Fund Cuts, Technical Troubles Slow Surveyor, Voyager Programs

In recent months the National Aeronautics and Space Administration has made changes in schedules and payloads which amount to a major recasting of NASA's whole program of unmanned exploration of the moon and planets.

The first flight of the Surveyor spacecraft, designed to be the soft-landing successor to the Ranger moon craft has been moved back yet again to the second quarter of this year.

A first mission of NASA's very big, very expensive Voyager planetary explorer has been "slipped" 2 years, to 1973. Until late last year, an orbiting mission to Mars in 1971 had been set for Voyager. The new schedule calls for the landing of a capsule on the Martian surface in 1973. The concept of the spacecraft has been radically altered, and a bigger booster will be needed.

The Mariner program, which had ended officially and very honorably after successful flybys of Venus and Mars, has been resurrected to fill the gap in the interplanetary program. A Mariner which was a "backup" vehicle for the Mars shot in 1964 has been taken out of storage and will be adapted for a launch toward Venus in 1967. In 1969, two new vehicles, of a design based on Mariner technology, will be readied for a Mars mission that year.

The reasons for the realignment are mixed. Pressure on the NASA budget is being exerted from inside by the demands of the manned lunar landing program and from outside by rising military expenditures. The unmanned program continues to be haunted by original underestimates of the difficulty of unmanned exploration—now particularly, perhaps, by early underestimates of the intricacies of achieving soft landings. The Soviet unmanned program is currently much more active than ours. Two of their spacecraft are on the way to Venus now. The Russians have also unintentionally demonstrated the problems of sophisticated exploration. It is believed that four attempts at a soft landing on the moon have been made and have failed in the past year.

The Surveyor program occupies an urgent category in the overall space program because it is being counted on to provide information on the characteristics of the lunar surface, information needed for the design of the Apollo lunar excursion module.

Apollo's need for information obviously influenced a recent decision to make the first seven Surveyors engineering test vehicles. These will not be bare-bones spacecraft; each will have a payload consisting mainly of test equipment designed to monitor closely the operation of systems in flight and to give project scientists and engineers answers they will need if aught should go awry. The initial Surveyors will carry television cameras intended to send back closeup pictures of the surface, and instruments such as accelerometers and strain gauges mounted on the craft's landing gear should provide limited but useful information about surface characteristics. The series of seven seems intended to increase the odds that data will be obtained.

The new schedule calls for a "Block 2" of three "operational" Surveyors with payloads of scientific experiments to follow the seven engineering-model Block 1's. But no Block 2 launches are expected before 1968. The scientific experiments to be included in the operational models have not been chosen. And it is understandable if scientists are disappointed to learn that the first scientific Surveyor flights are likely to come some 5 years after the original, optimistically planned date.

Surveyor, it must be remembered, is not simply a bigger Ranger. It must perform the technologically very demanding task of making a soft landing —which has been described as a "reverse lift-off"—in very thin atmosphere, at a picked landing spot, by successfully executing a very delicate balancing act which will keep the vehicle's attitude exactly right all the way in.

In addition, the craft's very complex radar and other systems must withstand the rigors of a launch, the perils of space flight, and the hazards of a landing and then operate under the extreme temperature conditions of the moon, where surface temperature varies from 260° to −245°F (127° to −154°C).

Almost everyone connected with the project admits that it was undertaken in a mood of blithe overconfidence. This overconfidence was fully dispelled in 1963 and 1964 when a series of tests yielded results that might fairly be called disastrous.

Surveyor's troubles in the past year attracted congressional attention. The Jet Propulsion Laboratory, which is managed under contract by Caltech, has responsibility for the technical direction of the project, the Hughes Air Craft Company, which is the prime contractor, and NASA headquarters, which is ultimately answerable for everything in the vast program it administers, all drew critical fire.

Perhaps the best available summary of Surveyor's difficulties—technical and managerial—is to be found in a report* published last fall by the committee on oversight of the House Science and Astronautics Committee. The study which produced the report was headed by Representative Joseph E. Karth, chairman of a Surveyor panel formed in the subcommittee. Karth played a similar role in hearings on the Ranger Project when that was passing through a time of troubles (*Science*, 15 May 1964).

The phenomenon of mounting costs was one factor that attracted congressional attention. The report notes that in 1961 the Surveyor Project cost was put at an estimated $50 million. The report goes on to observe that the first launch will come some 3 years behind the original schedule, that scientific payloads have been reduced, and that costs of the project have climbed to an estimated $725 million.

The report concedes that, "in view of the challenging nature of the Surveyor mission, well understood today, but little understood in 1961, it is not surprising that launch schedules have been revised, costs have increased and payload capability has decreased."

The subcommittee points the accusing finger rather impartially at JPL, Hughes, and NASA headquarters. In general, NASA is censured for having done inadequate preliminary work, with the result that a series of modifications

* "Project Surveyor," available from the Committee on Science and Astronautics, House of Representatives, Washington, D.C.

Surveyor and Its Mission

Surveyor is the unmanned spacecraft scheduled to make the first American soft landing on the moon. The first seven Surveyors will weigh approximately 2200 pounds (1000 kilograms) each, including 62 pounds of engineering equipment. Designed to carry various engineering and scientific payloads, the Surveyor "basic bus," with its triangular framework, stands about 10 feet (3 meters) high and within a circle about 14 feet in diameter. The spacecraft's launch vehicle will be the two-stage Atlas-Centaur, which links the serviceable Atlas with the new, liquid-hydrogen-burning Centaur second stage.

Shortly after launch Surveyor will be separated from the Centaur and sent on a coast trajectory toward the moon. The craft will "lock" onto two space references, the sun and Canopus, and a solar panel will be oriented toward the sun for generation of power.

Some 20 hours after launch, when trajectory has been accurately determined, a crucial mid-course maneuver will be made to direct Surveyor toward a selected landing spot on the moon's surface. The flight will take an estimated 66 hours, and if things go according to plan the following sequence of events will lead up to the soft landing.

At about 1000 miles from the moon the craft will maneuver to align the thrust axis of the main retro-engine with the velocity vector. Television viewing of the surface, on Surveyors with "vertical" cameras, will begin at about 10 minutes before impact. Approximately 5 minutes before predicted impact radars are turned on, and from that point on the landing sequence is automatic.

At a slant range of some 50 miles from the surface the vernier engines on the tripod legs and the main retro-engine are turned on. After the spacecraft has been slowed from a speed of about 9000 to 350 feet per second, the main retro-rocket engine is ejected. The vernier propulsion system, in concert with the inertial reference system, keeps the craft's attitude correct. At an altitude of 13 feet, when the craft is supposed to be traveling at about 5 feet per second, the vernier units cut off and the spacecraft "free-falls" to the surface. The planar array antenna is then commanded to point toward the earth, and the solar panel toward the sun, and "operational" Surveyor should go into full operation.

and "program redirections" were necessary. JPL and Hughes are taken to task for faults in organization, management, and liaison. "The result," says the report, "has been one of the least orderly and most poorly executed NASA projects."

In the early 1960's, JPL, it seems, was fully engaged with the Ranger and Mariner Projects, which it was conducting "in-house," and was constrained by a manpower ceiling imposed by NASA. The report says that JPL virtually turned over the Surveyor Project to Hughes.

By the end of 1963 NASA was aware that the project was in trouble, and in March of 1964 a team from the NASA Office of Space Sciences and Applications was assigned to evaluate the technical status of the project and the management relationship between JPL and Hughes.

The survey team observed that the Surveyor group at JPL was understaffed, and it urged a buildup. It also strongly recommended that, at both JPL and Hughes, Surveyor groups be "projectized"—that personnel be assigned exclusively to Surveyor and a project manager be given solid authority over the groups at each place. The team had reported that, at both Hughes and JPL, Surveyor had been administered under the matrix system, whereby individuals assigned to functional divisions were made available to work on Surveyor, in many instances part time. The team was also critical of JPL methods of supervising, and of Hughes's methods of monitoring reliability and assuring quality.

Starting in 1964, JPL fairly rapidly built up the group assigned to Surveyor, from 100 to about 500. Many of these individuals transferred from the Ranger and Mariner programs, which were winding up. The congressional report observes that the group was reorganized along project lines. Early last year, Robert Parks, who was an assistant laboratory director in general charge of lunar and interplanetary spacecraft development, was made Surveyor Project director, a role that demands the mixed talents of a scientific troubleshooter and diplomat.

JPL's swing to more active supervision caused some friction between JPL and Hughes. Acquainting JPL personnel with Surveyor problems was time consuming for Hughes people, and there was evidently some feeling that JPL scientists and engineers coming to Surveyor 3 years after the start of the project were indulging in second-guessing.

Hughes officials have disputed the assertion that organizational changes were needed or, in fact, made. But a congressional memorandum dated 22 December and written after a subcommittee visit following up the original Surveyor report, notes a tightening up at Hughes and indicates that interface problems between JPL and Hughes appear to have been solved. The memo also observed that NASA headquarters appears to be closely monitoring the important test programs now under way.

Success with recent vehicle-descent tests and a feeling that problems revealed in solar-thermal-vacuum tests have been largely identified and corrected seem to have produced an air of sober confidence at JPL and Hughes about the coming launch. There seems also some relief over the fact that there will be an engineering series of seven Surveyors rather than four.

There is a lurking concern that, even should things go perfectly, the signal from the spacecraft could be lost at the crucial moment of touchdown. JPL and Hughes officials admit that noise and vibration associated with landing might interfere with the relatively weak signal being transmitted at the moment of impact. Some speculate that dust or some other substance on a loosely compacted surface might smother the signal. And there are some things that simply can't be tested on earth.

JPL is also project manager for Voyager, the unmanned spacecraft designed for the exploration of Mars and beyond. Some 400 persons at JPL are involved with the Voyager Project, some 60 of them with project management. Three contractors—Boeing, General Electric, and TRW/Systems have been engaged in preliminary design

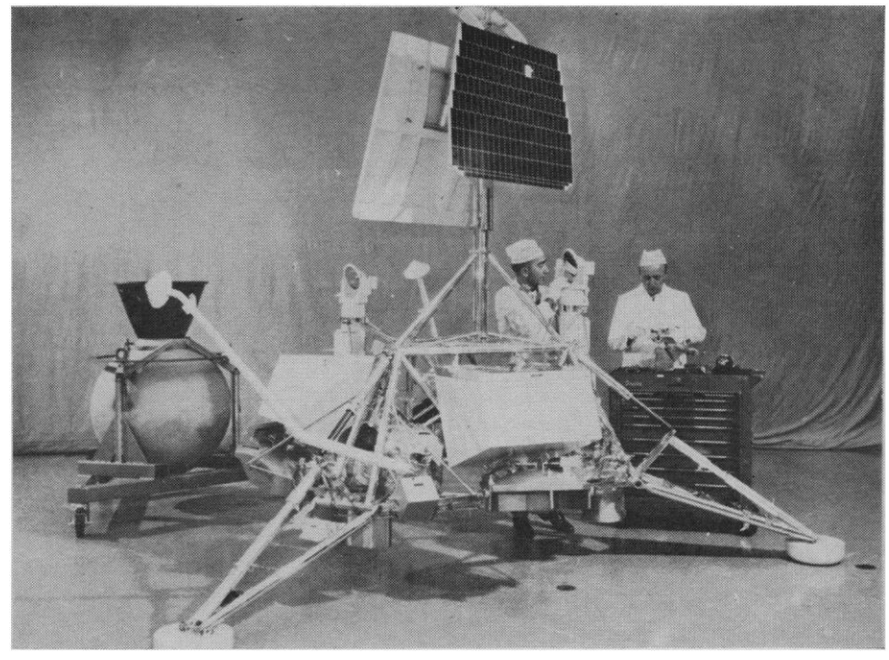
study. The contracts for these studies were recently extended for 3 months—to the end of January—because of a radical reorientation of the project.

This revision was prompted specifically by information obtained by the so-called occultation experiment performed by Mariner IV last July. Mariner IV, after approaching Mars, flew by and then, in relation to earth, passed behind Mars. For a brief period Mariner was hidden from the earth. As Mariner approached the planet and then passed beyond it, the signals from the spacecraft were changed in character, by passage through the Martian atmosphere. The data acquired indicated that atmospheric pressure on Mars is much lower than had been supposed. It is between 4 and 7 millibars, according to Mariner data. (Atmospheric pressure on the earth is 1000 millibars at sea level.) In recent years, estimates of atmospheric pressure on Mars have been rather steadily pared down. Just prior to the Mariner flight, pressure was put at 10 to 20 millibars, on the basis of ground observations.

This indication of low pressure, coupled with the likelihood of strong winds on the Martian surface, drastically altered the assumptions on which Voyager planning had been proceeding. Into the discard went a design providing for a two-part spacecraft which would have separated as it approached the planet, the landing capsule, slowed down by the atmosphere, heading in for a soft landing and the "bus" going into orbit.

In view of the Mariner findings it is thought necessary to combine bus, lander, and retro-engine in a spacecraft which will go into orbit around Mars. In this concept, after the orbit is established the lander can be released with a precision sufficient to allow it to enter the Martian atmosphere at a shallow angle to maximize the slowing effect of the atmosphere.

The change in concept requires a much heavier load of fuel for the retro-engine and therefore a much heavier spacecraft—22,000 pounds, or more than double the weight required under the original design. This load puts Voyager beyond the capacity of the Saturn IB-Centaur which was being developed for it and demands the use of the gigantic Saturn V, which is being developed for the Apollo landing on the moon. The 1973 Voyager shot could be a doubleheader, with two spacecraft launched on one moon rocket. Cost of the revamped Voyager program, which would include additional shots after 1973, is estimated at $3 billion.



Surveyor spacecraft is an "operational model carrying scientific payload rather than an engineering model. Large retro engine (left) fits in base of craft.

In its memorandum, the subcommittee (which, incidentally, has become a progressively better informed and more effective monitor of the NASA unmanned program) had this to say about haste and waste.

"Evidence of the existence and nature of extraterrestrial life continues to be an objective of the Voyager Project, although scientists believe that if life does exist on Mars, it is of a very low form. It is possible that life once existed on Mars, but is now extinct. The primary emphasis of Voyager, therefore, seems to have shifted somewhat from the search for extraterrestrial life to the acquisition of scientific data in general which may throw light upon the nature, origin and evolution of the solar system.

"In short, Voyager Project had undergone a complete revision and reorientation during the past 6 months. The launch vehicle, the design of the spacecraft, the mission description, the launch schedule, and to some degree the objectives, all have changed. And all because of the results of a relatively simple experiment aboard the Mariner IV.

"The data regarding the Martian atmosphere produced by the Mariner IV occulation experiment is meager and imprecise. Yet, it has been sufficient to cause a revolutionary modification in the Voyager program. The taxpayers of this country may well breathe a sigh of relief that this simple experiment was successful, for it seems to have saved NASA from undertaking a program which would have cost a minimum of $1.3 billion and which, in the light of the Mariner IV data, would almost certainly have been a failure. Whatever might have been learned from such a mission would have been learned the hard way, the expensive way. Fortunately, the Mariner IV data arrived at a most opportune time, during the paper study phase, and before Voyager hardware development had begun.

"It is important to remember that NASA officials were prepared, a mere six months ago, to make a huge commitment to a complex program to explore Mars, relying upon the best information then available. They undoubtedly believed that the best available data were correct data.

"It is recognized that all research projects, by definition, are undertaken in some degree of uncertainty. On the other hand, rational scientific methods certainly require that, whenever possible, new knowledge be developed incrementally, in an orderly and gradual way, so as to avoid major costly mistakes. It hardly needs to be stated that great caution should be exercised in the more costly projects, and Voyager is by far the most expensive unmanned space project undertaken by NASA to date."—JOHN WALSH