THE MANNED LUNAR MISSION

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ABSTRACT

This paper presents the requirements that the manned lunar mission imposes, the manner in which the experiences obtained from Project Mercury are related to this mission, and the basic approach that will be used in attempting to achieve this goal. Accomplishments of Project Mercury are reviewed. The chosen scheme for the manned lunar mission, lunar orbit rendezvous, and the major reasons for this choice are described. Comparisons are made of the Apollo and Mercury space vehicles and spacecraft. Apollo mission maneuvers, their requirements, and the major technical challenges of Apollo are presented. Discipline requirements and the major technical challenges of Apollo are presented. Discipline required for development of mission capability and its application conclude this paper.

INTRODUCTION

NASA has been in existence not quite four years. Since its beginning, NASA has had a strong program in the development of manned space vehicles. Furthermore, the Manned Space Flight Program has been expanded very rapidly, becoming the dominant program within NASA, which is likewise growing at a rapid pace. The next major outstanding goal of the present Manned Space Flight Program is the exploration of the moon.

This paper presents the requirements that this mission imposes, the manner in which the experiences obtained from Project Mercury are related, and the basic approach that will be used in attempting to achieve the goal.

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PROJECT MERCURY

Table 1 is an exact copy of one that was used at the inception of the Mercury program. It is used to indicate the technology status and the approach taken at the start of Project Mercury. The objective was simply to have men experience orbital flight and to determine their capabilities in this environment. The environment considered included launch, re-entry, and recovery, as well as the orbital environment.

The remainder of Table 1 is more or less self-explanatory. Existing ballistic missile boosters and a spacecraft concept that emphasized simplicity were used. An escape rocket was incorporated, since the boosters were known to be capable of failing with a high-yield explosion. The program concept embodied a progressive build-up of test objectives in much the same manner as that used in aircraft flight testing.

Before discussing future efforts, the accomplishments of the Mercury program will be reviewed. From the standpoint of developing manned spacecraft technology, four important things have been learned. First, four of the astronauts have had an experience in space flight, and this environment has not induced any impairment in their capability to think or act. A great deal about spacecraft design has been learned. The concept and development of America's first generation spacecraft is now an experience that can and is being used in future projects of NASA. In the same manner, a great deal about the operation of a manned space mission has been learned by these experiences. Finally, a method of selection and training of astronauts and a way of relating this training to the actual mission have been developed.

Although the Mercury program will not be completed until a few tests of longer duration have been made, it has yielded a base of high confidence and knowledge for proceeding into the next two projects, Gemini and Apollo.

In many ways Gemini is an exploitation of the goals achieved in the Mercury project. It will provide additional capability in orbital flight which will broaden the technology. The primary aims are a longer mission duration and operational capability for rendezvous. Both of these aims will directly support the development of Project Apollo.

APOLLO PROGRAM OBJECTIVES

The objectives of the Apollo program are to land men on the moon, explore the local vicinity, and return the men. Although the objectives may be simply stated, the task is a difficult one. It is important, however, in a difficult task to know what the objectives are so that the program energy will not be dissipated in side issues or imaginary needs.

FLIGHT TO THE MOON AND RETURN

The three major schemes for the lunar mission were the direct approach involving no rendezvous, rendezvous of two parts of the mission payload in Earth orbit, and use of a separate lunar landing spacecraft that will rendezvous with the return spacecraft in lunar orbit. Regardless of the scheme to be used, the mission path would be as shown in Fig. 1. The mission is originated from a parking orbit about Earth. The vehicle is maneuvered into an orbit about the moon from which the landing is made. The return from the moon is also made from the lunar orbit. These maneuvers will be discussed in a subsequent section of this paper.

The scheme that has been chosen for the Apollo mission was announced July 11, 1962 as the lunar orbit rendezvous method. This scheme was first studied in detail by John C. Houbolt of NASA Langley Research Center a year and a half ago. The Manned Spacecraft Center started a serious study of this scheme almost a year ago. Every element within NASA with a major role in the Apollo program has also carried out studies of the various mission schemes, and there exists at this time a unanimous agreement among these elements that the lunar orbit rendezvous scheme is the preferred method to carry out the Apollo mission.

The important characteristics of the lunar rendezvous approach are as follows:

1 A separate spacecraft is used for landing on the moon.

2 The total amount of mass that must be boosted to escape velocity is greatly decreased.

3 A minimum number of additional elements not already being designed and manufactured are needed to achieve the mission objectives.

The fact that the lunar landing is made in a separate spacecraft has both good and bad features. On the negative side, the crew landing on the moon is reduced by one, and those who make the landing must also successfully rendezvous with the parent spacecraft to return to Earth. These considerations are overriden by the fact that the landing spacecraft can now be designed specifically for the landing maneuver without being compromised by considerations related to earth launch, re-entry, and landing. Thus, the structural arrangement, the crew position, the control panel, the window provisions, and other features can be optimized for the most difficult maneuver of the mission--landing on the moon. Furthermore, the size of the lunar-landing vehicle is a great deal smaller. This reduction in size not only makes it an easier machine to land, but it also enhances the possibilities of flight testing during the development phase.

The decision to adopt this method means that only the lunar landing craft itself must be added to the other hardware elements already being constructed to complete the requirements for the Apollo mission. The other schemes would have resulted in the need for new launch vehicles or new launch vehicle elements as well as the development of a cryogenic lunar-landing propulsion stage. In addition, new or extra launch facilities would have been needed. Finally, each mission operation would have been associated with launching about twice the total weight that would be required for the lunar rendezvous mission. The net result would be that the program would have taken longer and would have cost more.

The magnitude of the Apollo project from the standpoint of developing the capability of carrying out the mission will be discussed in the following sections.

COMPARISON OF THE APOLLO AND MERCURY SPACE VEHICLES

Fig. 2 shows the arrangement of the Apollo spacecraft and the Saturn C-5 launch vehicle. For the purpose of comparison, a Mercury-Atlas combination is included on the figure to the same scale. During the launch of the Apollo-Saturn combination, the command module with an escape rocket is carried at the nose position in order to facilitate a possible abort action. Directly behind the command module is the service module. The service module structurally supports the command module during the launch maneuver. The service module is in turn supported by a long adapter section on the front of the S-IV-B stage of the Saturn. This adapter is large enough to contain the lunar excursion module - the spacecraft that makes the lunar landing. The lunar landing module is separately supported within the adapter section.

COMPARISON OF THE APOLLO AND MERCURY SPACECRAFT

Fig. 3 illustrates the arrangement of the Apollo spacecraft for the lunar-orbit rendezvous method. Again for the purposes of comparison, the Mercury spacecraft is shown to the same scale. The Apollo spacecraft modules are shown in the relative positions that they will be given shortly after the time of injection into translunar flight. As in the Mercury project, the escape system will be discarded shortly after dropping the first stage of the Saturn and by mechanical means or a docking maneuver the lunar excursion module is brought into the mated position shown. For the ensuing period, up to the time for lunar landing, the crew is able to move freely between the command module and the lunar excursion module. This freedom of motion provides the crew with additional living space, facilitates functional checks of equipment in the lunar excursion module, and makes available the use of equipment within the lunar excursion vehicle to provide additional redundancies during some phases of the mission.

APOLLO MISSION MANEUVERS

Table 2 is a summary of the velocity maneuvers associated with the normal mission. Listed with the maneuver is the module or propulsion system used to carry out the maneuver. These maneuvers are defined as the controlled action taken to change the velocity state of the spacecraft. Such maneuvers require control, guidance, and navigation capability and some means for the application of accelerative force. In all but the re-entry maneuver, a propulsion system is employed to produce the desired velocity change. The total of the velocity changes carried out during the mission is almost 100,000 fps. The majority of these maneuvers must be carried out with great precision in timing, magnitude, and direction. Furthermore, these quantities must be computed during flight from measurements made during the flight. The large number of velocity maneuvers is contrasted to the Mercury mission, in which only three velocity maneuvers are made: launch into orbit, retrofire, and re-entry. In the case of Mercury launch, precision is required only in magnitude and direction, and the requisite computations are made long before the mission is started. In the Mercury retrofire maneuver, precision is required in timing, the magnitude is built-in, and the direction need not be controlled with great accuracy. The Mercury re-entry is ballistic and requires no flight-path control.

This list of velocity maneuvers indicates the need for high quality in navigation and guidance capability and also in the propulsion system. Suitable systems must be developed in order to achieve the reliability needed for a manned mission. It should also be noted that lunar rendezvous maneuver imposes no additional requirements from a standpoint of quality, since it is only one of many remote propulsive maneuvers that must be carried out with precision in response to mission-determined navigational computations.

One other aspect to the lunar mission that adds to the complexity of the project is the fact that the crew must leave their spacecraft and carry out useful work in the extremely hostile environment of the lunar surface. Space suits will, therefore, be developed which will provide reliable protection from the extremes of the lunar surface temperature as well as the vacuum of space. Comfort, mobility, and adequate communication also must be provided. Well-planned lunar surface exploration procedures aimed at anticipating all possible difficulties, the limitations imposed by the suit, and the unfamiliar environment need to be finalized.

The major technical challenges presented by the Apollo mission are as follows:

1 The mission is a remote operation in which a number of vital maneuvers and operations must be carried out a quarter of a million miles away.

2 There is an implicit requirement for real-time navigation using equipment that must operate from within the spacecraft.

3 There will be repeated and critical dependence on the propulsion systems throughout the mission. There are about 50 separate rocket motors needed for the spacecraft modules alone. These must all be brought to a sufficiently high degree of readiness prior to launch to commit the mission with confidence.

4 The crew must be protected from exposure to the environment of the lunar surface during the exploration.

With these considerations in mind, it is necessary that a strict discipline in the activities toward creating the mission concept, the mission hardware, and the operation procedures be adopted.

DEVELOPMENT OF MISSION CAPABILITY

Table 3 lists some of the more important areas where this discipline should apply. In particular, three areas must be approached in a realistic manner - reliability, performance margins, and mission operations - if the requisite mission capability is to be developed.

The needed reliability may only be achieved by making it a basic design consideration, by not overextending the basic mission requirements or design approach, by insuring high quality in manufacture, and by providing for use of the crew in the many areas where their judgment and capabilities are beneficial, especially in the cases where extensive system simplification results from crew utilization.

Performance margins in the design are vital. Without adequate margins, the risk of serious embarrassment will be felt from weight growth that invariably occurs from problems not foreseen early in the program. Performance reserves are also an important part of the mission reliability, particularly when it is desirable to be able to employ emergency modes that may have degraded precision. This situation is most likely to occur in early missions when unforeseen contingencies are often encountered. Similarly, the propulsion system and propellant utilization control may suffer degradation in performance due to a partial failure or an out-of-tolerance condition.

Equal in importance to the development of space worthy hardware is the development of sound operation techniques. It is vital, therefore, that the operation schemes be developed in step with the hardware development. Early operations should be designed to provide the highest possible performance margins in conjunction with adequate operational flexibility. An analysis of all aspects of the mission will lead to hardware designed for optimum utilization.

In a mission in which vital operations and maneuvers are performed at the remote distance of the moon, the spacecraft command must be in the hands of the crew. The operations center back on Earth must, however, provide every practical support that can be afforded. Tracking, computing, analysis, communications, and recovery must be organized to provide support in a dependable manner, night and day, throughout the duration of the mission.

Finally, the hardware and the operational capability to perform this mission will best be developed by progressive mission experience. These experiences will be fed back into the flight hardware, the operation techniques, the training programs, and the ground facilities so that the landing mission may be launched with the greatest chance for success.

Table 1 Project Mercury

Objectives
Orbital flight and recovery
Man's capabilities in environment
Basic principles
Simplest and most reliable approach
Minimum of new developments
Progressive build-up of tests
Method
Drag vehicle
ICBM booster
Retrorocket
Parachute descent
Escape system

Table 2 Apollo mission maneuvers

Velocity maneuver	Propulsion system
Launch into Earth orbit	Launch vehicle
Injection into translunar flight	Launch vehicle
Outbound midcourse maneuvers	Service module
Decelerate into lunar orbit	Service module
Orbit adjustment maneuvers	Service module
Descend to lunar surface	Lunar excursion module
Launch into lunar orbit	Lunar excursion module
Rendezvous maneuvers	Lunar excursion module
Injection into transearth flight	Service module
Inbound midcourse maneuvers	Service module
Re-entry deceleration	Command module

Table 3 Development of mission capability

Reliability	
	Basic design consideration
	Quality
	Judicious use of crew
Performance margins	
	Weight growth
	Mission velocity maneuvers
	Propulsive systems and propellant utilization
Mission operations	
	Operations analysis
	Onboard command
	Ground support
	Progressive mission experience

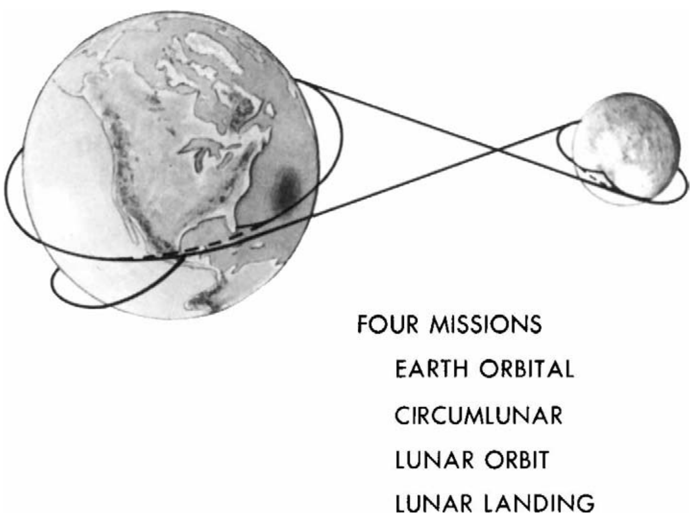

Fig. 1 Flight to the moon and return. Apollo development

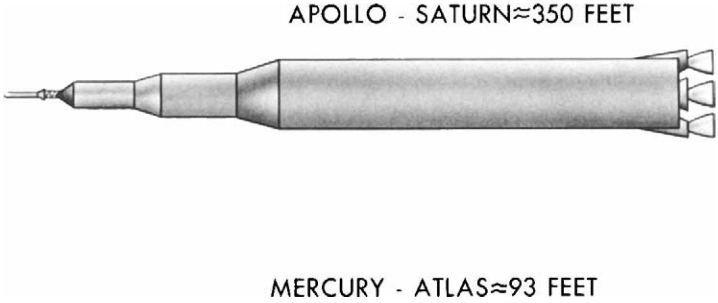

Fig. 2 Comparison of the Apollo and Mercury space vehicles

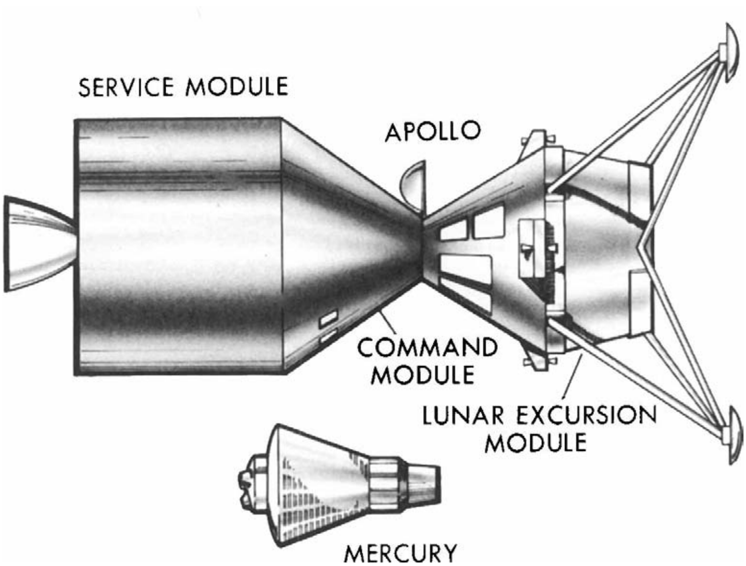

Fig. 3 Comparison of Mercury and Apollo spacecraft