N64-30332

MAN'S EXPLORATION OF SPACE

JOSEPH F. SHEA
Manager
Apollo Spacecraft Program Office
NASA Manned Spacecraft Center

Dr. Gilruth's presentations traced the origins of our manned space program, and Dr. Mueller's, the path upon which we have firmly placed our feet. In preparing this paper, which attempts to describe the development of the Apollo spacecraft, I was reminded of a *New Yorker* cartoon of several years ago. The scene was ancient Egypt, during the period when the Pharaohs were taking advantage of the latest scientific breakthrough to erect their new monuments. At the foot of a half-completed pyramid, a train of hundreds of workers was pulling one of the large stones into place under the baleful eye of the construction foreman, dutifully outfitted with hard hat and whip. In the traces, one of the laborers was saying to his partner, who had obviously been grumbling, " Stop your complaining. Don't you realize that it's a privilege to be associated with a project this vast?"

The Apollo spacecraft are the apex of the lunar program pyramid—the top 90 feet of the 375-foot-high vehicle which some day in this decade will rise majestically from the pad at Cape Kennedy, propelling three of our more adventurous citizens to their historic rendezvous with the Moon.

There are today over 130,000 Americans laboring "in the traces" to make this dream a reality. Although the goal of the program provides an overlay of glamour, the work is the same type of hard, detailed, technical development task which we have been tackling in this country to meet defense or space goals over the last three decades.

The main difference comes from the fact that the space environment, coupled with the demands of the lunar mission, is terribly unforgiving. Any design or quality deficiency in the spacecraft or any of its subsystems will be sure to appear some time during the 2-week mission, causing, at the very least, an abort, and, at the worst, tragedy. Although we have provided redundant backup for critical systems aboard the spacecraft, our emphasis is on developing each system to the point where it will not malfunction. Fortunately, the Space Age has matured to the stage where we understand the environment; we understand how to design to meet it; we understand how to test in our Earth-bound laboratories to determine deficiencies which otherwise would be found during flight tests.

This maturing of our understanding has shaped our entire program. The lunar effort began in 1961. The first major contract awarded was to the Instrumentation Laboratory at Massachusetts Institute of Technology (MIT) for development of the guidance and navigation system. In December of that year, North American Aviation, Inc., was awarded development of the command and service modules. Almost a year later, the lunar orbit rendezvous approach to the overall mission was selected, and Grumman was brought onto the team to develop the lunar excursion module. Almost a year and a half of detailed study had been devoted to defining the mission and developing the specifications for the necessary system elements.

The development program has proceeded with similar deliberation. The command and service modules, and their subsystems, have been in design and developmental test for almost 2½ years. The fruits of this effort are just beginning to ripen. Last month the first functional Apollo guidance system was qualified in Cambridge, Mass. In May the launch escape system and the Earth landing system will be tested under flight conditions with a *boilerplate* spacecraft at White Sands. A few days later, a command and service module, again of boilerplate construction, will be launched from Cape Kennedy atop a Saturn I to check our calculations of the aerodynamic loads which will be encountered during launch. These two flight tests mark the gradual transition of the program from the developmental phase, where we work out the early design problems, to the qualification phase where we prove that the design is indeed worthy of flight. The focus is the first launch of a complete command service module aboard a Saturn IB early in 1966.

If there is any one thing that sets the manned space flight program apart from other, apparently similar, development programs, it is the rigor with which we execute the ground test program. The guidelines we use are simple:

1. Test hardware as early as possible.
2. Make procedures rigorous.
3. Provide consistent test plans and procedures.
4. Provide responsive malfunction investigations.
5. Provide accurate configuration control.
6. Conduct test readiness review.
7. Analyze results; report concisely and quickly.
8. No testing with unresolved anomalies.

In a way, these guidelines sound like a litany of good generalizations, but we take them literally. Every failure encountered in ground testing must be understood and corrected before the spacecraft is certified for flight. This program discipline—the refusal to shoot and hope—should make our flight tests demonstrations of the fact that we have solved our problems on the ground. The only failures which should be encountered in flight are those which can arise from a combination of environments which we were unable to simulate in our laboratories. Since there are still several such conditions, we cannot expect a perfect record—but the success ratio should be relatively high.

The flow of the overall program is shown in figure 1 The early command (CM) and service modules (SM) are injected into earth orbit by a Saturn IB to certify the spacecraft and work out crew operations for periods up to 14 days. About a year later, the lunar excursion module (LEM) is added to the stack for its initial flight test. Subsequent tests will work out the rendezvous procedures between the two spacecraft and simulate the lunar mission without ever leaving Earth orbit.

These tests will take place at the same time that the Saturn V, the massive vehicle required to place the fully fueled spacecraft on the trajectory to the Moon, is being developed and flight tested. Thus the parallel testing paths will provide a spacecraft and booster which, when mated, will be ready to consummate the lunar mission.

One of these national conferences would not be complete without at least a brief description of that mission. Since last year we have concentrated on filling in the detail around the nominal lunar orbit rendezvous mode. Since the Earth–Moon geometry varies continuously, many trajectories must be developed in our computers to be sure that all essential conditions can be covered by our design.

The particular trajectory shown in figures 2 to 4 is for May 6, 1968. (This is not an announcement of intent, merely an example.) For operational reasons we wish the launch and Earth landing to take place during daylight, and the lunar landing to occur

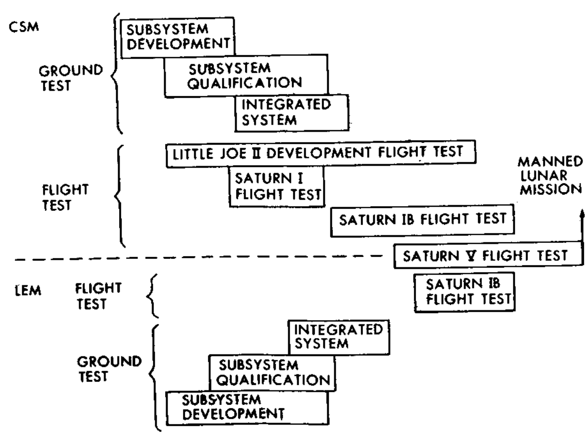

FIGURE 1.—Apollo spacecraft test program.

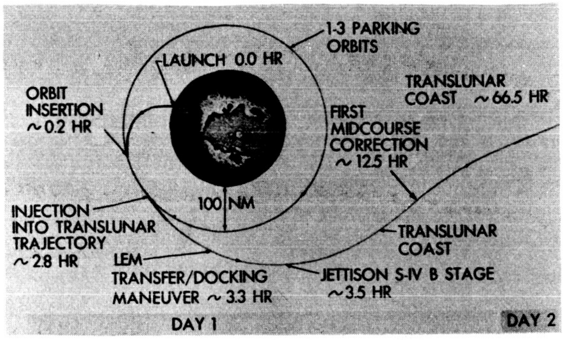

FIGURE 2.—Earth launch phase of typical lunar mission profile.

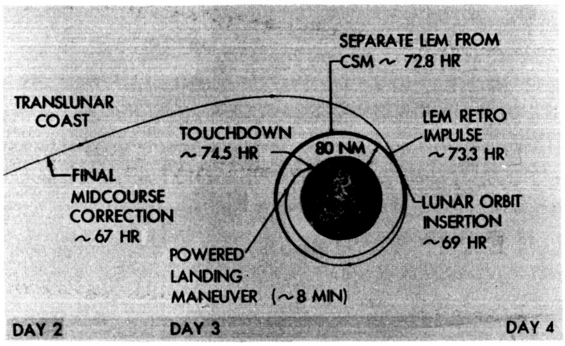

FIGURE 3.—Lunar landing phase of typical lunar mission profile.

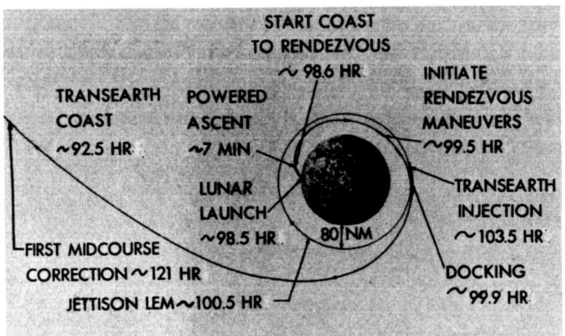

FIGURE 4.—Lunar launch phase of typical lunar mission profile.

when the Sun is 45 degrees above the lunar horizon, to provide optimum lighting conditions for control of touchdown. Table I is a possible schedule of another possible mission.

TABLE I.—*Mission Schedule*

May	Day	Cape time	
15	Monday	1:32 p.m.	Launch: pad A, complex 39, 72° launch azimuth. Had 2½-hr launch window but made it right on nominal time. Translunar trajectory <18° relative to Moon orbital plane. 12 min to orbit.
		3:50 p.m.	Docking completed
16	Tuesday	1:00 a.m.	First midcourse.
18	Thursday	7:30 a.m.	Final midcourse.
		9:30 a.m.	Lunar orbit insertion behind Moon.
		1:50 p.m.	LEM retro.
		3:02 p.m.	Lunar touchdown.
19	Friday	3:02 p.m.	Lunar launch.
		4:02 p.m.	Rendezvous behind Moon.
		8:02 p.m.	Trans-Earth injection behind Moon.
20	Saturday	1:30 p.m.	First midcourse.
23	Tuesday	2:02 p.m.	Final midcourse.
		4:02 p.m.	Jettison service module.
		4:38 p.m.	Parachute deploy.
		4:50 p.m.	Touchdown in Pacific at 12:50 p.m. Honolulu time.

FIGURE 5.—Suggested lunar landing areas.

Figure 5 is a map of possible lunar landing areas. The lunar landing site was arbitrarily selected, but represents the gneral area in which we can expect to explore. Later missions may stay somewhat longer than 24 hours on the Moon's surface, and up to 7 days in lunar orbit.

The Earth landing area will, in general, be the Pacific Ocean. On this particular mission it is about 400 nautical miles north east of Hawaii. The exact point of touchdown will depend on the exact mission flown and the other constraints placed on the flight.

In summary, much has been accomplished since 1961—much more must yet occur before the command module splashes down, still warm from its triumphant reentry. Important as that splash will be, in a sense, it will be an anticlimax. As Havelock Ellis said once, about philosophy, "It is not the attainment of goals that matters; it is the things that are met with on the way." On the way to the Moon we will meet, and solve, all the problems which stand between us and mastery of space. The heritage of the lunar program will not be merely the lunar rock we bring back, but rather the Apollo space ships and launch vehicles, coupled with a broad-based national team capable of coping with any and all requirements for operations in space which may be thrust upon this Nation.

The past year has seen much progress in the development of the spacecraft. We are on the schedule and within the budget discussed at this conference last year. We hope to be able to report increasing accomplishment within those same two constraints next year and each succeeding year until, in 1970, we can, as Dr. Gilruth did with Mercury, summarize how it was done.