

Reorganization and the Creation of Viking

The cancellation of *Voyager* wiped clean NASA's slate of proposed planetary missions. An unthinkable turn of events, it gave the space agency a unique opportunity to redefine its planetary goals and evaluate the wisdom of earlier projected activities. But, unlike the early 1960s when *Voyager* was conceived, NASA planners by the end of 1967 had a technological and scientific base on which to build. The nearby planets were not as much a mystery as they had been at the beginning of the decade. And the agency had several proven launch vehicles from which to choose. But more significant, NASA engineers and scientists better understood the technology of spacecraft designed to explore deep space.

An eager group at NASA's Langley Research Center in Virginia was anxious to seek alternative missions to replace the *Voyager* series, and at the top of their list of possibilities was a Mars landing craft. Having participated on the fringes of the agency's Mars activities for several years, the Langley group created its own new series of proposals, from which the Viking spacecraft evolved. As with many other aspects of NASA's planetary program, Viking's heritage was tied to the many projects—both successful and unsuccessful—that preceded it. At Langley, Viking's roots extended back to 1964, three years before *Voyager* was canceled.

LANGLEY ENTERS THE MARS BUSINESS

By early 1964, it was widely recognized within NASA that Mars was the next likely major target for exploration following Apollo's expeditions to the moon. Leonard Roberts, head of the Mathematical Physics Branch in the Dynamics Load Division at the Langley Research Center, became interested in the technological problems associated with vehicles passing through the Martian atmosphere.¹ Langley, by virtue of its extended research into the behavior of airplanes and spacecraft operating in Earth's atmosphere, was generally recognized as the leading NASA center for the study of the aerodynamic and heat-load aspects of the entry design of such vehicles. Pursuing the Langley tradition of researcher-generated study projects, Roberts brought together an informal group of center personnel to

examine the possible application of its expertise to the problems associated with landing vehicles on Mars. From that group, he selected William D. Mace, Flight Instrumentation Division; Roger A. Anderson, Structures Research Division; and Edwin C. Kilgore, chief of the Flight Vehicle Systems Division, for a team* that would determine how Langley personnel could best contribute their talents to the investigations of the Red Planet.

Starting from "near zero in knowledge pertaining to . . . interplanetary missions," the Roberts group decided to concentrate on the area in which Langley had talent—vehicle entry aerodynamics. It would work on devising the optimum entry vehicle for landing payloads on Mars. The decision had been influenced by an early look at what other NASA organizations were doing. In Pasadena, the Jet Propulsion Laboratory was the lead "center" for planetary missions. Both Ames Research Center and Goddard Space Flight Center were studying probes that would obtain information about the Martian environment. Langley would examine the specific class of problems related to a vehicle from the time it was released by its transporting craft (orbiter or flyby) until it came to rest on the planet's surface.

After a few weeks of study during which they exchanged telephone calls, cryptic notes, and other informal communications, Roberts and his specialists chose to focus their efforts on the design of a basic, or "baseline," entry vehicle. About two and a half meters in diameter (to fit the Mariner launch shroud), it would weigh 136 kilograms (compatible with Atlas-Centaur capacities). The Langley Mars probe would contain instruments that would make direct measurements of the Martian atmosphere while the vehicle was descending on a parachute deployed from the protective heatshield. About 20 persons in scattered locations at Langley participated in this preliminary planning activity, with the engineering office of the Flight Vehicles and Systems Division becoming the focal point for coordinating all the work. Finding volunteers for the project was no problem, since the Langley people realized that they might be getting in on the "ground floor" of something big. As James McNulty subsequently recorded, during the early period "no sophisticated analyses were made, designs were broad based, and most work was done on scratch paper."² Primarily, the Langley team wanted to get a feel for ideas; "a lot of work and concepts were turned out, analyzed, modified, or discarded. . . ." Langley researchers were taking the same kind of initial course that their counterparts at JPL had followed with Mariner B and Voyager.

Two major problems considered by the Roberts group were optimum designs of a heatshield and a descent television experiment. Descent television was considered useful and a "glamorous" idea, but it was scrapped because of weight and the long time lag for transmission and processing of video images. The heatshield also raised the issue of weight allowances.

*James F. McNulty and Clarence T. Brown, Jr., were also in the team's early meetings.

Roberts' team looked at heatshields for several different landers—from a simple spherical probe (hard-landing) that would enter the atmosphere at an angle and travel a long tangential path to the surface, to a series of much larger, complex craft (soft-landing). But hard or soft, the landers would need a heatshield to overcome aerodynamic heating and assist in slowing down the craft before touchdown. Writing in the fall of 1964, Roberts noted that during the past decade considerable research had been applied to the design of ICBM and manned entry vehicles for use in Earth's atmosphere, and much of that technology could be adapted for planetary exploration. However, there were some significant differences, "primarily because we face different planetary atmospheres and higher entry velocities."

Although it became obvious that existing heatshield technology would not meet payload weight limitations for the large landers, a solution did appear to exist for the smaller probes. Roger Anderson's Structures Research Division at Langley was working on a new heatshield—a "tension shell" with a peaked cap—in which the payload would be placed below the main ring of the heatshield structure. The membrane, stretched between the payload and the ring, would deflect the entry heat pulse and provide the necessary drag. For the thin Martian atmosphere, this new shield promised to be more efficient than those used for Earth reentry.³ Concurrently, Langley researchers under William Mace examined the problems posed by sterilizing hardware using intense heat over long periods of time.

In the summer of 1964, Roberts asked the center management to fund a \$500 000 industry study of a Mars probe with a tension-shell heatshield. After a vigorous selling job by Roberts, NASA Headquarters allocated the requested funds, half from the Office of Advanced Research and Technology and half from the Office of Space Sciences and Applications. It was December before the request for proposals (RFP) was released, and the six months gave the Virginia team time to define the contractor's tasks.

Preparing a statement of work for the contract proved a challenge. In Langley's first plunge into the interplanetary realm, Roberts and his colleagues discovered it was a difficult task to define on paper exactly what needed to be done. In addition to the probe, NASA Headquarters was urging Langley to examine the lander in more detail. Since the lander had been considered thus far only as it affected the design of the heatshield, this study gave the men at Langley new opportunities. Despite the extra work required, the team was enthusiastic about working on a new lander, since it enlarged the scope and importance of the study. It also gave Langley a chance to enter a domain previously dominated by JPL. A shift away from the Atlas-Centaur launch vehicle to the Saturn IB-Centaur permitted a more realistic examination of larger landing craft. As McNulty said, ". . . it was a new and bigger project—and it was Langley's responsibility."

As it finally evolved, the Langley statement of work for the contractor study contained some familiar ideas and some new ones. While planning in

detail for a 1971 probe mission, the contractors would also examine larger, more complex landers for 1973 and 1975. Unlike earlier proposals, Langley's proposal recommended separating the landing probe from the spacecraft before the spacecraft's encounter with Mars. The main part of the craft would subsequently fly by the planet after relaying a short transmission from the probe.⁴ Released in December 1964, the request for proposals generated eight responses from industry, which were evaluated in March 1965. A contract was awarded to the Research and Advanced Development Division of AVCO.

This \$600 000, seven-month examination was one of three Mars-related studies being funded by NASA in the summer of 1965. First—and foremost—was the Voyager phase IA under the direction of JPL, with Boeing, General Electric, and TRW as contractors. Second, Ames Research Center had contracted with AVCO for a six-month, \$300 000 study of a lightweight (11-kilogram), nonsurviving probe. And third was Langley's new contract with AVCO to develop an entry system and survivable lander.⁵ The three contracts, two of them managed by Office of Advanced Research and Technology (OART) centers—Langley and Ames—raised many issues that had to be resolved at NASA Headquarters.

Basic to all other concerns was a management problem—how to integrate the Office of Advanced Research and Technology centers into the activities of the Office of Space Sciences and Applications. Langley had no Voyager office as such at this time, but with the increased tempo of Mars activities the Virginia center set up a Planetary Mission Technology Steering Committee, chaired by Leonard Roberts. Through this committee, the center's staff could bring members of Langley into planetary activities without taking them away from their primary responsibilities in their technical divisions. Charles J. Donlan, Langley deputy director, outlined three tasks for the steering committee—guiding the AVCO study, beginning a Langley research program in support of Voyager, and preparing a working agreement defining relations between JPL and Langley.

In the process of overseeing AVCO's work, the steering committee discarded one of its pet ideas, the tension-shell heatshield. The concept had given Langley a foot in the door, but the heatshield had failed to prove out in the wind-tunnel tests. The Apollo and blunt-body heatshields were its equal in performance without some of its structural weaknesses. As one participant noted, "Thus, one of Langley's main selling points—its unique knowledge of tension shell technology—was quietly discarded without notice."⁶ Langley's attention shifted to a blunt cone for entry, because it was easier to package than the bigger Apollo heatshield.

In defining the research program, the Langley team demonstrated its bias toward research and technology development rather than the conduct of flight projects. Since the creation of its first facilities shortly before World War I, Langley had been dedicated to applied research. In the NASA era, flight projects were viewed as status symbols, good for public relations and

as a source of funding, but the center's managers sought a careful mix of missions and research and strove to keep flight projects subordinate to the research program. At Langley, Voyager-related research in 1965 called for a wind-tunnel test program (\$330 000), capsule-heatshield development (\$400 000), and parachute development (\$865 000). Parachute technology was an important area to be studied, because no parachute then in existence would survive deployment at the extremely high speeds (mach 1.2) needed for a Mars mission.⁷

Defining Langley-JPL working relations was no simple task, because of JPL's unique position in the NASA organization.⁸ In July 1965, when the California laboratory was selected as the capsule system manager for Voyager, Homer Newell told JPL Director William Pickering that Langley would act "in a capsule technical support role relating to design, development and testing of the entry system."⁹ With management charter in hand, 12 representatives from JPL visited Langley to work out the details of Langley's support, and it was quickly apparent, according to McNulty, that JPL and Langley had some diverse views as to Langley's role. From the Tidewater perspective, it appeared that "JPL was interested in getting Langley out of the 'systems' area which JPL wanted to control and into narrow specific technology tasks (i.e., type of heat shield material) which would support its mission concept." The Langley people, on the other hand, took a broader view. To them, support in the area of entry technology included entry concepts, design, methodology, materials testing, and the like. JPL, in addition, was miffed over the AVCO probe contract with Langley, believing that it might lead to "preferential treatment [of] AVCO in subsequent Voyager capsule procurement."¹⁰ McNulty later wrote that there was much "free discussion but few agreements" between Langley and JPL. Headquarters would have to help define the roles the centers played.¹¹

The specialists in Virginia spent the late summer months of 1966 working with the AVCO study and making occasional trips to Voyager capsule advisory group meetings. Like everyone else, the Langley group was surprised at the October shift to the Saturn V launch vehicle. AVCO was redirected to consider the implications of the adoption of the giant booster.¹² More significant, Langley Deputy Director Donlan told the Planetary Mission Technology Steering Committee that the center management wanted to use Voyager as a focus for its research programs, since it was the only major approved NASA activity after Apollo. In addition to seeing Voyager as a source of post-Apollo work, the Langley management could not fail to appreciate the fact that a "real" NASA center might be assigned the Voyager management role instead of the "contractor" laboratory in Pasadena.¹³

AVCO delivered its final report on 1 March 1966, with the following proposed mission highlights:

Experiments

- 3-camera television system

ON MARS

- 4 penetrometers to measure surface hardness
- instruments to determine atmospheric composition

Entry capsule

- 4.6-meter-diameter cone
- 925-kg weight

Only technological problem area

- development of parachute for low dynamic pressures.¹⁴

Delivery of AVCO's results came just a week before the cancellation of the 1969 probe mission and the 1971 Voyager flight. The Langley team embarked on an in-house study of alternative approaches to Voyager landers and landings, giving special attention to out-of-orbit entry versus direct entry from a flyby.

On 2 June 1966, JPL's Centaur-powered *Surveyor 1* became the first American spacecraft to soft-land on the moon. While the landing demonstrated the feasibility of terminal retrorockets, there was some question about the application of other Surveyor mission elements to a Mars flight. Direct entry to the lunar surface was relatively easy, given the detailed knowledge of the moon's motion and the reasonably good views of landing areas from Earth. Mars was a much less well defined target. The absence of any lunar atmosphere also obviated the need for a heatshield and parachute. After the success of the soft-landing rocket system, the Langley team considered using a retropropulsion unit in conjunction with a heatshield and parachute for Mars landers. On 14 August, *Lunar Orbiter 1* orbited the moon, the first American vehicle to do so. Besides mapping the lunar surface in detail for Apollo landing site selection, this Boeing-built, Langley-managed spacecraft demonstrated the center's ability to supervise a major project with a reasonably small staff. Langley also had fewer cost increases and schedule slips with the orbiter project than JPL had with the lander. That fall, successful tests of parachutes similar to those that would be needed for a landing on Mars also spoke for Langley's technical and managerial capabilities.

In August 1966, the results of an in-house study were presented to the Langley Planetary Missions Technology Steering Committee. Reflecting an increasingly complex series of planetary missions for the 1970s, the study made several recommendations regarding Mars landers: employment of a 5.8-meter conical heatshield, the maximum diameter compatible with the Saturn V launch shroud, to provide the fullest aerodynamic braking; development of a standard cone sized to the largest landers so that only one entry vehicle would have to be developed and flight-qualified; and use of the parachute for additional braking after the heatshield had been discarded and before the retrorockets had been fired. This study report, approved by the steering committee, was a rough outline of how Langley planned to land Voyager on Mars.¹⁵

As a result of Langley's work, Edgar M. Cortright, deputy director of the NASA Headquarters Office of Space Science and Applications, called a meeting for 26 September to discuss that center's role in the Voyager mission.* Earlier that month, a JPL group had described a different approach to landing a spacecraft on Mars. Retrorockets would be actuated at about 6100 meters, continuing to fire through ports in the heatshield until the lander was separated from a protective aeroshell at about 610 meters. Final descent would be slowed by firing the lander engines from 24 to 3 meters. This approach had three major problems: it would be difficult to design ports that would not reduce the effectiveness of the heatshield; the lander and its experiments would have to be protected during separation from the effects of the retrorockets; and, given the unknown density of the Martian atmosphere, the engines would have to have a complicated electronic throttle and carry enough fuel to permit maximum thrust if the density of the atmosphere was at the lower end of the calculated range.

Leonard Roberts described for headquarters Langley's proposed landing techniques, stressing the role of the parachute. The Langley approach had been carefully thought out and analyzed. It was simpler than JPL's approach, more realistic, and practical. Langley's Mars team won their center a major role in the Voyager project—the development of the entry system, or capsule bus as it was called in space engineering jargon.¹⁶

Langley Research Center personnel took part in three kinds of Voyager activities during 1967. Twenty Flight Vehicle Systems Division engineers under Ed Kilgore worked on design aspects of the capsule bus. Nine engineers under David G. Stone, who had replaced Roberts as the focal figure for Voyager after Roberts had transferred to NASA's Ames Research Center, coordinated all project details. Another 60 research engineers were engaged in developing new technology. Both Stone and Kilgore sat on the NASA-wide Voyager Management Committee, but Stone's job brought him into more frequent contact with the other centers.

Jim Martin Joins the Mars Team

On 23 June 1967, Langley Director Floyd Thompson announced the appointment of James S. Martin, Jr., as manager of the capsule bus system, thereby forming a project management organization to control all Voyager-related activities at Langley.

Martin had joined the Langley staff in September 1964 after 22 years with the Republic Aviation Corporation. His experiences as assistant chief technical engineer, chief research engineer, and manager of space systems requirements at Republic, as well as his reputation for troubleshooting and no-nonsense management, had been the major reasons Langley Director

*Oran Nicks and Hearth represented OSSA; Mac C. Adams, OART; Kilgore and McNulty, Langley; and William H. Pickering and senior Voyager staff members, JPL.

Thompson had recruited him for the Lunar Orbiter assistant project manager job. During the nearly three years he had been on the Orbiter team, Martin had further demonstrated his ability to get contractors to meet the schedule and budgetary requirements of Langley's first major space project. By summer 1967, only one Lunar Orbiter* flight remained, and Martin and his teammates could turn their attention to new projects. The Voyager capsule bus system was their high priority item.¹⁷

Martin and five engineers set up the Voyager Capsule Bus Manager's Office in June 1967. Plans called for the remaining Lunar Orbiter staff, about 25 more engineers, to join them in September after their last flight. Martin's approach to managing the capsule bus was structured around his people, who would handle project implementation. Ed Kilgore's team would act as consultants and advisers, tutoring Martin's managers. Stone's work on entry systems was controlled by Martin's use of the budget. Dollars would be allocated for only the activities that he thought were germane to the tasks at hand, and all requests for funds had to be justified to the Management Office.¹⁸

Cancellation

Martin had been at his new tasks for only two months when Voyager was denied further funding by Congress. In the wake of this blow, the Langley Planetary Missions Technology Steering Committee convened a "what-do-we-do-next" meeting on 6 September. Eugene C. Draley, assistant director for flight projects, and former supervisor of Lunar Orbiter in the director's office at Langley, told the nearly 50 persons at the meeting something of the background of Voyager's demise. The Office of Space Science and Applications in Washington had been informed by congressional staff members that NASA's budget cuts had been primarily the result of other higher priority programs, not simply disapproval of Voyager. As a result, headquarters requested JPL, Ames, Langley, and Lewis to help define a more modest planetary program. Draley told his audience that Langley's goal was to have a project concept ready for submission by 1 November 1967, and he asked the Planetary Missions Technology Steering Committee to investigate and recommend scientific objectives for such a new project.¹⁹

Eugene S. Love, chairman of the steering committee, presented a preliminary list of candidate missions. He believed that Mars should continue to be the focus of the agency's interest. "Venus is not nearly so interesting when we consider long term NASA objectives such as ultimately placing men on the surface. In looking at possible unmanned Mars exploration in the 1971-1973 time period at costs much lower than the Voyager concept, a number of approaches are possible." He listed seven of them at the early September meeting:

*The first four Lunar Orbiters had returned several hundred detailed photographs of the lunar surface, which would be used in Apollo landing site selection.

- a) Direct entry probe, no fly-by spacecraft.
- b) Fly-by spacecraft only.
- c) Fly-by spacecraft with entry probe.
- d) Short period orbiter, no entry probe.
- e) Short period orbiter with entry probe.
- f) Long period orbiter, no entry probe.
- g) Long period orbiter, with entry probe.²⁰

All of these alternatives had been considered at one time or another in the course of formulating Mariner and Voyager proposals. In Love's opinion, only the last choice deserved further investigation. "A long period orbiter (a goal covering one complete Martian year) capable of providing color photo mapping of most of the planet's surface over an entire seasonal cycle would provide information of immense and lasting value." The pictures taken during such an orbital mission could be used to compile an atlas that would be of "great value to astronauts in future missions." Scientists would find the images of "inestimable value in assessing past hypotheses and generating new knowledge of the planet." Whereas "color photo mapping of Mars over a seasonal cycle should in itself justify the mission, and should be the primary objective," correlation of the photographs with infrared and radar mapping would yield even greater insights into the nature of the planet.

But orbital photography and scientific measurements, according to Love, were only half the story. "Adequate information on the structure of the Martian atmosphere cannot be obtained from orbit." The addition of a simple entry probe, however, could provide the means for examining the atmosphere and obtaining data essential for refined engineering design of future Martian entry vehicles.

Getting the orbiter and its probe to Mars was still the major problem. Love recommended that "the examination of candidate launch vehicles should be limited to those that are available or will be unquestionably flight proven considerably before the mission time period." He further suggested that the candidate boosters be few.

The initial study activity should progress as follows: (1) definition of the payload capability for a Mars mission for the candidate launch vehicles, (2) choice of the launch vehicle that gives the best overall capability provided costs are reasonably competitive, (3) definition of the fraction of the payload capability that must go into the orbiter, (4) definition of weight remaining that can be allotted to an entry probe, if any.²¹

At the 6 September 1967 gathering of the steering committee, Chairman Love appointed a subcommittee to recommend a list of scientific

objectives for Mars and Venus missions. While the subcommittee deliberated and the committee adjourned for five days, Jim Martin traveled to Pasadena for the sixth meeting of the Voyager Management Committee. Donald P. Heath told the attendees that the Voyager Interim Project Office would be closed out in early October. To make the best use of the information generated by Voyager, Heath laid down an orderly plan for terminating existing work and preparing for a new project.²²

On 11 September, the Langley Planetary Missions Technology Steering Committee met again to discuss the science recommendations. In a fashion reminiscent of earlier JPL reports, the subcommittee emphasized orbiter and probe experiments rather than lander investigations (tables 18 and 19). There was considerable discussion as to the merits of orbiters, probes, and "minimum semihard-landers," and Clifford Nelson requested that a lander not be "locked out" for a 1973 mission. The other attendees agreed, although there was little enthusiasm for sending life-detection experiments to Mars that early. To carry out further study toward a November recommendation to headquarters, Nelson headed a Langley ad hoc study group of 80 engineers divided into 13 working groups.²³

Table 18
Sample Areas of Scientific Interest

1. Orbits	7. Atmosphere
2. Rotation	Constituents
3. Size	Scale height
Mean diameter	Density
Shape	Meteorology
4. Mass	Clouds, winds, temperature
Mean density	Temporal changes
Distribution	8. Surface structure
5. Fields and particles	Topography
Gravitational	Relief, morphology
Magnetic	Cartography
Electric	Temporal changes
Trapped radiation	9. Surface composition, properties
Micrometeoroids	Constituents
6. Ionosphere	Temperature
Existence	Texture
Strength	Radiation
Temporal changes	Albedo and color
	Temporal changes
	10. Internal structure
	Constituents
	Volcanism
	Seismicity

Table 19
Specific Objectives of an Early Mars Orbiter Probe

To obtain maximum coverage of the planet's topography with sufficient resolution to identify major geological structures and features, including distinguishing characteristics, or different planetary areas during seasonal changes.

To obtain topographical data over limited areas with sufficient resolution to provide morphological patterns, evidence of vegetation and volcanic activity, and terrain features of geological interest.

To determine the structure, composition, and temporal changes in the atmosphere.

To obtain information on the gravitational and magnetic fields and radiation and micro-meteoroid environments.

To obtain information on the extent and nature of clouds.

To observe diurnal and seasonal changes in surface temperature.

Alternatives for Planetary Investigation

That fall, NASA Headquarters, Langley, and JPL planetary project planners pursued possible alternatives to Voyager for Mars and Venus missions. In Washington, Cortright and Oran Nicks outlined four planetary options for Administrator James E. Webb, Deputy Administrator Robert C. Seamans, and Associate Administrator for Space Science and Applications Homer E. Newell in late September. Nicks later told Jim Martin that the lack of any comments from the managers at headquarters regarding the briefing indicated to him that Webb was still feeling the pressure of the White House's cost-cutting drive.

At a 9 October presentation for Administrator Webb, space science and applications representatives outlined five possible options they believed would help answer the general question: Should NASA plan any flight missions for planetary exploration in the 1970s? As they saw it, the alternatives included (1) providing no funds for fiscal 1968 and 1969; (2) providing the planetary program with a sufficient budget to "maintain technology and pools of scientific, technical and managerial talent to support" subsequent development of planetary missions after Mariner 1969; (3) establishing two 1972 Mariner flights to Venus and two 1973 Mariner flights to Mars; (4) planning for Voyager flight in 1975 if money was made available in fiscal 1970; or (5) initiating the Voyager program in fiscal 1968 or 1969 with a very small budget aimed at producing an orbital flight in 1973 and a lander mission in 1975 (table 20).²⁴ The space science staff at NASA Headquarters* favored an extension of the Mariner flights (option 3)

*Effective 1 October 1967, Newell became associate administrator. In October, John E. Naugle became head of the Office of Space Science and Applications and Cortright became deputy associate administrator for manned space flight. Nicks filled Cortright's old position as deputy associate administrator for space science and applications, and Hearsh became director of lunar and planetary programs.

Table 20
Post-Voyager Proposals for Planetary Exploration Projects

Jet Propulsion Laboratory (3 October 1967)		Plan 1	Plan 2	Plan 3	Plan 4
1970	Mariner-Venus Mercury 70, Atlas-Centaur, using Mariner Mars 69 equipment.				
1971	Mariner-Mars 71 orbiter (if funding permits).				
1972	Mariner-Venus 72 flyby, 2 probes, Atlas-Centaur.				
1973	Mariner-Mars 73, orbiter-probe, Titan III (2 flights).				
1973	Mariner-Venus-Mercury 73 flyby (if funding permits).				
1974	Mariner-Jupiter 74, flyby, Titan-Centaur.				
1975	Voyager-Mars 75, orbiter-surface laboratory, 2 on 1 Saturn V.				
Langley Research Center (5 October 1967)					
1971	Mars orbiter, Titan IIIC.	1973 Mars orbiter-probe, Titan IIIC (68-kg probe).	1972 Venus orbiter-probe, Titan IIIC (68-kg probe).	1971 Mars orbiter, Atlas-Centaur.	
1972	Venus orbiter-probe, Titan IIIC (68-kg probe).		1973 Mars orbiter-probe, Titan IIIC (136-kg probe).	1973 Mars orbiter-probe, Titan IIIC (181-kg probe).	
1973	Venus orbiter-probe, Titan IIIC (136-kg probe). (Start in spring 1968 at cost of \$893 million, exclusive of launch vehicle.)	(Start in spring 1969 at cost of \$339 million, exclusive of launch vehicle.)	(Start in summer 1968 at cost of \$566 million, exclusive of launch vehicle.)	(Start in spring 1968 at cost of \$378 million, exclusive of launch vehicle.)	

Plan "3-Extended"

- 1975- Soft-landed missions to
1977 Mars with 1180-kg landing
capsule, Titan III-C-
Centaur, 14-kg science
package.
(Start in CY 1971.)
-

NASA Headquarters
(3 & 10 October 1967)

"Plan 5"

Mariner class spacecraft

- 1970 Venus-Mercury flyby, Atlas-Centaur, FY 1969 start.
1971 Mars orbiter, Atlas-Centaur, FY 1969 start; JPL using MM '69
equipment.
1972 Venus orbiter-probe, Titan III, FY 1969 start, Langley.
1973 Mars orbiter-probe, Titan III, FY 1970 start; JPL-developed
spacecraft, Langley-developed probe.

Voyager class spacecraft

- 1975 Mars orbiter, lander, Titan III and Saturn V, FY 1971 start.
1975 Mars lander, Titan III, FY 1972 start.
1975 Mars orbiter-probe, Titan III or Saturn V, FY 1972 start.
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SOURCE: Donald P. Burcham, "Planetary Extension Program (PEP)—Historical Documents (incl. only pertinent Voyager refs.)," 27 Dec. 1967; and J. R. Hall and J. D. Church, "Schedule and Cost Analysis of Selected Planetary Programs," 5 Oct. 1967.

with plans for work on a mission like Voyager (option 4) to begin in 1970. No budget, or a very small one for 1968 and 1969 (options 1 and 2), would seriously affect the continuation of JPL's work for the space agency. In fact, the first option would have reportedly required "the phase out of JPL after Mariner 69, the loss of the scientific support presently being provided to the planetary program, termination of all contractor efforts and the reassignment of all in-house personnel to other agency programs." Choice number 5 was equally unsatisfactory because the projected costs were too high. But a combination of options 3 and 4 might "provide for continuation of the planetary exploration (without a Voyager commitment) at a reduced level and more effectively use the scientists, engineers, and administrative personnel by focusing their activities at specific missions which incorporate the technologies required for future detailed exploration of the planets."²⁵

Combined options 3 and 4 became known as "Plan 5," or the Planetary Extension program. While there were no commitments to specific flights beyond Mariner 69, the managers did have a "wish list" ready if more money became available. Plan 5 was an attempt to keep the planetary team intact by focusing "new technologies (flyby, orbiter, probe and lander) activities toward classes of missions (Venus, Mars, Jupiter and Mercury) and various launch vehicles." This proposal would give the agency a flexibility in choosing future missions, provide a realistic environment for engineers carrying out mission studies, and build a planetary program data bank of mission concepts, technology, and scientific experimental techniques within the limits of current budgets. The agency would use its "supporting research and technology" (SR&T) monies to underwrite technical studies that would permit centers to undertake new projects at some later date without wasting time or talents. Use of SR&T funds would not constitute a new programmatic start, which Congress had banned.²⁶

By early November 1967, less than two weeks after Congress had canceled Voyager, Administrator Webb was ready to propose a revised planetary program. His opportunity came during congressional hearings on NASA's proposed operating plan for fiscal 1968. He responded to the inevitable question from Sen. Margaret Chase Smith regarding what the agency planned to do in the field of planetary investigation. The Office of Space Science and Applications was proposing five new Mariner missions (1971-1976), a Voyager-style flight to Mars with two orbiters and two small probes for 1973, and a more ambitious soft-lander expedition for 1975. The 1971 Mariner flight, launched by an Atlas-Centaur, would be a long-term orbiter to make extensive observations of Mars. It would replace the 1971 Mariner proposed earlier by NASA, a flyby craft with a small atmospheric probe. Without the expense of developing that probe, NASA planners expected that the new 1971 Mariner mission would be more economical; they also would use equipment left over from the 1969 Mariner project. The other Mariner flights Webb specifically mentioned to Congress were to Venus in 1972 and 1973 using the Air Force Titan IIC launch vehicle. The

revised Voyager for 1973 had been scaled down so that it could be launched by Titan, as well, rather than by Saturn V, which would cost 10 times as much. However, the 1975 Voyager-style mission was still geared to Saturn.

Webb told the senators that "the conclusion of Mariner V, Lunar Orbiter, Surveyor and deferral of Voyager . . . all occur at the same time—the end of this year." He noted that the decision on the 1969 budget would determine if "these teams, representing an estimated 20,000 to 30,000 man-years of experience, are to be disbanded. Together they have launched 16 spacecraft toward the moon and the planets. It cost over \$700 million to do the work represented by their competence." While NASA could use SR&T funds during 1968 "to hold a limited portion of this competence together," Webb stressed that "the President's decision on the 1969 budget and further consultations with this and other committees of Congress will guide our reprogramming action."²⁷

Webb's "bold" step toward maintaining NASA's planetary program was influenced by several factors. The principal sources for financing any new planetary efforts were funds that could not be spent on the Apollo Applications Program (AAP). Conceived as a means of exploiting Apollo-developed technology for various manned earth-orbital and extended lunar-based missions, the Apollo Applications Program had also been cut by Congress during the 1968 budget deliberations—from a request of \$454.7 million to an appropriation of \$315.5 million. Since the number of Apollo applications flights had been sharply reduced and no flights were scheduled before 1970, Webb could argue for more planetary missions without necessarily seeking an overall increase in NASA funds. This proposed alteration of planetary priorities would require overcoming resistance at the White House and the Bureau of the Budget and on Capitol Hill. But Webb believed that space science was a timely and worthwhile cause for which the agency should fight.²⁸

As Webb and his headquarters managers prepared for the fiscal 1969 budget process, the centers began to work on plans for executing new planetary missions should the money be made available.²⁹ JPL was assigned management responsibility for the two Mariner Mars 1971 orbiters, and Langley was directed to manage the Titan Voyager Orbiter 1973 project, which became known as Titan Mars 1973 Orbiter and Lander. On 29 January 1968, President Johnson assured these projects their survival when he said in his budget address to Congress, "We will not abandon the field of planetary exploration." He recommended the "development of a new spacecraft for launch in 1973 to orbit and land on Mars." The new Mars mission would cost "much less than half the Voyager Program included in last year's Budget." Johnson went on: "Although the scientific results of this new mission will be less than that of Voyager it will still provide extremely valuable data and serve as a building block for planetary exploration systems in the future." Although Webb still viewed this new planetary activity as austere, he was glad to see it gain the support of the president.³⁰

ON MARS

In a press conference on the budget, John E. Naugle, the new associate administrator for space science and applications, noted that this Mars exploration program would cost about \$500 million, rather than the \$2400 million for Voyager. Further, "This program of four orbiters and two landers . . . is a minimum program consistent with the need to maintain expenditures at a minimum. Nevertheless, when you compare it to the automated lunar exploration program we have just completed, we think it is an extremely good and sound program." When asked about experiments, Naugle indicated that this topic was still under study. Landed television pictures had a high priority, as did measuring atmospheric pressure and meteorological changes such as wind velocity. Don Hearth predicted a 90-day orbital lifetime for the 1971 orbiters and 180 days for the 1973 craft. But he added, "Bear in mind that *Mariner IV* lasted for three years. So these numbers could be very pessimistic." Hard-landers weighing 360 kilograms were being contemplated for the later mission, which meant that about 10 kilograms of scientific instruments could be landed. This payload was about half the projected instrumented payload for *Mariner B* in 1961.³¹ Though austere, Titan Mars 1973 might actually have the chance to fly (tables 21 and 22).

Titan Mars 1973

Getting a start on a new series of planetary flights was just a first step on a long road. To get Langley and JPL going, Naugle asked them on 9

Table 21
Estimated Costs for Mars Program
(January 1968, in millions)

	FY 1968	FY 1969	FY 1970	Total All Years
Spacecraft:				
Mariner Mars 69	\$59.2	\$30.0	\$ 5.0	\$125.0
Mariner Mars 71	—	18.0	40.0	86.0
Titan Mars 73	—	20.0	50.0	347.0
Launch Vehicle:				
1969 (Atlas-Centaurs)	8.0	3.2	—	20.0
1971 (Atlas-Centaurs)	—	3.4	13.0	20.0
1973 (Titan IIC)	—	—	—	38.4
Nonrecurring costs for Titan III-Centaur ≈ \$30.0				

SOURCE: Donald P. Hearth, 30 Jan. 1968.

REORGANIZATION AND VIKING

Table 22
Mars Program

(January 1968)

Year	Mission	Spacecraft Weight (kg)
1964	<i>Mariner 4</i>	Flyby (1) 260
1969	Mariner Mars 69	Flyby (2) 385
1971	Mariner Mars 71	Orbiter (2) ^a 410 (useful ^b)
1973	Titan Mars 73	Orbiter (2) ^c (Science instruments) 75 Lander (2) (Science instruments on surface) 365 (total) 14
	<i>Voyager (for comparison)</i>	Orbiter (2) (Science instruments) 230 Lander (2) (Science instruments on surface) 2700 (total) 75

Weight Summary

1971	Mariner Mars 71	Useful orbiter Propulsion Total gross weight at Mars Atlas-Centaur capability	410 <u>455</u> 865 910
1973	Titan Mars 73	Useful orbiter Lander Propulsion (orbit insertion) Total gross weight Titan IIC capability Titan-Centaur capability Titan IIC—dual burn of spacecraft propulsion	455 365 <u>725</u> 1545 c.1130 c.4100 c.2540

^a 1971 orbiter a modification of 1969 flyby.

^b Spacecraft weight without propellant.

^c 1973 orbiter same as 1971 except as modified to support lander.

SOURCE: Donald P. Heath, notes, 30 Jan. 1968.

ON MARS

February 1968 for a study of Titan III-class missions to Mars for 1973. "The objective of this study is to evaluate the baseline mission submitted to the Congress . . . together with all promising alternatives, to permit a mission definition for the 1973 opportunity." Langley's work in fiscal year 1968 was "intended to advance the state of the art of such potential missions and will not be directed at a specific flight project until such a project is authorized by the administrator." The baseline mission included:

1. Two launches in 1973.
2. Launch vehicle to be either a Titan III [D]/Centaur or a Titan III with multiburn spacecraft propulsion for interplanetary injection as well as orbit insertion.
3. Each launch vehicle to carry a Mariner 71 class orbiter and a rough-landing capsule. The capsule may . . . enter the Mars atmosphere [either] directly or from orbit.
4. The 1973 mission is constrained to a total program cost of \$385 M[illion], including launch vehicles. This is believed to be consistent with the use of a minimum-modified Mariner 71 orbiter and an 800 pound [360-kilogram] class rough lander. . . .
5. The science objectives should include the following:
 - A. Orbiter: Carry payload similar to Mariner 71.
 - B. Entry vehicle: Measure atmospheric temperature, pressure, composition, and 3-axis acceleration.
 - C. Lander: Transmit limited imagery and measure atmospheric temperature, pressure, wind, soil composition, and subsurface moisture.

The science objectives of a Mars lander mission would have to be tailored to fit physical and budgetary limitations. Naugle asked the people at Langley to consider two alternative missions:

1. Hard-landers, with or without orbiters, direct entry, or out-of-orbit entry.
2. Soft-landers, with or without orbiters, direct entry, or out-of-orbit entry.

Project management was assigned to the Langley Research Center. JPL would provide assistance in such areas as system management of the orbiter or the lander.³²

The 1973 Mars Mission Project Office under Jim Martin's direction prepared statements of work and awarded study contracts to industry. These studies concentrated on aspects of the "mission-mode" question. General Electric examined the hard-lander possibility; McDonnell Douglas investigated a soft-lander option; and Martin Marietta looked into the virtues of direct versus out-of-orbit entry for the landers. Martin's staff worked with

JPL to ensure the laboratory's support of the orbiter portion of the Mars mission.³³

PROBLEMS—MANAGEMENT ASSIGNMENTS AND BUDGETS

During the spring and summer of 1968, Don Hearth at NASA Headquarters and Jim Martin at Langley wrestled with two familiar problems—project management and project budgets. The Jet Propulsion Laboratory management still wanted to control such planetary missions as Titan Mars 73. And the 1968 debates over the fiscal year 1969 budget were threatening the agency's Mars lander goals.

JPL Director Pickering began a high-level management debate in April 1968 with a letter to Charles Donlan, the acting director at Langley.* After cordial comments about the "excellent working relationships" being established between JPL and Langley, Pickering went on to say that his organization agreed with "the previous position taken by LaRC [Langley] representatives relative to Voyager, namely that Project Management and Orbiter System Management should be the responsibility of a single center because the total mission design is so tightly coupled to the Orbiter System functions of acquiring scientific data and transporting an entry-lander to acceptable release conditions." To conform with this management concept, Pickering thought it might be wise to assign "both Project management and Orbiter System management responsibilities to JPL, particularly in follow-up of the Mariner Mars 71 Project." A second alternative would assign project and orbiter management to Langley, with JPL providing "Project-level missions support and Entry-Lander System management." With either approach, Pickering believed his team in Pasadena was the one that should work with Langley in managing the 1973 Mars lander mission.³⁴

Eugene Draley, Langley assistant director for flight projects, recorded in a memo for the record that JPL seemed to prefer working on the lander rather than on the orbiter, but Jim Martin's proposed management did not agree with JPL's suggestions. Langley wanted to oversee the project and the development of the lander with JPL supervising the work on the orbiter, which would evolve from the 1971 Mariner orbiter.³⁵ While sympathetic to the merits of JPL's alternatives, the Langley team wanted to pursue its proposed management scheme for several specific reasons. First, an anticipated tight budget for the 1973 mission required NASA to keep the modifications of the Mariner 71 orbiter to a minimum. Since JPL was responsible for that project, it seemed logical from the standpoint of continuity and cost-effectiveness that the Pasadena facility adapt the 1971 orbiter

*Former Langley Director Floyd Thompson had been appointed special assistant to Administrator Webb to evaluate future manned space programs in February 1968. He was scheduled to retire at age 70 in November. Edgar M. Cortright became Langley director on 1 May. Donlan was acting director in the interim.

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for the 1973 flight. If Langley were to manage the orbiter, the technological and fiscal risk would increase, since the essential experience and important test equipment were at JPL. Additionally, Langley would have to hire more personnel at an increased cost to the project. Second, the Langley managers believed that their center had entry expertise and other technological experience that would permit them to carry out the lander part of the project more successfully than JPL. Although the California laboratory could claim abilities in this area based on experience with the Surveyor lunar lander, Langley's planners insisted on managing both the overall project and the lander.

Langley's people, having worked hard on planning for a mission to Mars, believed they had won the right to manage the project. Development of the lander was a technological challenge, and they wanted to meet it. According to the planetary experts in Virginia, the lander was important for a host of reasons:

- Landed science remaining pioneering task for Mars exploration.
- Entry science is a new frontier in the Mars exploration program.
- Lander science accorded high priority in 73 mission by [President's Science Advisory Committee] and [Bureau of the Budget] because M71 [Mariner 71] will have accomplished prime orbital science objectives.
- Lander objectives are forcing function in mission design and operations.
- Entry-Lander most challenging technical task of 73 mission.
- 2/3 of variable \$ will be spent on lander.

In addition, three other considerations led the Langley people to believe that they should manage the 1973 project. They believed they had a better understanding of experiments that should be carried aboard a Mars lander. Equally important, they argued that Langley needed the management of a major project for the prestige it would bring the center and for developing their management skills.³⁶

The management issue was resolved at a May meeting between representatives of Langley and JPL, where after a detailed discussion the laboratory participants agreed to the Langley proposal. In an attempt to improve communications between the two teams, a Mission Design Steering Committee was established, with members from the project management office and from the four major system areas—orbiter, lander, launch vehicle, and tracking and data acquisition. Jim Martin was chairman, with Israel Taback representing the lander system, J. L. Kramer of Lewis acting as launch vehicle delegate, and JPL employees Charles W. Cole and Nicholas A. Renzetti temporarily serving as orbiter and tracking and data acquisition specialists. Walter Jakobowski represented the headquarters Office of Space Science and Applications.³⁷ Concurrent with the formation of the intercen-

ter design committee, Cortright redesignated Langley's Lunar Orbiter Project Office the Advanced Space Flight Projects Office. The director chose this broad title as "a hedge against the Mars mission getting scrubbed."

As the Mission Design Steering Committee set up working groups to address specific technical topics, renewed budgetary battles were being fought in Washington during the fall of 1968. The Bureau of the Budget cut NASA's initial request by about \$1 billion before it went to Congress. Compared to the preceding years, the lunar and planetary proposal was lean, but then so was the total research and development figure—\$3.677 billion for fiscal 1969, dropping from budget plans of \$3.970 and \$4.175 billion for fiscal 1968 and 1967.³⁸

Table 23
Lunar and Planetary Exploration Budget Plan, FY 1969

(in thousands)

Budget Item	FY 1967	FY 1968	FY 1969
Lunar and Planetary Exploration	\$184 150	\$141 500	\$107 300
Supporting research and technology/advanced studies	22 350	19 800	30 000
Advanced planetary mission technology	—	12 000	6 700
Data analysis	—	600	2 600
Surveyor	79 942	35 600	—
Lunar orbiter	26 000	9 500	—
Mariner IV and V	13 058	3 800	—
Mariner Mars 1969	30 130	59 200	30 000
Mariner Mars 1971	—	—	18 000
Titan Mars 1973	—	—	20 000
Voyager	12 670	1 000	—

SOURCE: NASA, "Background Material, NASA FY 1969 Budget Briefing," news release, 29 Jan. 1968.

For whatever consolation it offered, NASA managers and engineers knew that the space agency was not the only organization suffering budget cutbacks. Federally funded science and technology faced bleak times generally. At the beginning of February 1968, the journal *Science* reported, "A scientific community that is already in a state of alarm over a tightening of federal funds in the current fiscal year will find scant cause for rejoicing in the budget that President Johnson presented to the Congress this week." The Johnson administration proposed a five percent increase over fiscal 1968, which would, given inflation and other factors, only keep programs even with the preceding year's levels. The *Science* article concluded that the lesson seemed clear—"there's a long and rocky road between proposing a budget and actually rendering support to the scientist at the bench." NASA's road looked particularly rough, since apparently only two-thirds of the dollars requested for space activities would be appropriated.³⁹

On 2 May, the House of Representatives accepted reductions recommended by the Science and Astronautics Committee and made additional cuts before voting 262 to 105 for the FY 1969 space authorization bill. The approved amount, \$4 031 423 000, was \$1 billion less than NASA had originally proposed to the Bureau of the Budget and about \$370 million below the budget submitted to Congress. On 21 May, the Senate Committee on Aeronautical and Space Sciences lopped an additional \$27.35 million from NASA's request. The amount finally approved by conference committee in October 1968 was \$3.7003 billion.⁴⁰

While waiting for final action on their appropriations bill, NASA officials worked up an interim operations plan based on anticipated reductions. Under the interim plan, work on Apollo, aeronautics, and space applications would proceed at the authorized levels. Activity in other areas would be adjusted, meaning there would be additional personnel cutbacks, with civil service ranks being reduced by 1600 persons and support contractor numbers by at least 2000. Personnel reductions would hit new programs the hardest, since agency leaders believed that Apollo and other ongoing programs could not be pared any further if they were to be executed successfully and on schedule.

Apollo Applications, Titan Mars 73, Saturn launch vehicle development, and the nuclear propulsion program, NERVA, were among the projects most affected by the budget crunch. The Apollo Applications Program would receive about \$140 million of the \$440 million requested. Only one Saturn IB Workshop would be flown, with an Apollo Telescope Mount. With the exception of the backup launch vehicle and workshop, production on Saturn IB and Saturn V boosters would be terminated. Only 15 giant Saturns would be produced instead of the projected 19. NERVA was once again delayed, with only limited development approved. The plans for a Mars 1973 mission were revised "to conform to sharply reduced funding in FY 1969. The instrumentation to be landed on Mars and the scientific return will be substantially less than in the program presented in the FY 1969 budget."⁴¹ As Don Heath and his colleagues juggled the various options so that money, limited as it was, could be made available for the 1969, 1971, and 1973 missions, the space agency was mustering outside support for these projects.⁴²

SUPPORT FOR MARS EXPLORATION

Since the winter of 1967, Administrator Webb and others at NASA Headquarters had been generating support for a post-Voyager planetary program from two groups—the Space Science Board of the Academy of Sciences; and the Lunar and Planetary Missions Board, an internal NASA advisory board. The Space Science Board provided high-level endorsement and advocacy for continued planetary exploration, and the Lunar and Planetary Missions Board gave the agency more detailed scrutiny of its planning, especially as it affected the selection of scientific experiments.

From both, NASA managers sought support that would help counter the budget-cutting proclivities of Congress.

Space Science Board, 1967-1968

Harry Hess, chairman of the Space Science Board, wrote Jim Webb in November 1967 after a briefing on the planetary program by John Naugle: "... the Space Science Board met last week and ... expressed its deep concern over the weakness of the whole NASA science program and the planetary program in particular." Reductions in the NASA budget had led to greater cuts in money for space science, which in turn meant "a loss of some 50 to 75 percent in terms of effective research results." Hess was writing Webb at this particular time because the Space Science Board wanted to have an influence on the agency's planning process. At a time when NASA was cutting back its planetary launches, it was "fairly evident that the Soviets [would] have flights to Mars and Venus at every opportunity as they have had for the last few years." And as the 1967 *Venera 4* mission to Venus had demonstrated, "these are apt to be successes."* The Soviet Union had a "highly successful planetary lander" and, as Hess reminded Webb, "we don't even have one planned in the period to 1975." Unmanned planetary exploration was apparently going to be one of the major USSR space endeavors, and "great discoveries in this area can only be made once. Shall succeeding generations look back on the early 1970's as the great era of Soviet achievement while we did not accept the challenge?"⁴³

Hess and his colleagues did not wish to see the U.S. fall behind the Soviet Union. They recommended increased space science activities and a reduction of manned projects like the orbital workshop of the Apollo Applications Program. A planetary science program should take precedence over other NASA activities. These themes were repeated in December 1967, with emphasis on the newly created Mariner and Titan-class Mars spacecraft. While differing in details—the board favored more Venus research—the Space Science Board proposals were basically supportive of NASA's wishes to maintain a planetary exploration program.⁴⁴

The Space Science Board pursued its recommendations with a week-long summer study in June 1968 and published its findings under the title *Planetary Exploration 1968-1975* (see appendix D).⁴⁵ While helpful in that they pushed for more planetary missions, the board's proposals were also

*Evaluations of *Venera 4* were mixed. Entering the atmosphere of Venus early on the morning of 18 October 1967, the landing capsule touched down in a purported soft landing about two hours later. According to Soviet scientists, the atmosphere as measured by the instruments was almost entirely CO₂ with traces of oxygen, water vapor, and no nitrogen. The temperature range was from 40° to 280°C. Atmospheric pressure was 18 times that on Earth. *Venera 4* stopped transmitting data shortly after landing. The Soviet information did not agree with evidence provided by *Mariner 5* or Earth-based radio astronomical measurements. *Venera 4* probably stopped transmitting at an altitude of about 26 kilometers, as the surface pressure is more on the order of 100 times that of Earth's and the temperature at the surface is about 400°C. After a short time, the Soviets stopped claiming that their spacecraft had actually landed on the Venusian surface.

somewhat detrimental, since they did not coincide exactly with the agency's announced goals. In times of extreme congressional scrutiny, Webb and his colleagues at NASA would prefer more closely orchestrated advice. Another source of advice was the Lunar and Planetary Missions Board.

Lunar and Planetary Missions Board, 1968

To overcome the shortcomings of the President's Science Advisory Committee and the Space Science Board, the Lunar and Planetary Missions Board was established in 1967 to provide NASA with detailed critiques of its proposed missions from a scientist's point of view. But even quasi-internal criticism was sometimes difficult to accept. As the space agency was to learn, scientists tended to be of an independent mind, and their comments often cut more deeply than Webb and his associates would have liked. In fact, this particular group had grown out of a need to resolve conflicts between the space agency and outside scientists.

In January 1966, Webb had invited Norman F. Ramsey, professor of physics at Harvard, to form a panel to investigate NASA's relations with the larger scientific community. The administrator wanted advice on several quite specific issues: evaluation of the Space Science Board's 1965 summer study recommendations on an Automated Biological Laboratories Program, suggestions for a post-Apollo lunar exploration program, and comments on a National Space Astronomy Observatory. Webb was also interested in determining how he might increase scientific participation, confidence, and support for the American space program. As he expressed it to Ramsey, "We in NASA think it is essential that competent scientists at academic institutions participate fully in the next generation of space projects and we believe that we will need new policies and procedures and perhaps new organizational arrangements in order to enable them to participate."⁴⁶

Ramsey's panel responded in August with a series of proposals that would have profoundly altered the organizational structure of the space agency. The scientists were particularly critical of what they saw as NASA's emphasis on engineering at the expense of basic scientific research, citing the "overriding priority of engineering problems associated with launch schedules," which interfered with academic experimenters' control over their payload design. More attention needed to be given to purely scientific concerns: "The time is surely here when we must define maximum success in terms not only of 'getting there' but in terms of scientific accomplishment." Now that the space program had "matured," Ramsey's panel believed that major organizational changes were necessary. Reviving the idea of a general advisory council of scientists to help formulate NASA policy, the group also wanted to reorganize the field centers to give experimenters a greater voice and create a Planetary and Lunar Missions Board that would advise NASA on future Apollo flights and post-Apollo goals.⁴⁷

Jim Webb did not take kindly to most of these recommendations, and at an oral presentation of their suggestions he asked the scientists if they understood the real world of Washington politics. Did they realize that NASA was just a part of a larger governmental, economic, social system and as such could not yield to their demands? NASA's official response, drafted by Homer Newell, was made public about a year later, in June 1967. In a point-by-point critique of the Ramsey report, the agency rejected nearly all of the proposals. A general advisory council was out of the question; certain functions "must clearly . . . remain the responsibility of the Administrator." A permanent advisory body would "blur the lines of authority within the agency." Only the missions board recommendation was accepted, and it was diluted considerably.⁴⁸

Tentatively approved by NASA before the publication of the Ramsey report, the missions board would, in Webb's mind, be a full-time working organization rather than a part-time group of advisers. Each member would be expected to fight for his ideas in a competitive arena instead of pontificating from the cathedral. The term of membership would be limited. By the spring of 1967, the Lunar and Planetary Missions Board, with carefully delineated powers, was in operation. Acting in only an advisory capacity, the board could make proposals to NASA, but the agency reserved the right to reject or accept the advice. The associate administrator for space science and applications, Newell and later Naugle, provided the funds for the board's operations and drew up the questions it was to address itself to. Quite clearly, the administration of NASA did not want the missions board to grow into a general advisory council.

Within this restricted framework, the board had reasonable freedom. NASA granted its members access to internal agency documents, a privilege that the Space Science Board had been denied, and members were permitted to attend major NASA reviews and coordination meetings related to lunar and planetary exploration. Unlike earlier advisory bodies, the Lunar and Planetary Missions Board was asked to evaluate both general and specific objectives. Therefore, it would not only review the "general strategy for manned and unmanned" missions as the President's Advisory Committee and the Space Science Board had done, but also participate "in the formulation of guidelines and specific recommendations for the design of missions and for the scientific payloads to be carried on these missions."⁴⁹

Of the 18 original members* most were familiar faces to NASA's planetary specialists. Twelve were members of the National Academy of Sciences, five were on the Space Science Board, one served on the President's Science Advisory Committee, and four had been on the Ramsey panel. Of the academic scientists, all were full professors, and two were department

*J. W. Findlay, chairman, J. R. Arnold, A. F. Donovan, V. R. Eshleman, T. Gold, C. Goodman, J. S. Hall, H. H. Hess, F. S. Johnson, J. Lederberg, L. Lees, G. J. F. MacDonald, G. C. Pimentel, C. S. Pittendrigh, F. Press, E. M. Shoemaker, J. A. Van Allen, and W. V. Vishniac.

chairmen. Of the nonacademic, two were administrators of research institutes, and the third was vice president of an aerospace corporation. These established professionals were charged with widening NASA's contacts with the scientific community.⁵⁰

Although the missions board never proposed a single comprehensive plan for space exploration, its members did try to bring greater cohesion to NASA's efforts. They wished to avoid a series of disconnected projects; their goal was an orderly exploration of the solar system. They wanted to balance lunar and planetary projects so that one mission would not be pursued or funded at the expense of another. Achieving such goals was at best difficult. As scientists, they favored projects that emphasized science, flexibility in experiment planning, and year-to-year funding of research rather than mission-to-mission budgeting. They also wanted a continuing voice in experiment development, and they fought against one particular attitude prevalent in NASA centers: "Tell us what the experiment is to do, and we will build it, fly it, and deliver the data to the experimenter after it has been collected." As a committee headed by Wolf Vishniac reported in July 1967, "It must be recognized that a proposal of an experiment can no longer remain a one-way street. . . . A continuing dialogue and profound involvement of the scientist with NASA centers is required." According to the scientists, engineers responsible for overseeing instrument development must recognize that they must obtain the scientist's approval at each stage of design, development, and fabrication and his consent for changes.⁵¹ A major recurring theme in the mission board's reports and recommendations was the primacy of purely scientific considerations. The board, in insisting that its recommendations be followed without deviation, failed to acknowledge the realities of the political context in which NASA operated: scientists were but one of many constituents to whom the space agency had to answer.

When President Johnson and Congress dropped their support of the Voyager missions in 1967, the board was, of course, dismayed, but it supported NASA's attempts to pick up the pieces and create a new approach to planetary exploration.⁵² Unfortunately, the debate over what would replace Voyager gave way to friction among the mission board members and ultimately between the board and NASA. At the heart of the dispute was Administrator Webb's rejection of the board's alternative planetary program. Dollar, manpower, and facility limitations would just not permit it. Several members of the board, Wolf Vishniac, Gordon J. F. MacDonald, and Lester Lees among them, believed that their leader, John W. Findlay, had yielded to pressure from NASA to water down their recommendations. When the board's ideal, balanced, coherent planetary program clashed with dollar realities, the dream was shattered and the cordial relationship with the space agency was bruised. Many scientists regarded this affair as additional evidence that NASA still maintained its old attitude toward advisory groups—accept only that advice that meets its needs.⁵³

Although additional conflicts would surely come up in the future, the Lunar and Planetary Missions Board decided to resume normal operations in early 1968. Five working groups were formed—the lunar, Mercury, Venus, Mars, and Jupiter panels. George C. Pimentel, professor of chemistry at the University of California at Berkeley directed the Mars group.* A series of comments was elicited from that group during a familiarization briefing of Titan Mars 73 held at NASA Headquarters on 24 May 1968. All members of the Mars panel agreed that the lander was more important than the orbiter but that too much emphasis was being given to relaying television pictures from the landed craft. The main value of “lander imagery” was to define the landing site, geologically and topographically. Television could tell them what the terrain looked like and how the lander was situated, but it was a supportive activity rather than a prime experiment. The prime experiment, of course, was life detection, but thus far NASA had not included any biological or biochemical experiments in the science requirements for Titan Mars 73. Other lander experiments the panel suggested included mass spectrometry for determining atmospheric composition, x-ray fluorescent examination of soil composition, and determination of subsurface water vapor. The scientists agreed that meteorological experiments should also be examined, and Wolf Vishniac reported that lightweight (one-half-kilogram) life-detection instruments were already available but that they all had the common shortcoming of inadequate sample-gathering capabilities. Of additional concern to the Mars panel, the members considered the question of landing sites (preferably seasonally active ones), the evolution of suitable orbiters, lander lifetime, and the possibility that the Soviet Union would land a spacecraft on Mars in 1973 after sending an atmospheric probe in 1969.⁵⁴

After studying the topic for the entire summer, the Mars panel delivered its report on the scientific objectives for a 1973 Mars mission.⁵⁵ Building on the technical studies carried out at Langley and JPL, the panel reaffirmed the importance of a lander for the 1973 flight large enough to carry a meaningful complement of experiments. The group recommended using the Titan IIID-Centaur launch vehicle. Objectives of a lander-oriented mission should include investigation of the Martian atmosphere and surface, especially temperature and moisture variation and distribution patterns and diurnal and seasonal changes in temperature and moisture, since these factors would provide information that would affect the possibility of life on the planet. Although the Mars panel favored including an orbiter in the 1973 mission, a survivable lander was the more important issue. A soft-lander was favored over a hard-lander if the problem of contaminating the landing site by retrorockets could be solved. A soft-lander would permit selection from a wider range of experiments, not just the

G. C. Pimentel, chairman, J. S. Hall, W. Vishniac, M. B. McElroy, J. R. Arnold, and L. Lees made up the panel.

choice of the most robust equipment. Foremost among experiments were life-detection devices. "The lander should include an ensemble of complementing experiments relevant to the possible existence of life on Mars, since no single experiment is either completely definitive or unambiguous." Coupled but dissimilar experiments would be one satisfactory approach, such as a mass spectrometer that could detect carbon-containing compounds and a life detector that could search for signs of growing organisms with a carbon base.

In closing their report, the scientists noted that "the current plans of the Langley team are in general harmony with [our] recommendations and they have evolved in a manner evidently responsive to earlier suggestions" by the panel and the missions board. Jim Martin and his Langley team had worked closely with the scientific community and for the time being their effort had paid off with strong support for their plans for the 1973 mission. At the October 1968 meeting of the Lunar and Planetary Missions Board, the Mars panel report was officially approved with only minor alterations. The next big step was defining the mission mode—direct or out-of-orbit entry; hard-lander or soft-lander.⁵⁶

THE MISSION MODE DECISION

An intensive series of meetings was held at Langley in late October and early November 1968. Part of the mission definition process, the two-week session was under the leadership of Jim Martin. Besides Langley's Titan Mars team, John Naugle, Ed Cortright, William Pickering, Don Hearsh, and other senior staff members from headquarters, Langley, and JPL were there. The first week was set aside for contractors, as Hughes, McDonnell, General Electric, Boeing, the Martin Company, and JPL presented their reports and mission recommendations.⁵⁷ During the second week's internal agency deliberations, the Mars 73 team summarized the contractor reports and outlined the possible options:

- Launch Vehicle (Titan III-C or Titan Centaur)
- Support Module (Orbiter or Flyby)
- Entry Mode (Direct or Orbital)
- Lander (Hard or Soft, 3-Day Life or Extended Life)
- Launch Mode if orbiter selected (Combined or Separate)⁵⁸

Viewed dispassionately, it was generally agreed, all the alternatives were technically feasible, but the real question centered on what NASA could afford and realistically recommend to Congress.

Jim Martin's team presented two mission mode alternatives to the NASA managers—(1) a Titan IIC-powered direct-entry hard-lander with a flyby module, or (2) a Titan-Centaur-boosted orbital-release soft-lander

Table 24
20 Alternative Mission Modes Examined for Viking 73

Launch Vehicle	Delivery Mode	Lander	Lifetime	Support Module
Titan IIIC	Out-of-Orbit	Soft	Extended	Autonomous
Titan IIIC	Direct	Hard	3-day	Flyby
Titan IIIC	Direct	Soft	3-day	Flyby
Titan IIIC	Direct	Soft	Extended	Autonomous
Titan IIIC	Direct	Hard	Extended	Flyby
Titan IIIC	Direct	Hard	3-day	Flyby (unfueled Mars 71)
Titan IIIC	Direct	Soft	Extended	Flyby
Titan-Centaur	Direct	Hard	3-day	Orbiter
Titan-Centaur	Direct	Soft	3-day	Orbiter
Titan-Centaur	Direct	Hard	Extended	Orbiter
Titan-Centaur	Out-of-Orbit	Hard	3-day	Orbiter
Titan-Centaur	Out-of-Orbit	Soft	3-day	Orbiter
Titan-Centaur	Direct	Soft	Extended	Orbiter
Titan-Centaur	Out-of-Orbit	Hard	Extended	Orbiter
Titan-Centaur	Out-of-Orbit	Soft	Extended	Orbiter
Separate launches for orbiters and landers with Titan IIIC	Direct	Hard	3-day	Flyby
	Direct	Soft	3-day	Flyby
	Direct	Soft	Extended	Autonomous
	Direct	Hard	Extended	Flyby
	Direct	Soft	Extended	Flyby

SOURCE: W. I. Watson, "Viking Project Phase B Report," M73-110-0 [circa Nov. 1968], pp. 7-8.

with extended life and an orbiter with a science package. Given expectations at the start of the meeting, the first option was the mission Martin's people expected to get; the second was the one they really wanted. All of the possible mission configurations were debated in an executive session on 9 November. Don Hearth and Robert S. Kramer discussed the dollar implications of the different missions, and Hearth noted that the out-of-orbit mission, at \$39 million for fiscal 1970, would cost \$10 million more than the first fiscal year than the direct-entry mission.

Cortright spoke on behalf of a soft landing since the hard-lander apparently could not carry enough science for a realistic mission. He noted that the Langley senior staff preferred the Titan IIIC direct mission, as it was

Table 25
Viking Mission Modes
Examined at 8-9 November 1968 Briefing

Launch Vehicle	Support for Cruise and Relay	Entry Delivery System	Lander
Titan IIIC	Flyby modules New Spinner Stabilized Mars 71 (unfueled)	Direct: Spinning Stabilized Lifting Nonlifting	Hard: Limited life, relay only Limited life relay plus direct link Extended life replay plus direct link
Titan III-Centaur	Orbiters New Spinner Stabilized Mars 71 Minor modification Major modification for orbital entry	Orbital: Spinning Stabilized	Soft: Limited life, relay only Limited life replay plus direct link Extended life, relay plus direct link Other: Autonomous capsules

If no orbiter above is chosen:

Orbiter flown for orbital science	Orbiter flown for orbital science and as relay for lander	Separate launch
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SOURCE: Langley Research Center, "Titan Mars 73 Mission Mode Briefing," 7-8 Nov. 1968, p. 16.

the most cost-effective and manageable approach and it met scientific needs. With no orbiter to worry about, Langley could concentrate its efforts on the lander. Although a Titan-Centaur orbiter-lander mission would benefit from Mariner technology Cortright did not believe that the smaller lander dispersions—offering more control over the area in which the lander would touch down—promised from such a mission were a significant enough advantage to merit the cost. The addition of an orbiter to the package would not prove a face-saving element should the lander fail, since the lander represented 80 to 90 percent of the project. While the orbiter-lander combination would provide the most scientific information, it was also the most costly and the most complex alternative, both technically and organizationally. Looking at the amount of data that would be returned, Cortright noted that Surveyor had provided over 10 000 photographs, but it had been the first few that had provided the biggest payoff. Since the orbiter-lander

approach would cost about \$70 million more than the direct entry mode, Cortright believed that the agency should consider the relation between the scientific return and the expenditure. He was not convinced that the extra money would be well spent.

John Naugle's concerns lay in another direction: Which proposal would be the easier to sell to Congress and the new administration? Jim Webb had left NASA in October as a prelude to the end of President Johnson's term, and Thomas O. Paine, Webb's deputy, had assumed the reins of the organization as acting administrator. The significant question was what policy toward space activities would the Nixon administration pursue. With Richard M. Nixon elected to the presidency only four days before the high-level agency meeting, Naugle said that the unknowns of a new administration made it difficult to know what to do, especially in light of the criticisms by some scientists that the planetary program had been too conservative. Still, with all the uncertainties, Naugle favored the more complex mission. He believed that the costs of a lander could be reduced below current predictions and an orbiter with new science would enhance the overall mission. The orbiter had two important functions: orbital photography could be used in landing site selection, and the orbiter could serve as an information relay link, significantly increasing the amount of data returned from the Martian surface. The relay link would permit still further exploitation of the growth potential of the soft-lander for landed experiments. Naugle was willing to try to sell this orbiter-lander option to Paine, to the new president, and to Congress.

After considerable discussion among the NASA representatives, Don Hearth made the following summary of the mode they should recommend to Acting Administrator Paine:

- Soft-lander with extended life and a flyby support module.
- Direct entry.
- Titan IIC with advantages of Titan-Centaur to be studied.
- Separate launch of Mariner 71 orbiters to be examined by JPL and the Planetary Programs Office.⁵⁹

This proposal met with unanimous agreement, as did the name of the new project—Viking. But on 4 December 1968, NASA announced that Paine and Naugle had selected the more ambitious out-of-orbit option for Project Viking. After listening to the Langley briefing, Naugle believed that an extended-life orbiter with new post-Mariner 1971 experiments was essential to Viking. Looking back, Naugle recalled: "It is a little hard to recapture the mood of the times . . . but . . . one of the things that figured in my mind was the fact that we were in competition with the Russians. They had a good strong program of landers, and I . . . felt that we had to establish a good solid scientific mission." If "the Russians landed successfully in '71 or '73, what we landed . . . had to be

something that would stand up against what they had done." Acting Administrator Paine for his part was searching for a successful project for which he could assume responsibility, as most people would consider the manned lunar missions to be the work of NASA's second administrator, Jim Webb. In the autumn of 1968 when Paine looked to the future of NASA's program, he believed in the importance of unmanned planetary exploration and enthusiastically endorsed the Viking project in its most advanced form.⁶⁰

NASA chose a soft-lander with a "surface lifetime goal of 90 days" for the Mars project. A Mariner 1971-class orbiter would complement the lander science by providing "wide-area surveillance," which could be correlated with surface data from the landing site. The orbiter would also increase the data returned from the surface by providing a relay link between the lander and Earth. In 1968 NASA decided to employ the Titan IIID-Centaur launch vehicle for planetary missions because of its improved payload capacity. With the Titan IIID-Centaur, the lander and orbiter could be boosted together. Once the two craft reached Mars and went into orbit, the lander would be released. This approach to the mission would permit greater accuracy in landing at a preferred site, lower entry velocities, and more control over entry angles, three vital factors that affected lander survival.⁶¹ The Titan IIID-Centaur would also permit the mission reasonable payload weights:⁶²

	<i>Titan IIIC</i>	<i>Titan IIID-Centaur</i>
Total orbital weight	1136 kg	3400 kg
Lander	360	1000
Scientific experiments	10	30

This significantly improved pair of flights—an orbiter and an orbiter-lander, launched about 10 days apart—would cost \$415 million, up from \$385 million for the smaller, less productive mission discussed during the fiscal 1969 hearings.⁶³

After 17 years of promoting, planning, debate, enthusiasm, and despair, NASA could finally get down to the task of designing and building hardware. Although dollars for Viking would always be scarce, this Mars lander would actually journey to the Red Planet. On 6 December 1968, Ed Cortright announced the formation of an interim Viking Project Office at Langley to replace the Advanced Space Project Office (Unmanned):

Effective this date, the following are reassigned to the interim Viking Project Office in the capacities as indicated:

Project Manager	:	James S. Martin, Jr.
Deputy Project Manager	:	Israel Taback
Project Scientist	:	Dr. G. A. Soffen
Operations Manager	:	William J. Boyer
Engineering Manager	:	Israel Taback

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Executive Engineer	:	Angelo Guastaferrero
Space Vehicle Manager	:	Robert L. Girouard
Test Manager	:	William I. Watson
Spacecraft Manager	:	Edmund A. Brummer
Asst. Spacecraft Managers	:	Royce H. Sproull Frank E. Mershon
Missions Analysis Manager	:	Norman L. Crabill ⁶⁴

Under the organizational framework set up by Martin and his colleagues, Lewis Research Center would oversee the launch vehicle for Viking, JPL had responsibility for designing and building the orbiter, and Langley would supervise lander and system integration. Following the pattern of Lunar Orbiter, an industrial prime contractor would be selected to develop and build the lander, with Langley personnel members as technical managers. This scheme had been used successfully in numerous other NASA programs, notably the manned spaceflight projects, Mercury, Gemini, and Apollo.

Jim Martin opted for a reasonably simple management structure. Responsibility for the project passed directly from the Office of Space Science and Applications at headquarters through Langley's director to the project manager. All other NASA concerns working on Viking reported to Martin, who clearly established himself as the "boss." Three major tasks would dominate the years before the Viking launch: developing and building the orbiter, developing and building the lander, and selecting and building the scientific experiments. And Martin's team in Virginia would make sure that the necessary work was done on schedule and within the budget.