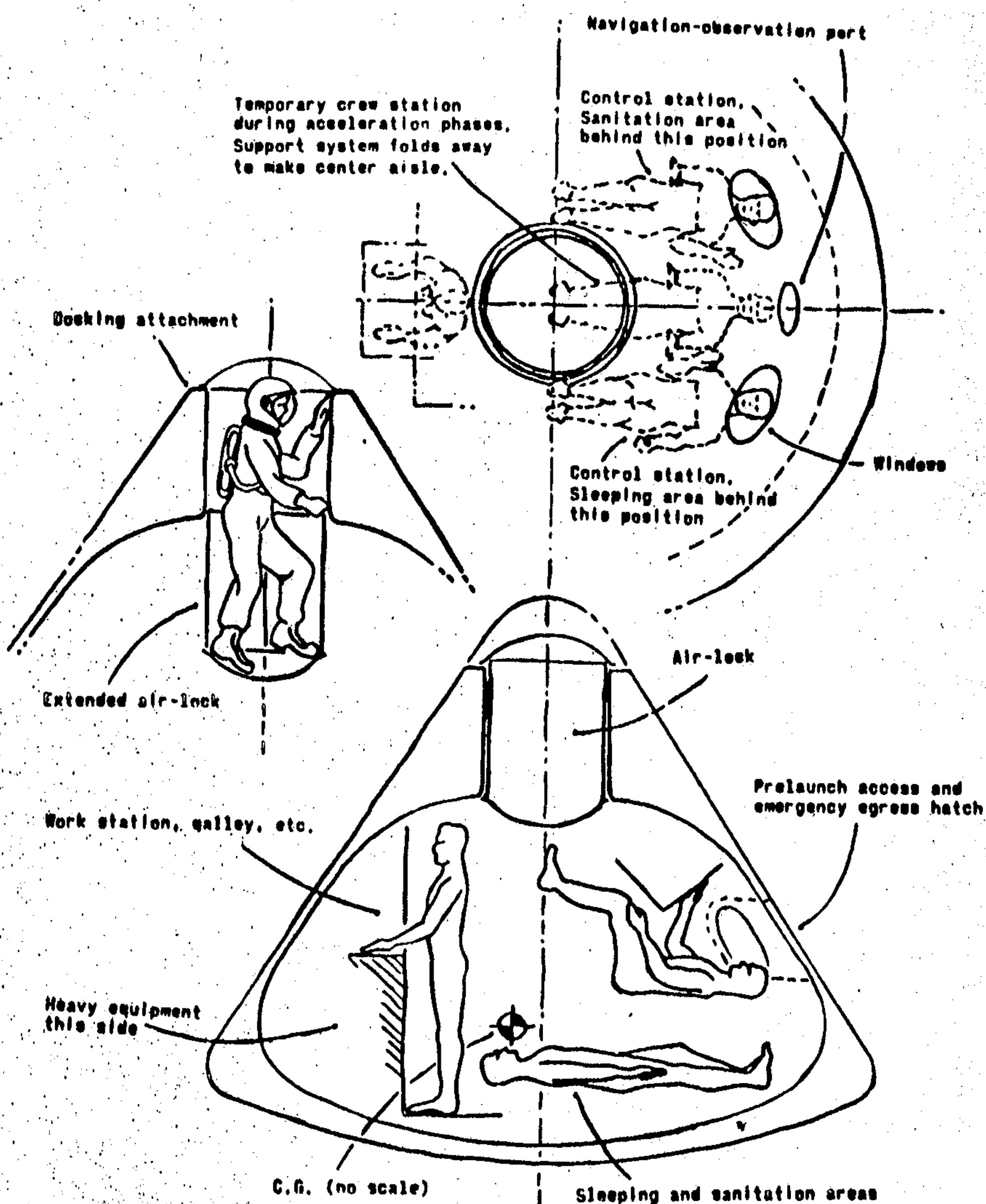

Figure · Command module - Inboard profile.

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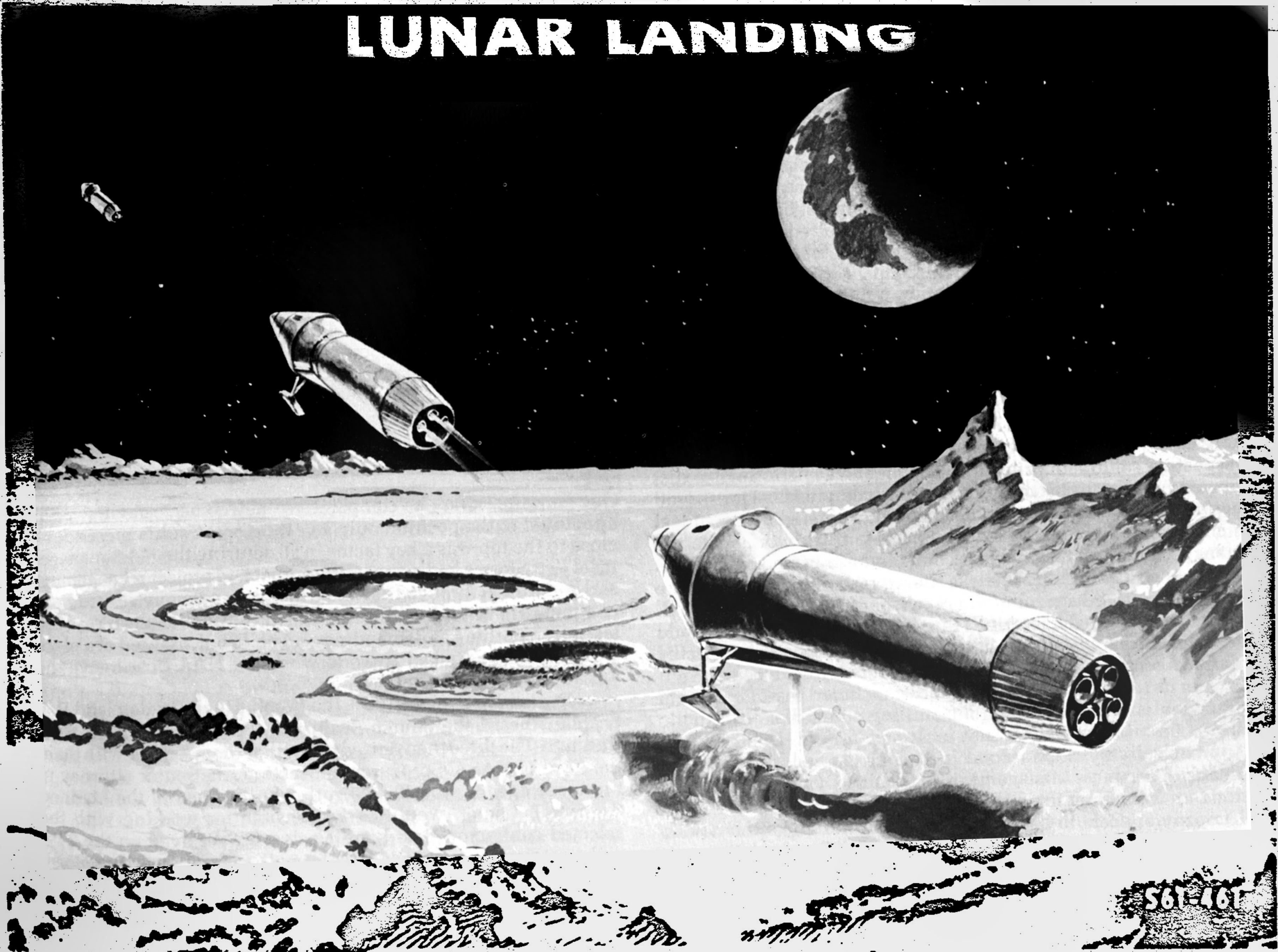
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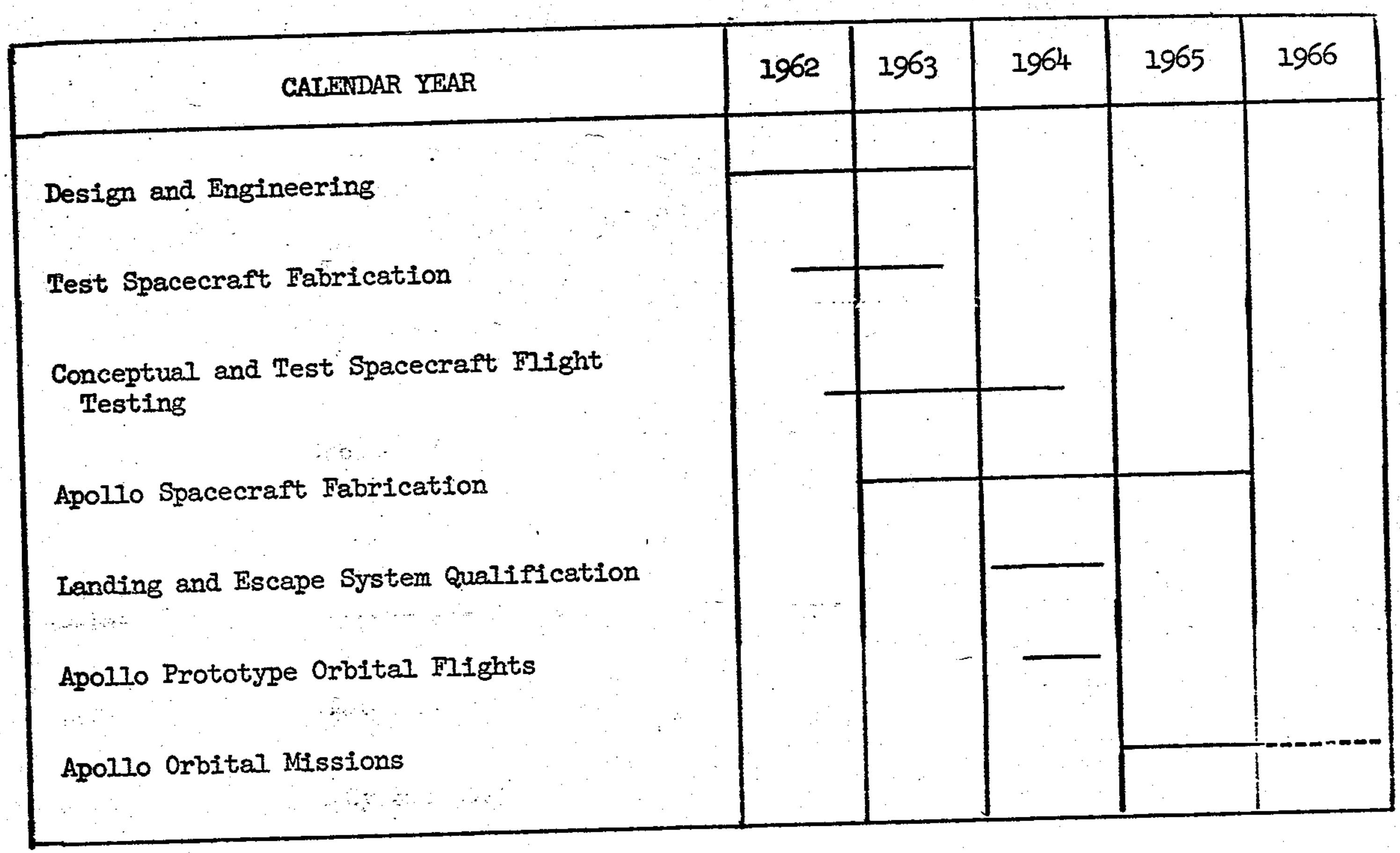

Figure 3. - PROJECT APOLLO PHASE "A" SCHEDULE

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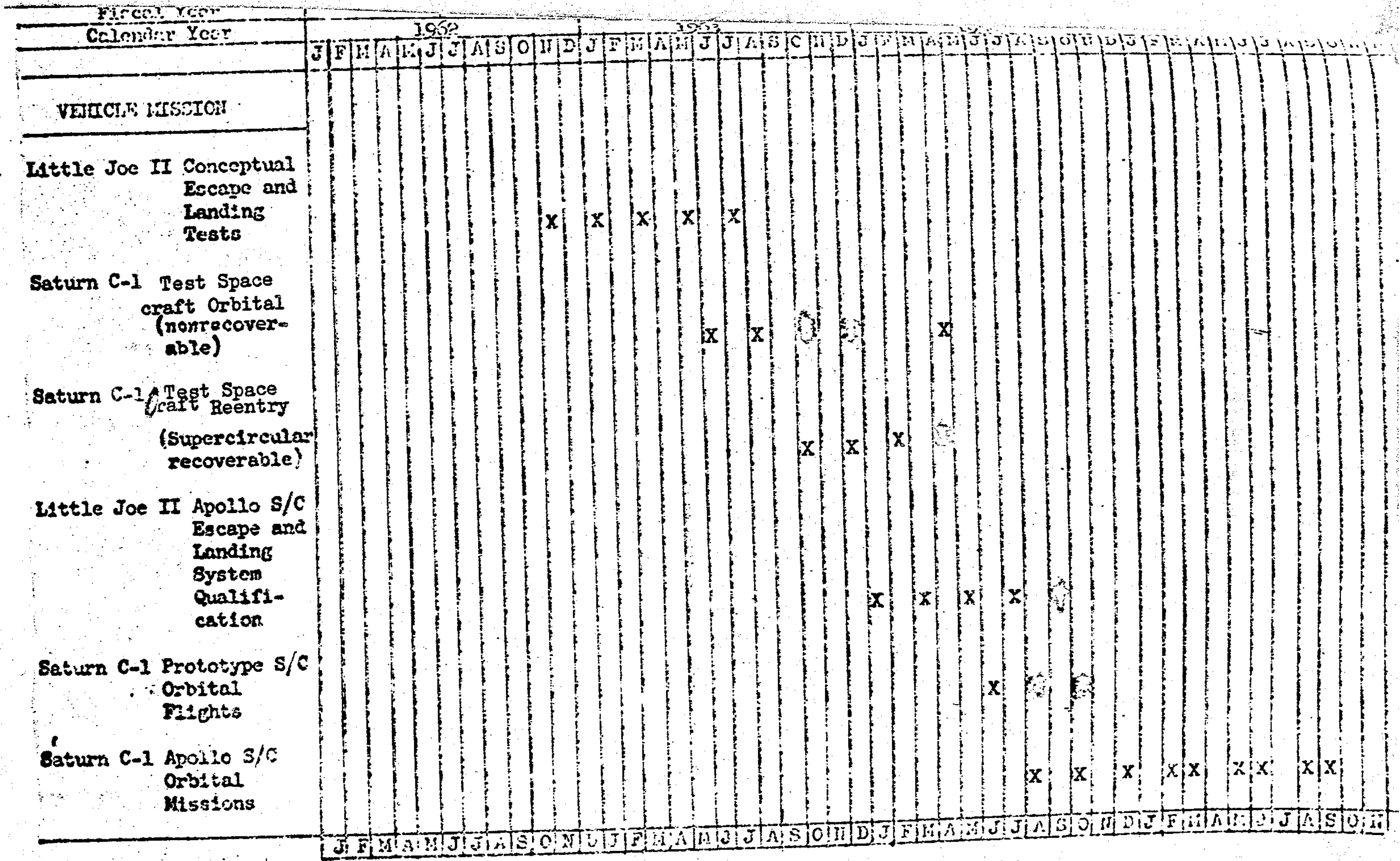

Figure 4. - PROJECT APOLLO PHASE "A" FLIGHT SCHEDULE

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APOLLO AND RELATED PROJECTS R&D FUNDING REQUIREMENTS

FISCAL YEAR	1962	1963	1964	1965
Spacecraft Advanced Technical Development	10	18	22	18
Spacecraft Flight Program				
Orbital Flight Development	47	75	68	14
High-Speed Reentry Flights	14	13	5	
Apollo Spacecraft	50	408	553	651
Launch Vehicle Procurement	33	163	286	295
TOTAL, Millions of Dollars	154	677	934	978

Figure 5. - APOLLO AND RELATED PROJECTS R&D FUNDING REQUIREMENTS

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