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Chapter 23

American Manned Planetary Mission Studies, 1962-1968[1]

Franklin P. Dixon[2]

In the 1960s, a major program to identify future missions for spaceflight and for the American space program evolved with a number of significant events and players. The concerned efforts were based on previous visions and the enthusiasm of a few persons. Probably the pictures of the planet Mars taken by Percival Lowell, the visions of Tsiolkovsky, Oberth, Goddard, and Willie Ley, the leadership of Wernher von Braun with his documentation of The Mars Project in 1953[3] and the circumstances of the organization of the National Aeronautics and Space Administration (NASA) in 1958, all had a hand to play in the course of the analyses, studies, and alternative considerations for manned planetary missions in the late 1950s and early 1960s. The focus of this presentation will be on the mission analyses, technology identification, development of capabilities, examination of system alternatives and evolving program options that became the base of planning for future manned planetary missions in the 1960s.

The logical beginning of this emphasis was at the Future Projects Office (FPO) of the NASA Marshall Space Flight Center (MSFC) in Huntsville, Alabama. In 1961, the decision to land men on the Moon with Apollo had been made by President John F. Kennedy, and the programs to develop the hardware were being organized. The Saturn I and Saturn V were part of the approved developments needed in Apollo. The future

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[1] Presented at the Twenty-Third History Symposium of the International Academy of Astronautics, Málaga, Spain, 1989.

[2] Program Development Manager, Rockwell International Rocketdyne Division, Canoga Park, California 91303, U.S.A. Member International Academy of Astronautics.

[3] Wernher von Braun, *The Mars Project*, University of Illinois Press, Urbana, 1953.

missions for exploration of space were receiving added interest, and Wernher von Braun's enthusiasm was shared by MSFC Future Project Office Director Hermann H. Koelle and Deputy Director Harry O. Ruppe. To focus planning the Early Manned Planetary-Interplanetary Roundtrip Expedition (EMPIRE) studies were undertaken. Three companies were given contracts in fiscal year 1962 to study different aspects of possible missions to Venus and Mars. The work done at Aeronutronic Division of Ford, Convair Astronautics, and Lockheed Missiles and Space Company brought focus on the past and considered several options for the future.

The missions included flybys, orbital capture at Venus and Mars, landing on Mars, and the possibility of landing on Venus. Also, the unmanned precursors and onboard experiments leading to a manned Mars landing were examined and are continuing today.

I became personally involved when the EMPIRE Dual Planet Flyby Study, started by Seymour Lampert, needed a program manager to complete the last half of the effort. An exciting arena of future possibilities was unfolded from July 1962 until the final report was published in December 1962. Our particular part focused on the 1970 to 1972 early dual planet flybys, and it analyzed the missions, systems development requirements, crew size, life support, Earth return with a lifting body at lift/drag (L/D) around 1.0, probes, communications, reliability, and value of expected results. The key point in the exercise was the final briefing to the MSFC personnel, and to Wernher von Braun after the work was completed in September 1962. It was following this event, and the same for the other two companies covering other missions to Venus and Mars, that public exposure came to the Apollo follow-on possibilities. Serious study efforts were expanded to evaluate priorities and identify critical technologies and precursor scientific data gathering needed for a sound plan for specific program development activities in the post-Apollo era starting in 1970.

The remainder of this paper will show the evolution of manned planetary mission studies, relate some anecdotes that may be of interest, and offer some conclusions for future mission planning that will be of value for the Next Forty Years in Space, the theme for the 40th International Astronautical Federation Congress at Torremolinos, Málaga, Spain in 1989.

Some EMPIRE Results

Following the 1962 conclusions of the first EMPIRE studies, NASA was reorganized and leadership of the Apollo Program was focused within the Office of Manned Space Flight (OMSF) on the Saturn and Apollo hardware and mission development. The Advanced Manned Missions Program was established to take care of supporting technology for the ongoing flight programs and to study the advanced mission and systems requirements and operations needs. The principal OMSF centers included the Manned Spacecraft Center (MSC) near Houston, Texas, the MSFC at Huntsville, Alabama and the NASA Launch Center at Cape Canaveral, Florida. The fiscal year 1963 study program included continuation of the three EMPIRE studies under the FPO at Marshall. However, the Aeronutronic Mars Landing and Surface Operations study emphasizing a Mars Excursion Module was transferred to the MSC under Max Faget and Bill Stoney.

The feasibility of manned missions to Venus and Mars with additional options were confirmed. The study by Convair under Krafft Ehricke even went beyond Mars capture to consider fast missions to Venus.[4]

By this time, topical conferences were being held by the American Institute of Aeronautics and Astronautics and the American Astronautical Society on a fairly routine basis. My first opportunity to participate came with an impromptu invitation to give a three-minute report on EMPIRE results of the Aeronutronic Dual Planet Flyby for 1971. Joe Shea was session chairman at the 2nd Manned Space Flight Meeting of the AIAA held in Dallas, Texas, in 1963 (co-sponsored by NASA). Ben Martin, Lockheed EMPIRE Program Manager, gave a paper entitled, "Manned Flights to Mars and Venus in the 70s."[5]

Krafft Ehricke and I were each given three minutes to summarize the EMPIRE results. I started off with a statement of conclusions for the Dual Planet Flyby of Venus and Mars. From Earth orbit a nuclear rocket injected the six-man crew on a symmetric trajectory, rather than the earlier identified Crocco trajectory, taking up to 631 days, and providing for Earth return with a lifting body re-entry vehicle. For a 1971 mission, developments could be accelerated, with a start in 1964, as a logical extension to the Saturn/Apollo technology, and could provide close approach to both Mars and Venus, with probes into both atmospheres and environmental data return, without manned entry of either atmosphere. Of course, this would be in addition to the Explorer, Mariner, and Voyager data expected to accrue at that time. The EMPIRE interplanetary spacecraft would extend its two living volumes and rotate slowly to provide 0.3 g of artificial gravity for crew health maintenance, without undue problems caused by excessive Coriolis forces due to short moment arms or too fast rotation.

The almost exactly 3-minute summary was then followed by Ehricke's 25-minute version of orbital capture missions to Venus and Mars in considerably more detail. Thus, at Dr. Harry Ruppe's suggestion, Shea included all three EMPIRE summaries at the 1963 Manned Space Flight Meeting, as the follow-on studies were getting underway. More detailed reports were presented by Dixon, Ehricke, and others later.

In the volume on Engineering Problems of Manned Interplanetary Exploration, AIAA, New York, 1963, Dixon[6] and Ehricke[7] published lengthy summaries of the EMPIRE results. In "The EMPIRE Dual Planet Flyby Mission," F. P. Dixon provided illustrations of the flyby hardware, as summarized above, by Aeronutronic. Figure 1 shows a conceptual painting of Earth departure, using a nuclear rocket superimposed with Mars

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[4] Ehricke, K. A., "Mission Analysis of Fast Manned Flights to Venus and Mars," Paper No. AAS 63-024, *Ninth Annual Meeting, Advances in the Astronautical Sciences*, Vol. 13, Eric Burgess, ed., American Astronautical Society (9th Annual Meeting, Los Angeles, CA, 15-17 January 1963), 1963 , pp. 470-546.

[5] Martin, B. P., "Manned Flights to Mars and Venus in the 70's," AIAA, New York, N.Y., 2nd Manned Space Flight Meeting (Unclassified Portion), 1963, pp. 236-253.

[6] Dixon, F. P., "The EMPIRE Dual Planet Flyby Mission," *Engineering Problems of Manned Interplanetary Exploration*, AIAA, New York, 1963.

[7] Ehricke, K. A., "Study of Interplanetary Missions to Mercury through Saturn with Emphasis on Manned Missions to Venus and Mars 1973/83 Involving Capture."

arrival on the flyby. Figure 2 shows more detail of the transplanetary injection. Further development of the Nuclear Engine for Rocket Vehicle Applications (NERVA rocket) was presumed at this point, although chemical rockets at greater initial mass were also possible. Figure 3 shows a blowup of the rotating spacecraft, with the extended tunnel joining the two opposing living quarters, where the 0.3 g force of artificial gravity was present. Interplanetary experiments and probes at Venus and Mars were part of the data gathering operations. Selection of probe entry was made during observation of the rotating planets as the spacecraft approached. The crew activities were time-lined. Even without a landing crew, 5.3 persons were required to perform the essential activities. The crew was sized at six to include some unassigned time enroute.

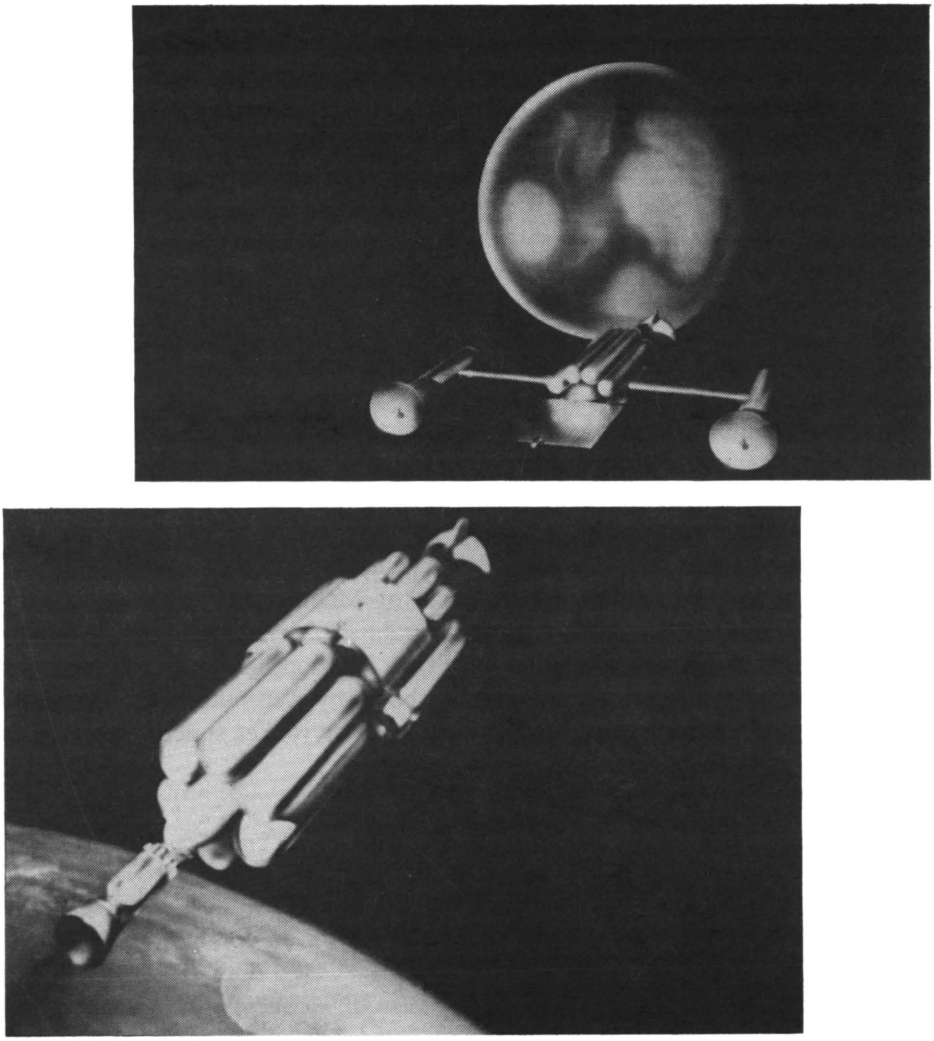

Figure 1 Aeronutronic artist's concept of EMPIRE spacecraft.

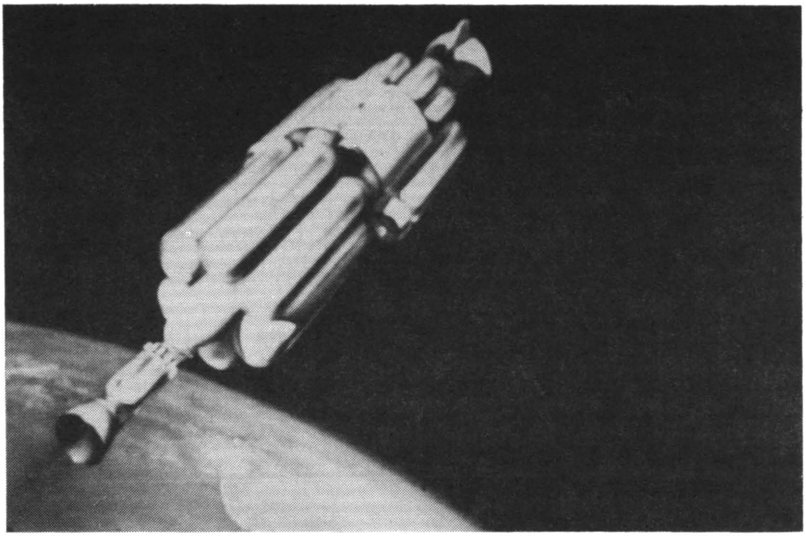

Figure 2 EMPIRE Earth departure using a nuclear rocket to leave orbit toward Mars.

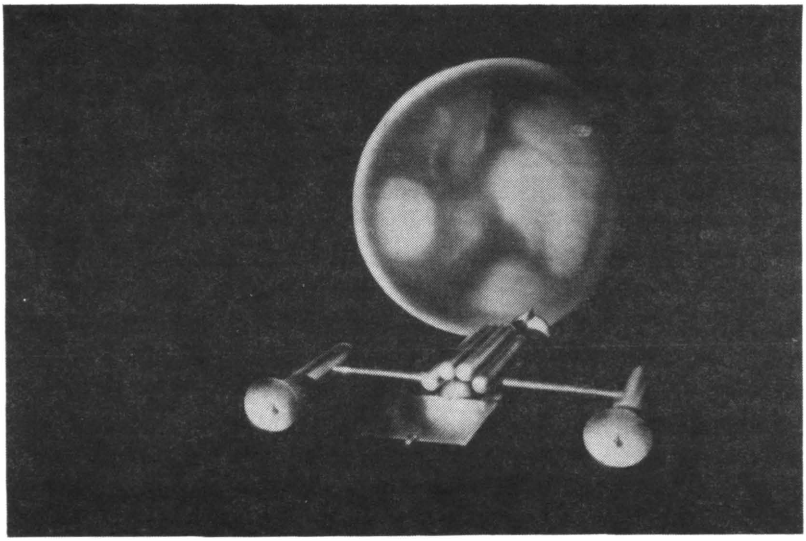

Figure 3 Arrival near Mars with extended and rotating crew mission modules at 0.3 g.

In the published Addenda,[8] Ehricke expanded on trips to Mercury through Saturn, emphasizing flight requirements to Venus and Mars from 1973 to 1982.[9] Also, Temple W. Neumann reported on "An Analysis of a Manned Mars Landing Mission," using the

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[8] *Ibid.*

[9] Ehricke, K. A., (Footnote 4).

Mars Excursion Module then under study for the MSC by Aeronutronic Division, then of Philco (bought by Ford Motor Company).

The volume also included Koelle's "Manned Interplanetary Flight. Where Are We Today?" and topical articles: on entry, Al Seiff, "Atmospheric Entry Problems of Manned Interplanetary Flight," on nuclear propulsion: T. F. Widmer "Application of Nuclear Rocket Propulsion to Manned Mars Spacecraft" and L. Goldfisher "Shielding Requirement for Nuclear Propelled Manned Space Vehicles." Also, electric propulsion was included in a paper by R. J. Dennington, W. J. LeGray, and R. D. Shattuck, "Electric Propulsion for Manned Missions." The Palo Alto Conference at the Cabana Hotel was a great success for manned planetary missions.

It should be noted that a paper on use of the Moon was included. There I first met Bill Escher when he presented his paper entitled "On the Utility of the Moon in Space Transportation: The Lunatron Concept." We later examined the Moon in some detail as a source of propellant to support planetary missions, but that is a more conventional approach. We later dropped this due to mission complexity and lower success probability.

Other publications were also including articles on planetary missions. The Astronautics and Aerospace Engineering article "From Mercury to Mars" by Max Faget and R. E. Purser[10] began to publicly document the special emphasis on Mars missions at NASA-Houston, along with Gemini and Apollo activities.

Expanded Planetary Interests

The prolific nature of Ehricke was seen early in 1963 in the cited volume edited by Eric Burgess, where a 76-page report was published, entitled "Mission Analysis of Fast Manned Flights to Venus and Mars," in the series *Advances in the Astronautical Sciences.*[11]

The topical conferences really focused on Mars in mid-1963. The AAS, with the enthusiasm of George W. Morgenthaler of the Martin Company, Denver Division, sponsored a meeting on The Exploration of Mars. One of my Aeronutronic Associates, R. M. L. Baker, gave a foundational paper on "Influence of Martian Ephemeris and Constants on Interplanetary Trajectories."[12] Among others like Lou Walters, it was Baker that had started Aeronutronic on the EMPIRE course along with his associate, Dr. Sam Herrick,

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[10] Faget, Max and Purser, R. E., "From Mercury to Mars," *Aeronautics & Astronautics Engineering,* Vol. 1, No. 1, February 1963, pp. 24-28.

[11] Ehricke, K. A., "Mission Analysis of Fast Manned Flights to Venus and Mars," Paper No. AAS 63-024, *Ninth Annual Meeting, Advances in the Astronautical Sciences,* Vol. 13, Eric Burgess, ed., American Astronautical Society (9th Annual Meeting, Los Angeles, CA, 15-17 January 1963), 1963, pp. 470-546.

[12] Baker, R. M. L., "Influence of Martian Ephemeris and Constants on Interplanetary Trajectories," Paper No. AAS 63-065, *Exploration of Mars, Advances in the Astronautical Sciences,* Vol. 15, George W. Morgenthaler, ed., American Astronautical Society (Symposium on the Exploration of Mars, Denver, CO, 6-7 June 1963), 1963, pp. 47-63.

both of UCLA ephemeri and trajectory renown. The kickoff of the conference was an Introduction session, started by Bill Purdy of Martin on "The Intent To Explore" with Harry Finger's presentation "Mars-A Target for Advanced Propulsion." Keith Boyer of Los Alamos spoke on "The Role of Large Thrust Nuclear Power in Mars Flight."

There were eight different parts to this conference, with an added introduction and a panel discussion in conclusion. I particularly enjoyed Willy Ley on "The History of Concepts about Mars." Eugene B. Konecci, then with NASA Biotechnology, later with the National Aeronautics and Space Council staff, and later with the University of Texas, presented "Human Requirements for the Mars Mission." George de Vacouleurs, W. M. Sinton, and Clyde Tombaugh each reported in a session on surface, atmosphere, color, and existence of life on Mars in Part 7. Part 8: The Scientific Value of the Mars Trip, included papers by Carl Sagan, "Biological Exploration of Mars," and Gordon J. F. MacDonald, "Astrophysical Experiments for Mars Mission."

It seemed as though a tremendous interest was growing in 1963 for unmanned planetary probes, and for manned missions looking more to Mars than toward Venus. It turned out that the more detailed studies and serious considerations of Manned Planetary Missions to unfold in 1964 to 1968 were being enabled by national interest, with government and industry laying a better foundation. But research and technology developments were not yet balanced. There were still areas of analysis needed, and better planning of all the mission and systems requirements to define the hardware and operations for actual mission definitions, schedules, and program plans. It would be about three more years before a cohesive examination would be completed, but serious interest was beginning to swell, and strong public appeal was found along with professional interest and enthusiasm.

Before Koelle and Ruppe returned to Germany, and before Federico Casal returned to Switzerland from NASA, their work would be hardened and a better foundation would be laid within NASA. The EMPIRE Studies were expanded to cover the years 1975 to 1985. The work in 1963 and early 1964 was summarized in a NASA-industry conference at MSFC in 1964.[13] It was at that conference that I reported on the Mars Excursion Module (MEM), which is shown in Figure 4, with two of the Astronauts setting up on Mars with instruments and communications. The MEM supported a 10-day stay on the surface, with lifting vehicle entry to provide lateral range for landing at the specific site chosen from orbit. Here again, observation on the arrival approach by the crew of eight in the Mars mission module of the interplanetary spacecraft would aid site and entry point selection, as the rotating planet gives better resolution. Probes to specific sites could also precede the MEM for atmospheric verification and surface properties confirmation.

It was at MSFC, Huntsville, that I first met with Edward Z. Gray (whom you may know as Zeke Gray from Boeing, Ed, or "E. Z." Gray as Director of the Advanced Manned Missions Program at NASA Headquarters or with Grumman, and again in NASA Headquarters before his retirement). He had arranged to meet, and he asked me if I would be interested in a position with NASA Headquarters as Director of Manned

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[13] Proceedings of the Symposium on Manned Planetary Status 1963/64, published as NASA TM X-53049, 12 June 1964, NASA No. 4-26979, p. 764.

Planetary Mission Studies in the Advanced Manned Missions Program (AMMP). I gave it serious consideration, spoke to my associates at MSC, MSFC, and NASA Headquarters, and decided to move from Newport Beach, California, to Washington, D.C. It would be June 1964 before the transfer was complete. However, the reason for my being what turned out to be the only Manned Planetary Mission Director with NASA, was the enthusiasm generated by the government, industry, and civilian responses, and the apparent timeliness for a serious move to formulate a reasonable set of program alternatives for manned planetary exploration. Support was also needed for precursor automated (or robotic) spacecraft, to gather the needed engineering data for the manned Mars landing and return, and for Venus orbital missions. The sequence of technology and flight opportunities would unfold further, but I was on the way to a central planetary role by June of 1964 in Washington, D.C.

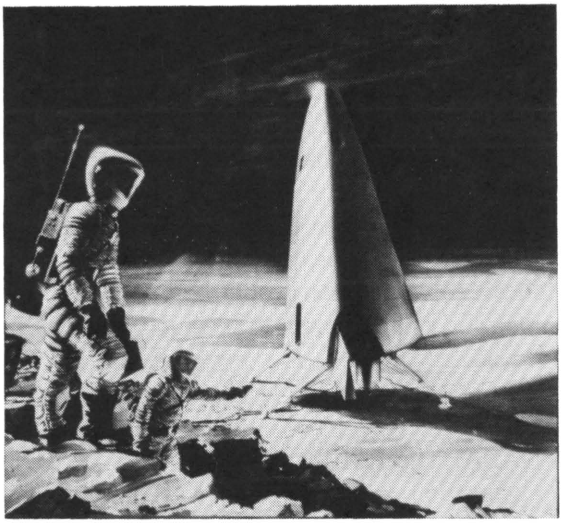

Figure 4 Mars surface operations near the Mars Excursion Module.

Planetary and Lunar Missions

The study program continued in fiscal year 1965, with more detailed study of mission and hardware options. In NASA, the OMSF studies were in addition to the Office of Advanced Research and Technology (OART) studies and developments, in particular those of the Mission Analysis Division located at Ames Research Center in California and the Office of Space Science and Applications (OSSA), for emphasis on biosciences and unmanned orbiters and probes for planetary exploration with the Jet Propulsion Laboratory (JPL) in Pasadena. The future mission alternatives included lunar and planetary, with Earth orbital life and performance testing preceding manned flight beyond, much as Apollo.

When I arrived in Washington, there was not much time to get acquainted before Dr. Casal and I went to the Jet Propulsion Laboratory, in July 1964, to brief the President's Science Advisory Committee on manned planetary missions and launch vehicle requirements. Three of us, including Ruppe, Deputy Director of the FPO in Huntsville, gave a 4-hour presentation on 23 July 1964. We divided up the topics, and Ruppe covered propulsion with chemical, nuclear and electric transfer, and Earth-to-orbit launches with Saturn V and post-Saturn, including orbital operations. Dr. Casal, Chief, Planetary Spacecraft Systems, from my office covered the other mission technology—natural environment, life support, atmospheric entry (Earth and Mars), guidance, navigation, communications, and auxiliary power. That left the introduction and mission analyses, scientific, and engineering objectives (interplanetary, orbital, and surface exploration) and program evolution for me. It was at this point that the estimate for a manned Mars landing in the early 1980s was generated, based on the fairly thorough studies done between 1961 and 1964. We were entering the fiscal year 1965 with plans to focus on more specific options and add to depth to our systems and program planning results, for a more competent set of alternatives for program evolution.

It's Cheaper Than We Think

A lesson for all technological efforts in the future might find a correlation in countries around the world. In mid-1964, a careful assessment of missions, developments, operational verification, and program costs was made. The President's Science Advisor, Dr. Donald Hornig, requested an estimate of cost from Mr. James E. Webb, Administrator of NASA, for a manned Mars landing to follow Apollo. The result was based on the plans, schedules, and costs presented also at JPL on 23 July 1964. In one week the following events transpired. The $32 billion estimates for a manned Mars landing and return in 1982, with work starting up in 1968, was reviewed, and $5 billion were added for the normal programmatic contingencies. The $37 billion figure was then forwarded to the NASA Administrator, and some additions were made for peripheral items of institutional and supporting activities and administrative overhead, increasing the figure to $50 billion. The estimate was then given to the Presidential Science Advisor, who carried it forward to a Congressional Committee as an estimate for a manned Mars landing by 1982 of $100 billion. The next day the newspapers quoted a Congressman as stating that a Manned Mars Landing Mission would cost $200 billion to accomplish. In only one week, a well developed estimate of $37 billion for a manned Mars landing program to follow Saturn/Apollo, with development starting in 1968, was multiplied into a $200 billion program with only minor benefits added. It is no wonder that such publicity is easily misunderstood.

Possibly the Congressman knew that such a program would be deferred because it cost so much, and, with inflation, would really turn out to be a $150 to $200 billion program. I understand that, due to inflation, the $23 billion Apollo Program in the 1960s would cost about $105 billion to do today. So a factor of 4.5 might be appropriate for inflation of the dollar. In that case, the $200 billion, if done today, would deflate back to around $40 billion in 1964, not too far from the considered estimate at that time.

Options Being Considered

It might be helpful to show you some of the program elements and a couple of the options assembled from the in-house and contractor studies by NASA. Figure 5 shows a future mission plan with Earth orbital, lunar, and planetary missions. This evolutionary program presumed that Gemini, Apollo, Saturn, and Nuclear Rockets would evolve as planned. Also, unmanned precursor missions to Mars and Venus are presumed. The Plan II, with a large lunar exploration program, an orbital laboratory and Mars landing and Venus capture of the manned interplanetary spacecraft developed from the Orbital Research Laboratory (ORL) hardware, appeared most logical in 1964. In the continuous program, the Apollo X Extensions with Apollo hardware included a lunar rover, 14 days on the Moon followed by 90 day stays, with a permanent lunar base starting in 1976. After all, when the plan was drawn, it was 4 or 5 years before Apollo accomplishment, planning for events 12 years beyond 1964. See Figure 6 for the profiles of funding estimates for Plan II.

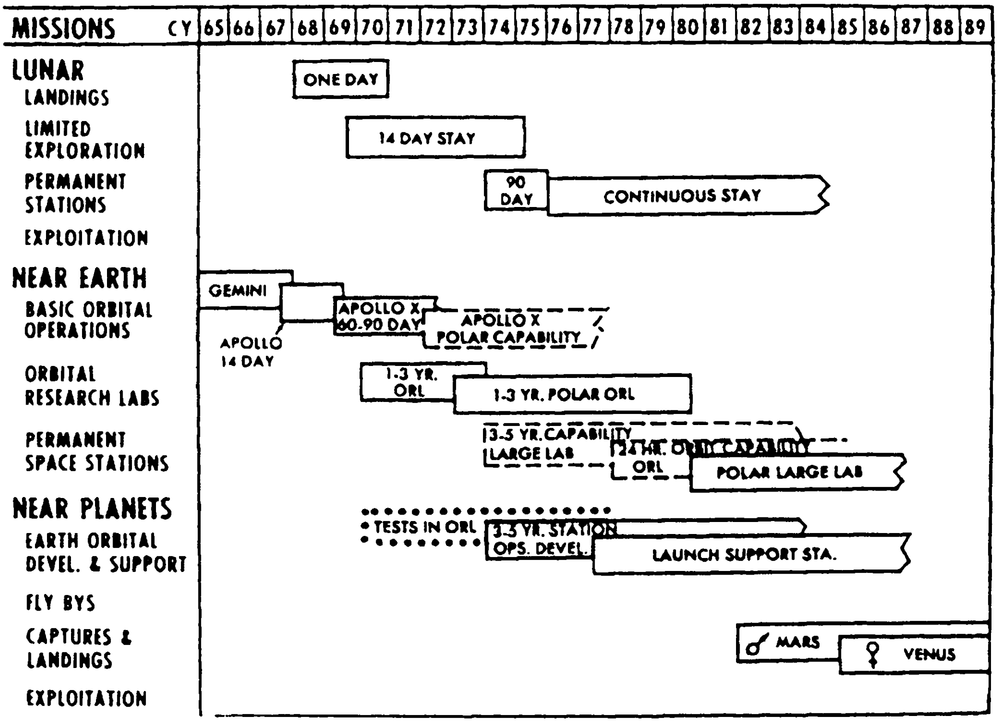

Figure 5 Plan II Manned Missions Schedule.

We also had other plans, for example Plan V, which did less lunar work and proceeded more directly with Apollo Extension Systems (AES) hardware in Earth orbit leading to an ORL designed to answer the zero-g/artificial-g question for manned flights of 1 to 3 years duration. Then the same basic spacecraft would become the core of the interplanetary mission module. A crew of six to ten was possible, depending on the lander size and stay duration. Figure 7 shows Plan V with a less ambitious set of goals and objectives. Figure 8 gives the estimated funding profile to support the alternative missions on a more modest basis. Here we stopped with 14 days on the Moon, slowed AES in Earth orbit, developed commonality for the ORL and planetary hardware, where possible, and dropped the manned planetary flybys.

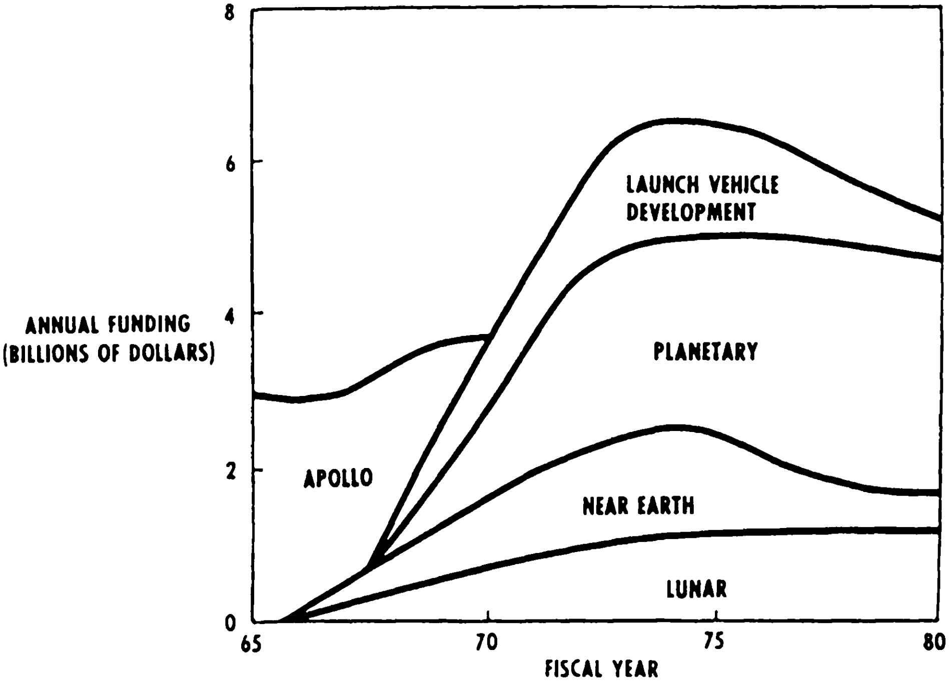

Figure 6 Plan II Resources Requirements.

In was in 1965 that I was given an additional assignment as acting director, lunar mission studies. The efforts were just expanding toward lunar bases, and exploration beyond the limited area that a walking astronaut could cover in the Apollo lunar landings. With the development of mobile vehicle concepts well along in three companies, and a mobile laboratory prototype provided by General Motors research, it was straightforward to develop a smaller lunar rover, assuming certain surface characteristics. We decided to start, and the development of the two-passenger vehicle was begun by MSFC with the Boeing Company and General Motors team. A key to later success was that the vehicle was required to be compatible with the lunar excursion module without major prohibitive modifications. I remembered that the rover was "to go on Apollo without changes in Apollo!" Of course that was not possible, but it was later possible to put the rover on Apollo for the last three flights, without loss of time for undue forced modifications, and three Apollo lunar excursion module crews used the lunar rover on the concluding flights of Apollo.

The dual assignment was several months, but the intensity of manned planetary interest would pick up before the end of 1965, and I turned the lunar missions over sooner than we thought would evolve at this time.

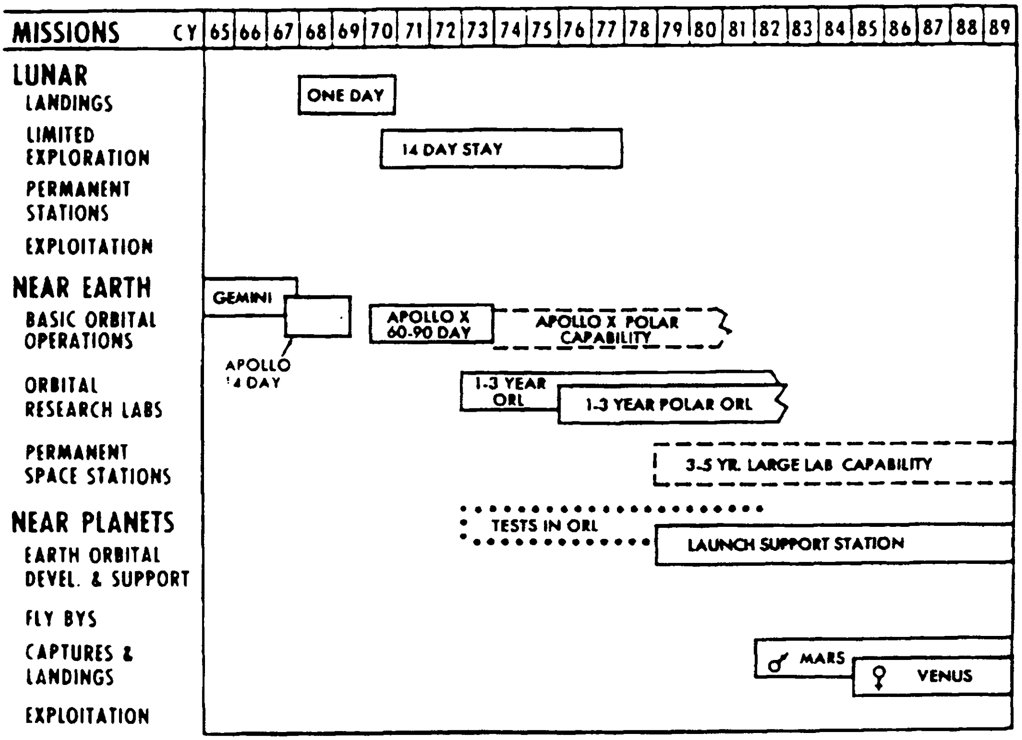

Figure 7 Plan V Manned Missions Schedule.

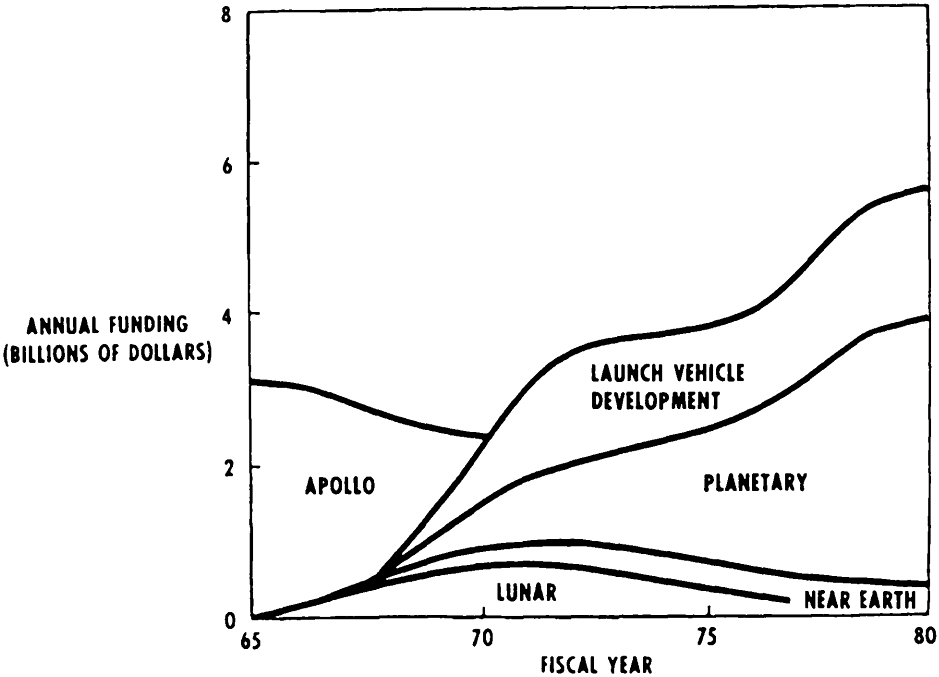

Figure 8 Plan V Resources Requirements.

Advisory Groups Stir Interest

In June 1965, the National Academy of Sciences Space Science Board working group was convened at Woods Hole, Massachusetts, under the chairmanship of Gordon J. F. MacDonald. A presentation was given on manned planetary missions, that later led to a request for me to give a presentation to the USAF Scientific Advisory Board meeting, to be held at the Manned Spacecraft Center in Houston in November 1965. Gerry M. McDonnel, associate professor of radiology at UCLA and chief of the adult diagnostic division at the UCLA Medical Center, wrote that he was program chairman and had specifically requested a briefing on manned planetary missions, based on the earlier Woods Hole presentation. Phil Culbertson had replaced me as director, lunar mission studies, although he had originally come from General Dynamics/Convair to NASA Headquarters to be the Director, Advanced Launch Vehicles, and he presented the lunar missions beyond Apollo. Bill Taylor also gave a presentation on the AES, to illustrate the applications of follow-on Apollo hardware. The AES, lunar, and planetary programs stimulated considerable interest with the Science Advisory Board members.

It was at this meeting, held at NASA-MSC in Houston, Texas, that I again met Guy Stever, his former student, Astronaut Pete Conrad, and Dr. Charles A. Berry, physician to the astronauts, with whom I became associated in confirming manned capabilities for longer duration spaceflight, and the 1 to 3 years of operations that might be eventually chosen for manned Mars missions, in 1965 thought to be possible at the earliest in the 1975 to 1985 time period.

The National Academy of Sciences Space Science Board Summer Study, USAF Scientific Advisory Board presentations, and the interest expressed by the Atomic Energy Commission to NASA in nuclear rocket engine development requirements, led to a more concentrated NASA in-house review by a planetary mission joint action group in 1966 and 1967.

Of course, further contractor detailed study was needed. The basic pattern of a space project cycle is shown in Figure 9, where the research, pre-development (or technology) phase, development of specific hardware through verification and demonstration, and then the first flight, can still be considered valid today. Planetary missions were, and still are, in the research stage. In order to make the transition, a goal must be set to move into the development stage. Before objectives become specific goals, there must be an accepted need and a basis for confidence of success in the time-scale under consideration. Many studies, and development of components, are required through the pre-development stage, before a firm commitment is finally made.

In the 1964 to 1968 time period, we planned to build on the Saturn/Apollo base with advanced propulsion, both chemical and nuclear, and with other critical technologies in order to enter development with high confidence. For nuclear propulsion and high performance hydrogen-oxygen rockets, that was done with demonstration of subscale hardware in NERVA, and by continued development of advanced oxygen-hydrogen engines, as well as space "storable" propellant engines, including high specific impulse (450 to 500 seconds) versions of higher pressure and novel rocket engine configurations. Here are two of the advanced engines tested by Rocketdyne with liquid oxygen and hydrogen. Figure 10 shows an aerospike nozzle test, which was very successful.

This engine, conceived in 1965, was tested a couple of years later. Figure 11 shows the test of a linear engine, box-like in cross section. Both gave improved performance and altitude compensation for pressure variations. Along with the NERVA, the major thrust segments could be confidently planned for future manned missions to the planets.

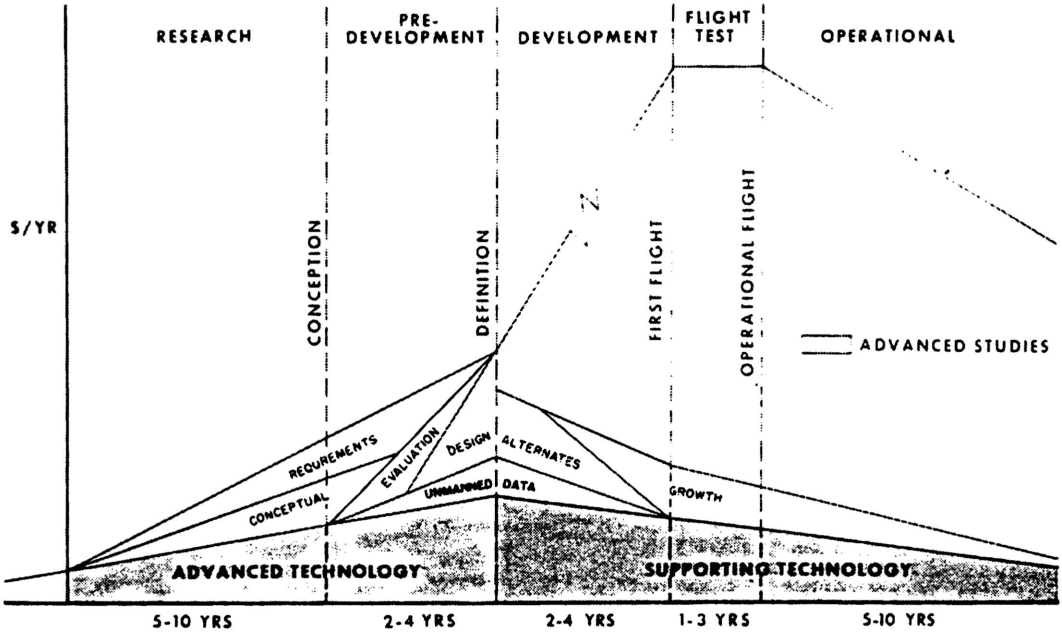

Figure 9 Space project cycle with typical phases, times, and technology before and after the development decision point.

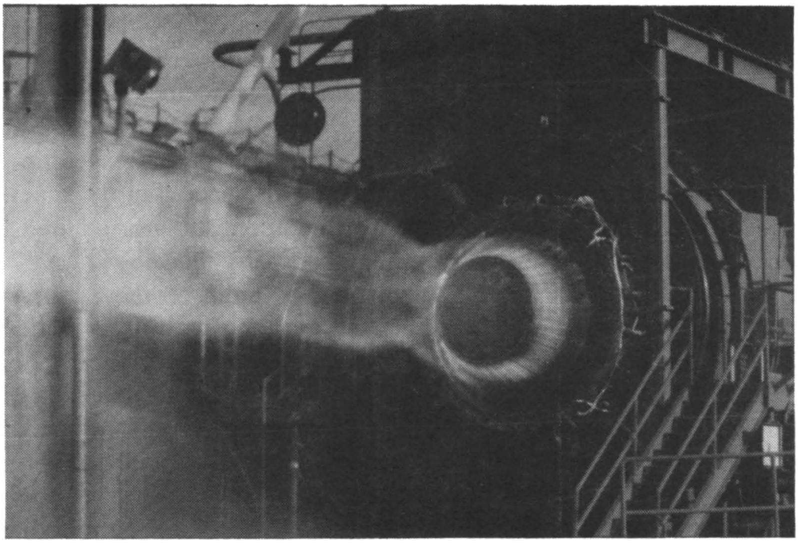

Figure 10 Aerospike engine test firing.

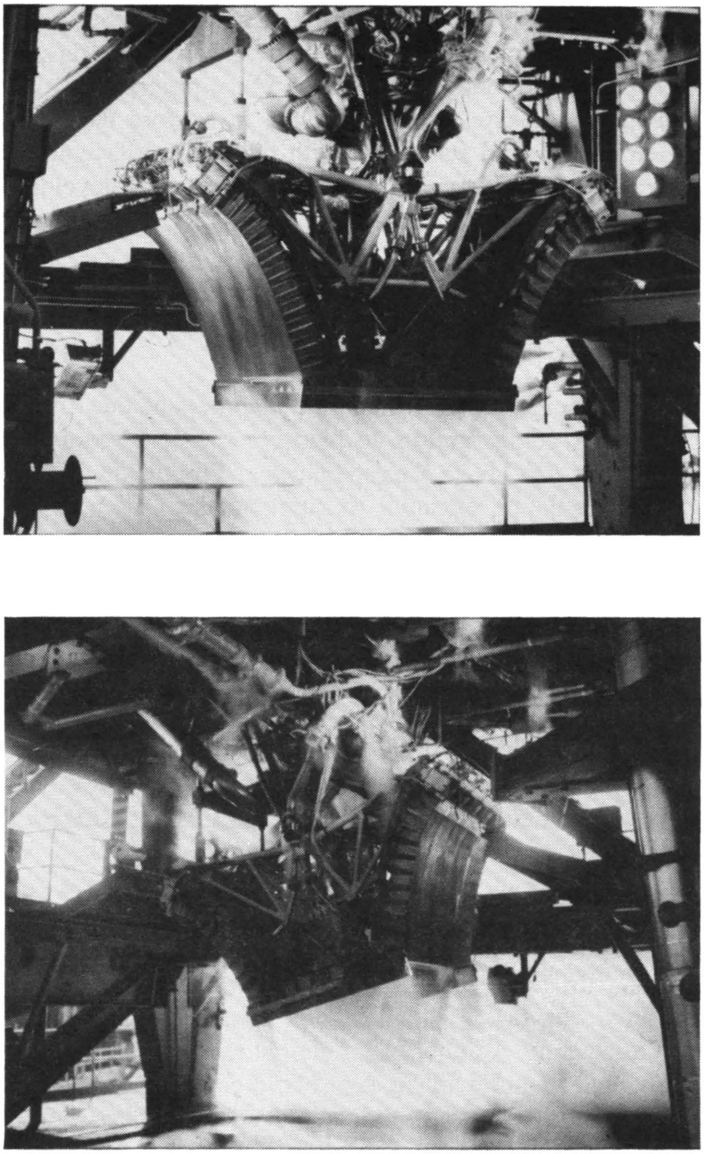

Figure 11 Linear engine test firing.

Other studies were made of storable fluids for Mars landers, longer space propellant storage, and general transfer applications. Trajectory corrections could use various engine systems. By 1968, the advanced propulsion, space power, and environmental control/life support systems were in pre-development to support manned Earth orbital, lunar, and planetary missions. A much stronger base of technology existed (and mostly still exists, on which to soundly base our present planning for lunar and planetary missions).

Unfortunately, the Saturn/Apollo, and demonstrated Phoebus and NERVA, technology is old history, placed in book cases and file cabinets. Retrieval of the previous work is essential, and for a serious, cost-effective space program of exploration beyond Earth orbit with lunar occupation, and a thrust on to explore the planets in our solar system, that data retrieval should start now, with the nuclear designs and test data and re-opening and upgrading facilities, with advanced technology development toward future decision options.

Planetary Emphasis Grows

In 1966, Glenn Seaborg, Chairman, and the members of the Atomic Energy Commission, met with NASA administrators to plan congressional support for the nuclear rocket program. The joint AEC-NASA Space Nuclear Propulsion Office was funded by both agencies, and it would be essential to come to the Office of Management and Budgets and Congress with a united front. A special action group, sometimes referred to as a joint action group, was established at Robert Seamans' (Associate Administrator of NASA) request. E. Z. Gray was to head the studies with my assistance, and the focus was to be on missions and technologies to successfully perform an interplanetary program with all its elements, including precursor unmanned science and data gathering missions for confirmation of engineering design validity for the Mars Landing/Venus orbiting manned planetary exploration missions.

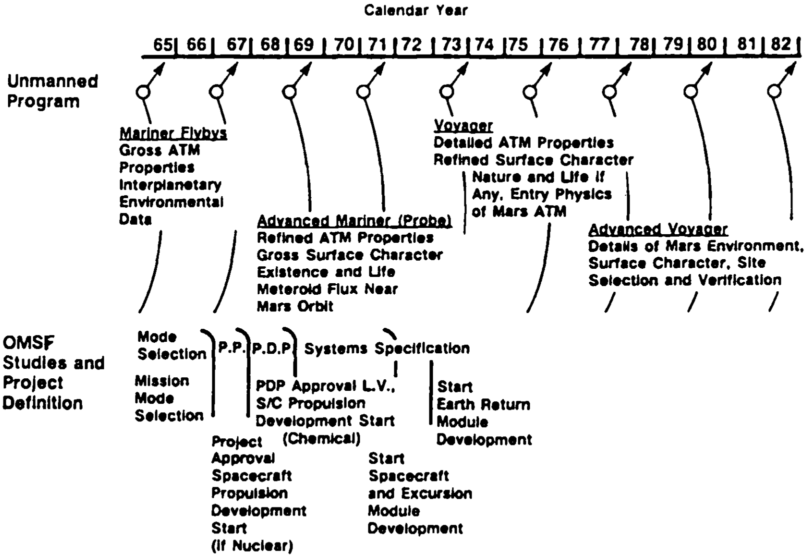

Figure 12 Manned Mars landing development schedule milestones.

Figure 12 shows an integrated planetary program approach with unmanned Mariner/Voyager precursors and other data gathering elements.

In January 1966, Charles H. Townes was chairman of the NASA Science and Technology Advisory Committee to the Associate Administrator for Manned Space

Flight, George E. Mueller. At a STAC meeting, Townes asked about the possible value to be gained from a manned Voyager mission to place man closer to the planets to be observed, with minimum technological investments. We thought of flyby missions again, with atmospheric probes, landers, and even sample return from Mars surface and other bodies for a manned Voyager.

Integrated Planning - SNPO, OART, OSSA, OMSF

Evolution of the common components, and need for precursor data for manned operations, became clearer with the conceptual design/study efforts by 1966. It was here that the utility of nuclear rockets and other advanced propulsion was better defined, and the experience from Apollo with Ranger and Surveyor results reminded the advanced planetary planners of the need for engineering data as early as possible from automated spacecraft. Also, the experience of an objective to land on the Moon with Saturn/Apollo, with President Kennedy's 1961 pronouncement, helped to keep national support and congressional appropriations on schedule. A similar goal for Mars would be of great utility, but it would require deeper study.

Part of the integrated unmanned/manned planetary missions reviews was the request by Seamans that identification of all needed technology to successfully accomplish a manned Mars landing and return mission be included in NASA planning, so there would be no technology "holes" when the time for explicit decisions and program efforts came for the technology predevelopment periods for different options.

The result pulled together all the NASA centers and offices in Headquarters, and a presentation was made to NASA administrators, Webb, Hugh Dryden, Seamans, and other headquarters personnel, including representatives of OMSF, OART, and OSSA. A key element was the integrated unmanned scientific planetary precursors, the advanced research, the advanced technology, and the systems developments to support future operations alternatives. A very favorable response came from Mr. Webb, who wanted to make sure that the needed research and technology was receiving adequate funding, while current NASA attention was largely taken with the immediate short-term program activities. We found that, with the broad base of government-funded industrial and university research and technology developments, there was no "essential" element that was not coming along at that time to meet planetary program development needs. This review and interaction with academic and aerospace industrial leaders gave a broad base for the next step of in-house NASA reviews and planetary element/program option evaluations.

During 1966 and 1967, a more focused view developed. Two summary overviews were presented, the first was a summary of the evolution building block approach for manned planetary missions, given at the University of Missouri in 1966[14] with the Saturn/Apollo, Apollo extensions, orbital laboratories, planetary flybys, Venus/Mars orbital

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[14] Dixon, F. P., "Manned Interplanetary Program Planning," Paper No. AAS 66-144, *The Management of Aerospace Programs, Science and Technology Series*, Vol. 12, Walter L. Johnson, ed., American Astronautical Society (Conference, Columbia, MO, 16-18 November, 1966), 1967, pp. 27-52.

capture missions, and manned Mars landing flights to begin with the 1982 mission. Results from the Venus observations had eliminated Venus landings for men, due to the atmosphere and high temperatures. However, the manned Venus capture, with closer observations and a variety of probes, was still of interest and was scheduled to follow the 1982 Mars landings.

- **Scientific**
  - **Increase man's knowledge of celestial bodies & space phenomena:**
    - **To understand the fundamental physical nature & origin of the universe**
    - **To understand the nature & origin of life**
    - **To relate this knowledge to terrestrial physical history & life**
- **Technological**
  - **Advance the technology of space exploration & operations**
    - **Focus for research & development**
  - **Develop the operational capability for space exploration & operations**
- **Prestige**
  - **Attain & maintain U.S. preeminence in space**

Figure 13 Why planetary exploration?

In 1967, the results of the contractor planetary mission studies had given much deeper considerations to missions, systems, and technology advantages, along with many inputs to NASA cost models for all the alternative approaches. The results of the NASA studies were summarized in a paper given at the "Voyage to the Planets," 1967 Goddard Memorial Symposium, by E. Z. Gray.[15] Here the nation's post-Apollo space goals were considered, with the merger from all considered directions, on the "Exploration of Our Solar System" as a commonly agreed objective. Gray started with "What are the objectives of the space program?" and stated:

> Based on our present system capabilities we will explore the moon; we will conduct earth orbital operations to serve science and develop operational capabilities; we will realize economic benefits to life on earth through earth-oriented applications; and we will enhance our national security through research and development applicable to Department of Defense technological capabilities. The growth rate of our capabilities to accomplish all of these, and the ultimate degree to which they are accomplished, is dependent on the time scale set for planetary exploration.
>
> This seeming paradox stems from the fact that not one of the other objectives in space places the same demands for progress on such a broad spectrum of science and technology. Also, the other objectives taken as a composite do not generate the broad base of support necessary for a vigorous stimulus to science and do not excite the same commitment of outstanding minds.

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[15] Gray, E. Z., and Dixon, F. P., "Manned Expeditions to Mars and Venus," *Voyage to the Planets, Science and Technology Series*, Vol. 16, Eric Burgess, ed., American Astronautical Society (5th Goddard Memorial Symposium, Washington, D.C., 14-15 March 1967), 1968, pp. 107-136.

Without the future planetary exploration objectives and specific, timely goals, a motivating and sustained space program would be harder to achieve. In Figure 13, the objectives of planetary exploration are given purpose in three areas: scientific, technological, and prestige. In Figure 14, scientific priorities for solar system exploration are listed, with an update of the 1965 Space Science Board summer study "Space Research: Directions for the Future." The sequence given in descending order: Mars, Venus, the Moon, major planets, comets and asteroids, Mercury, Pluto, and interplanetary dust. The clear consensus places Mars and Venus ahead of the Moon.

1. Mars
2. Venus
3. Moon
4. Major Planets
5. Comets and Asteroids
6. Mercury
7. Pluto
8. Interplanetary Dust

Based on recent discussions updating the 1965 Space Science Board Summer Study "Space Research: Directions for the Future"

Figure 14 Scientific priorities for solar system exploration.

The President's Science Advisory committee, in "The Space Program in the Post-Apollo Period,"[16] recommended the following: an integrated planetary exploration program with an optimum mix of unmanned and manned components for planetary explorations, establish a flexible Voyager concept compatible with possible manned ventures, and provide specific identification of man's unique, or most effective, role in planetary exploration. One approach was given, for an integrated planetary exploration sequence (Figure 15) leading to sample acquisition starting with Mars and early detection and characterization of life. Starting with the free return encounter missions in the 1975 to 1980 period, manned missions with Mars probe surface (and atmosphere) sample return and analysis aboard the spacecraft was encouraged as Gray said:

> The scientist's capabilities (at the planet) would enable him to determine the existence of even a non-carbon based life or exotic evolution proposed by some scientist. Correlated with this task would be the rapid determination of pathological relationships between terrestrial and Martian biota to allow the prevention of back contamination. The scientists would have many months enroute, during which time they can perform morphological, physiological, chemical, and pathological tests with a maximum of data return.

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[16] "The Space Program in the Post-Apollo Period," A report of the President's Science Advisory committee, February, 1967.

The scientists would also protect samples for later analysis on earth on which the virtually limitless resources of the entire scientific community could be brought to bear.

A typical trajectory is shown in Figure 16, which shows a 1975 Mars Manned Voyager. The outbound leg is relatively short (130 to 140 days) and the longer return trip, without propulsive assistance, would give a total trip time of 660 to 690 days. Passage within 300 to 1,000 km, or closer, would be desirable for the 22-month mission.

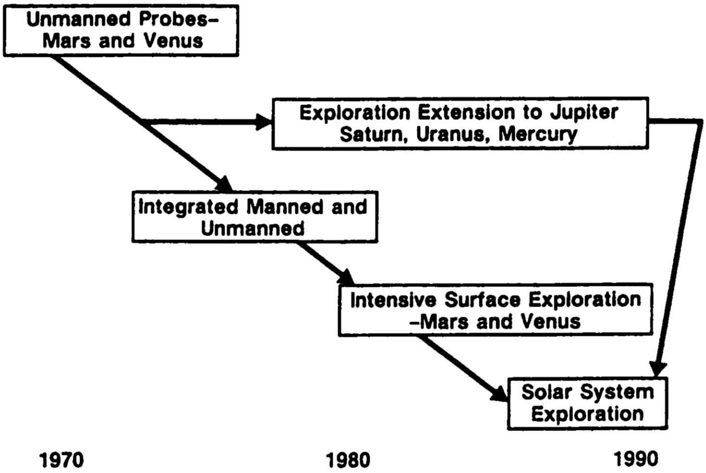


Figure 15 Integrated planetary exploration showing unmanned and manned mission areas leading to Mars and Venus surface and solar system exploration.

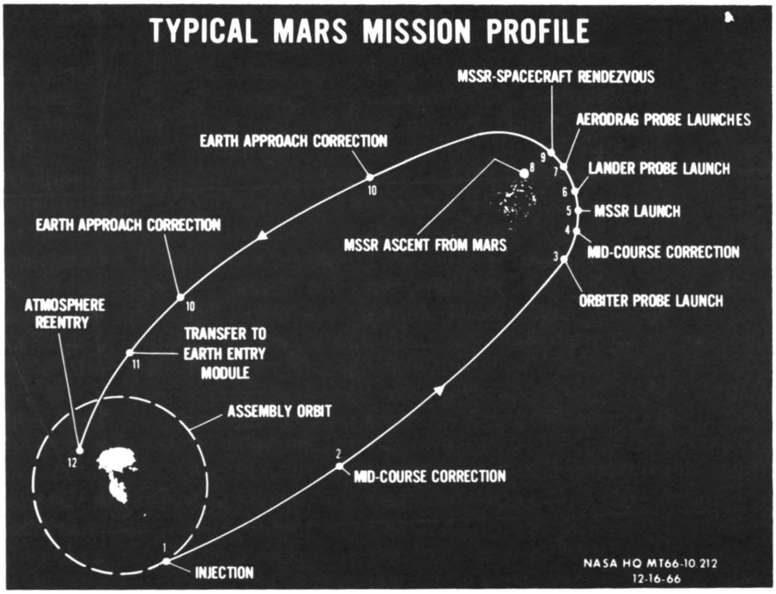


Figure 16 Typical Mars mission profile. The suggested 1975 manned Voyager mission using modified Saturn S-II stages for a Mars twilight flyby.

Venus encounter missions occur every 19.2 months. Designing for the Mars encounter missions would permit Venus missions requiring only 80% of the impulse energy for Mars and would give around 1 year for total Venus mission time.

Several variations were also mentioned, starting with a Mars encounter mission in September 1975, with injection velocity of 16,000 fps from Earth orbit and Earth return velocity of 49,100 fps. This capability could perform a 1977 Venus/Mars/Venus trip, a 1978 Venus/Mars trip, and the 1979 Mars trip. This series of four trips in five years would have resolved many questions on the two planets, their environments, life evidence, man's capabilities, hardware capabilities, and it would have extended, in a logical way, spaceflight to the manned interplanetary phase.

An evolutionary modular development, based on the planetary mission studies was presented with each needed element evolving from Apollo through the Space Station or ORL and Mars flyby to a manned Mars landing starting in 1982. Figure 17 shows the results of OMSF and other studies in FY63 and beyond for modular evolution of hardware elements.

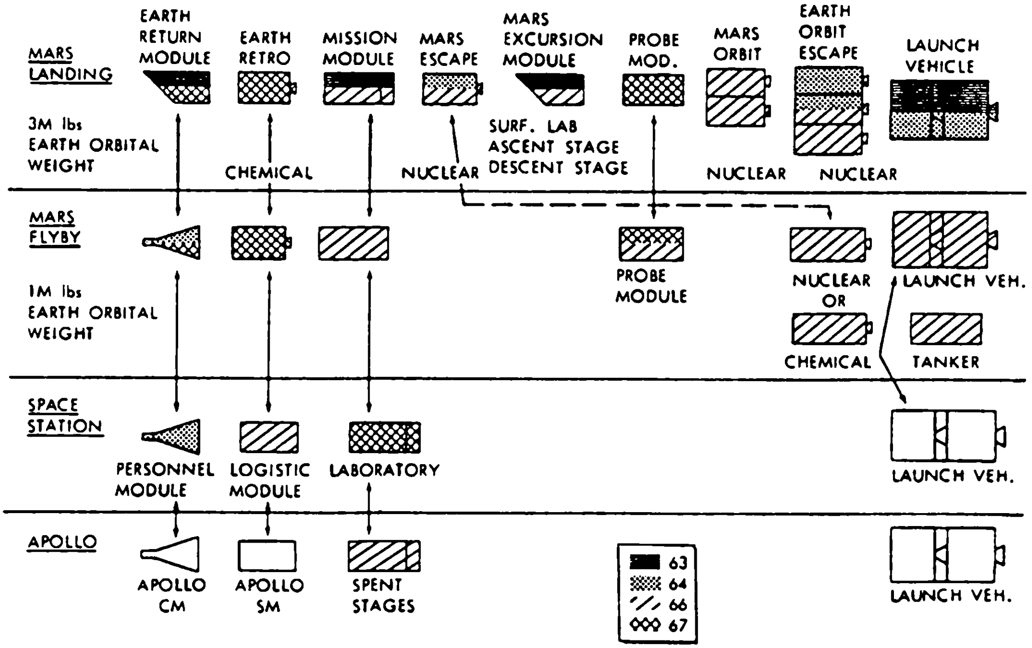
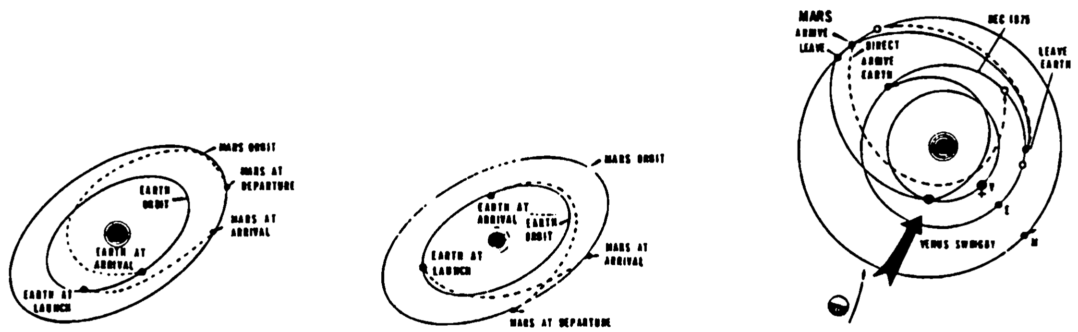


Figure 17 Studies defining evolutionary modular development.

The landing mission requirements and trajectories were shown (Figure 18) for the three additional practical classes of Mars missions. Velocity increments and Earth arrival speeds were shown with the obvious advantage of slower velocity (44,000 vs 66,000 fps) Earth return for Venus swingby, versus the faster trip time (430 days) for the Mars opposition.



OPPOSITION CLASS CONJUNCTION CLASS VENUS SWING-BY

	Δ V LEAVE EARTH (1000 FPS)	Δ V LEAVE MARS (1000 FPS)	V ARRIVE EARTH (1000 FPS)	DWELL TIME (DAYS)	TRIP DURATION (DAYS)
OPPOSITION	15	16.5	66	10	430
CONJUNCTION	14	8.5	39	480	920
SWING-BY	15	16.5	44	10	490

Figure 18 Manned planetary landing mission requirements.

Launch Date	Destination	Mission Type	Duration (days)
November '79	Mars	Landing-Conjunction	900
May '80	Venus	Capture	350
October '81	Mars	Landing-Opposition	460
December '81	Venus	Capture	350
January '82	Mars	Landing-Venus Swingby	567
January '82	Mars	Landing-Conjunction	900
July '83	Mars	Landing-Venus Swingby	446
July '83	Venus	Capture	350
October '83	Mars	Landing-Opposition	460
February '84	Mars	Landing-Venus Swingby	464
March '84	Mars	Landing-Conjunction	900
February '85	Venus	Capture	350
March '85	Mars	Landing-Venus Swingby	560
December '85	Mars	Landing-Opposition	460
April '86	Mars	Landing-Conjunction	900
September '86	Venus	Capture	350
May '88	Mars	Landing-Conjunction	900
May '88	Mars	Landing-Opposition	430
May '88	Venus	Capture	350
July '88	Mars	Landing-Venus Swingby	544
September '89	Mars	Landing-Venus Swingby	-
December '89	Venus	Capture	350
June '90	Mars	Landing-Opposition	440
June '90	Mars	Landing-Conjunction	900

Figure 19 Manned stopover mission opportunities in the 1980s.

A table showing the manned stopover mission opportunities in the 1980s was shown (Figure 19) with launch date, target planet mission type, and duration. The more attractive Mars trips were from 1982 to December 1985 departure/1986 landing for 446 to 460 days trip times.

The modular evolution from studies through 1967 gave the elements to accomplish the 1980 landings. Figure 20 shows a version of the Uprated Saturn V with 156-inch solid strap-on rockets, the Mars Excursion Module, and Earth return module, and a plan view of the Earth orbit array of nuclear propulsion modules of the interplanetary spacecraft.

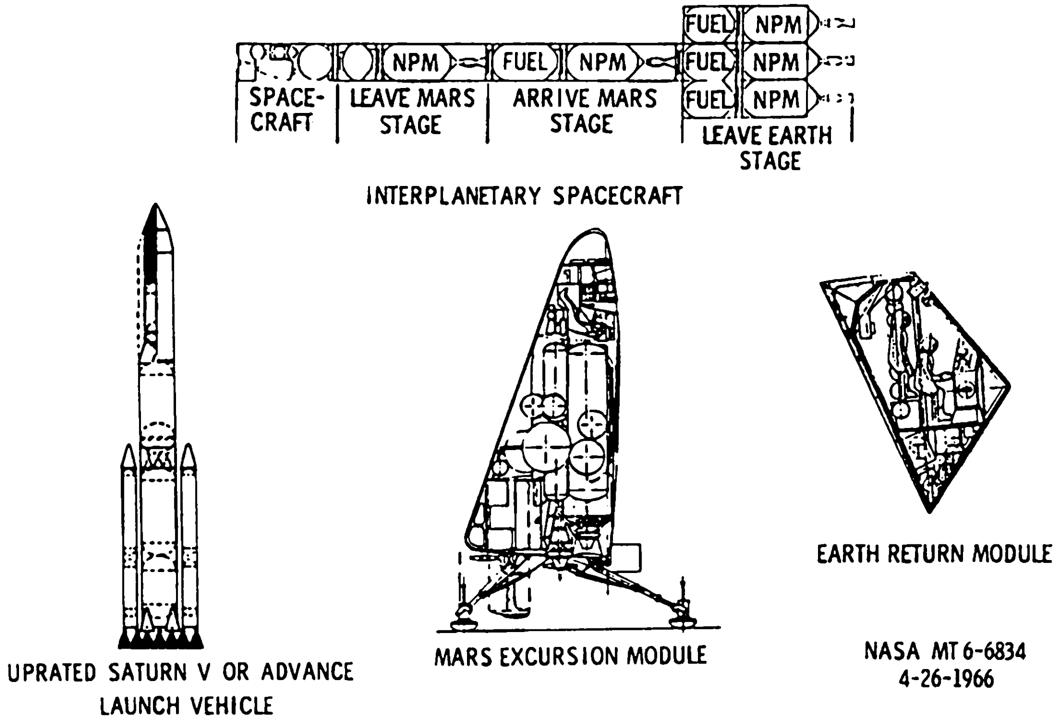


Figure 20 Manned Mars landing systems elements.

The conclusions favored the manned Mars, and Venus Reconnaissance/retrieval missions as a logical step to provide samples to help understand composition of planets and environs with the earliest (practicable) means to enhance our understanding of the existence of life forms there in a safe manner to reduce risks of back contamination. Mariner/Voyager programs were called on to provide precursor data to support landing of persons on Mars.

Overall requirements were developed for a 20-year cycle of Mars and Venus manned missions (Figure 21). Also given was a summary of initial mass in Earth orbit for the great variety of Mars and Venus missions. Practical missions, now including an aerobraking option at Mars, ran from 1 million pounds to approximately 6 million pounds before leaving Earth orbit. Figure 22 shows a nuclear modular version of the interplanetary spacecraft.

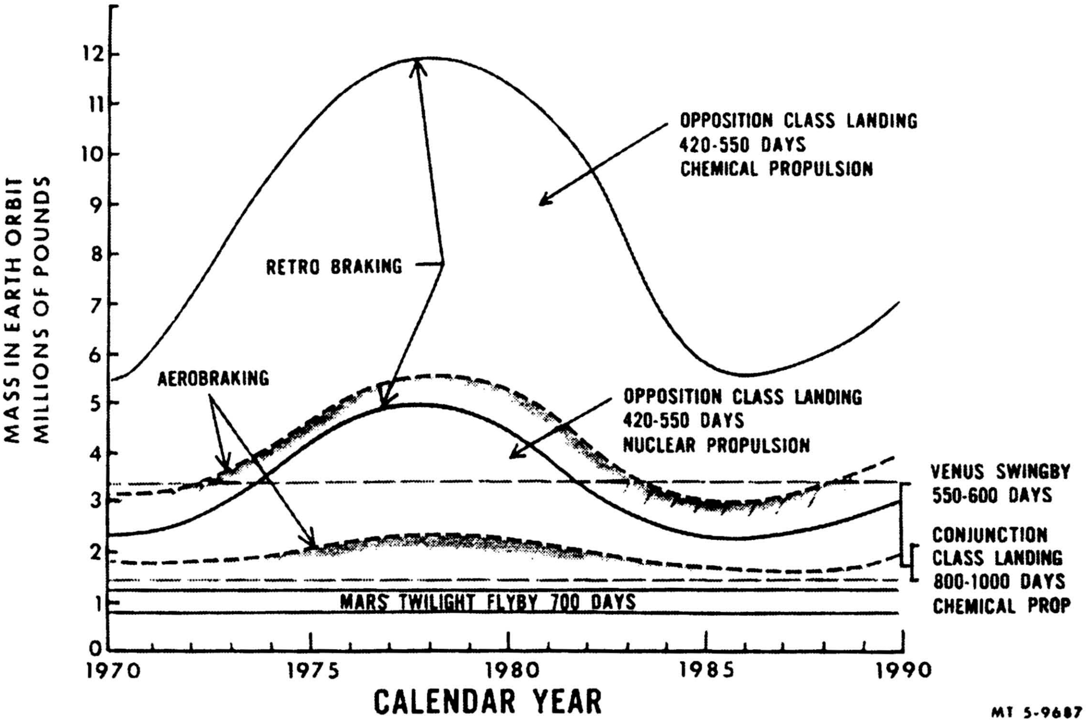


Figure 21 Manned Mars mission requirements.

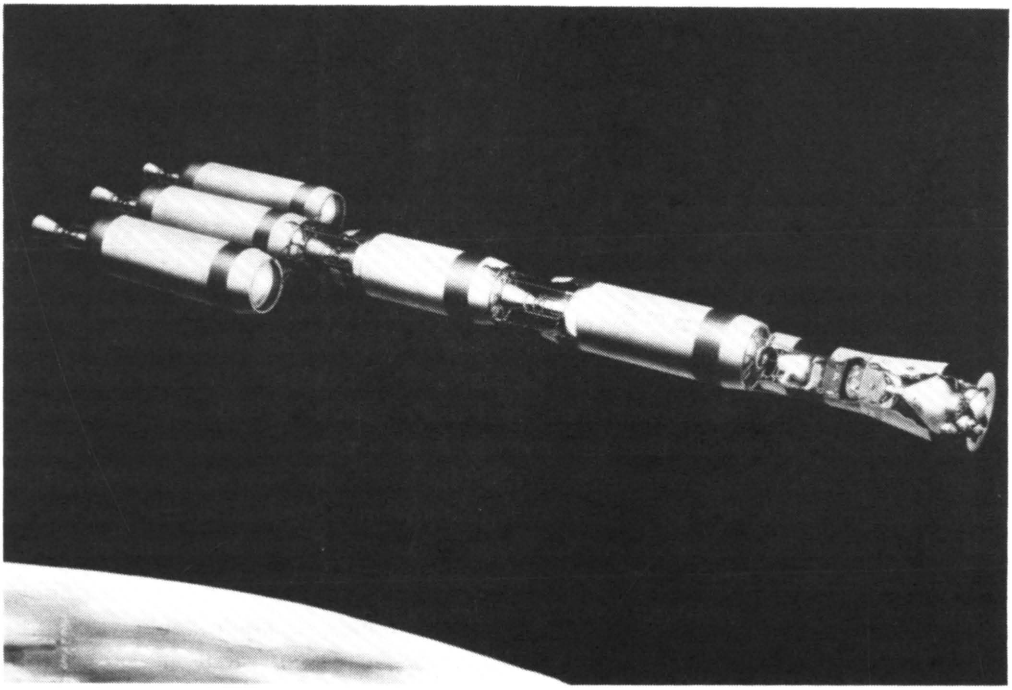


Figure 22 Artist's concept of a nuclear interplanetary modular vehicle.

The conclusions reached were that, with continued technology developments and the evolutionary approach, Manned Planetary Missions in the 1982 through 1986 timeframe were a logical extension from Apollo. The Space Station would become a core for the manned interplanetary mission module, provided a nearly closed or closed life support system were developed. That work was underway at Langley Research Center.

The nuclear rocket was coming along in the NERVA flight test program, and the study results showed that a 200,000 to 250,000 lb thrust NERVA II provided a reduction in total mass over the smaller 75,000 lb thrust NERVA, tested later as a result of reduced funding for NERVA II.

The higher speed Earth return at 40,000 to 60,000 fps required development and demonstration for a crew of six to ten.

There was a need for improved communications, onboard monitoring and subsystem self-healing, improved chemical propulsion, improved space power, and crew conditioning for the 1 to 3-year missions to the near planets. If nuclear rockets at a high specific impulse were available, long-term hydrogen storage would be required for efficient performance, and long missions would be required if oxygen-hydrogen improved chemical propulsion were to be used. The initial weights in Earth orbit would be two to three times larger for opposition missions with all chemical propulsion, but only a fraction more for the longer conjunction class missions with oxygen-hydrogen advanced engines and improved micrometeoroid protection and propellant storage.

Rocketdyne, among others, was pushing ahead with advanced chemical rockets. In 1967, an article was published, on liquid propellant rockets and the future, by Sam Iacobellis, Vern Larson, and Roger Burry.[17]

The plug nozzle and clustered plug, multichamber, or segmented aerodynamic spike were recommended for future applications. The segmented aerospike was further evolved into the linear system, and tests were run by Rocketdyne. Figure 11 showed a later test firing of the segmented injector combustion chamber in a 10 by 10 ft linear rocket system with a 10-segment injector on each side. This approach could be of great value for future launch vehicles, or even on a smaller scale to package planetary landers. A long nozzle extension is avoided with this design. There were other rockets, high pressure oxygen-hydrogen and storable fuels, but that is for a later update by others. The reason these were mentioned was that the confidence in mission success with performance, reliability, and safety had been achieved for the chemical and nuclear rockets and would be demonstrated in tests during the 1967 to 1972 time period.

The question of zero-g operation and health maintenance is still an issue. Although, the desire of Charles A. Berry and myself for two months of zero-g exposure, with conditioning devices and exercise, was more than met on Skylab. Instead of the goal of 56 days we had set, the longest duration on Skylab ran over 83 days, with confirmation of expected health maintenance. The more recent experience by the Soviet cosmonauts is even longer.

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[17] Iacobellis, S. F., Larson, V. R., Burry, R. V., "Liquid-Propellant Rocket Engines: Their Status and Future," *Journal of Spacecraft and Rockets*, Vol. 4, No. 2, December 1967, pp. 1569-1580.

We later discussed the results with others on an international basis. In 1970, at the IAF Congress in Konstanz, Germany, we had agreed to our individual belief that a short trip to Mars of 13 to 15 months would be practical without the need for artificial gravity. Of course, this would be demonstrated by Earth orbital simulation and re-entry, well before the time of the actual mission. However, the belief is stronger today, so the probability of having to carry the complex operations and heavier weights for spin-up, spin-down, and reorientation might well be avoided. Demonstration of this will also be a necessary and logical step.

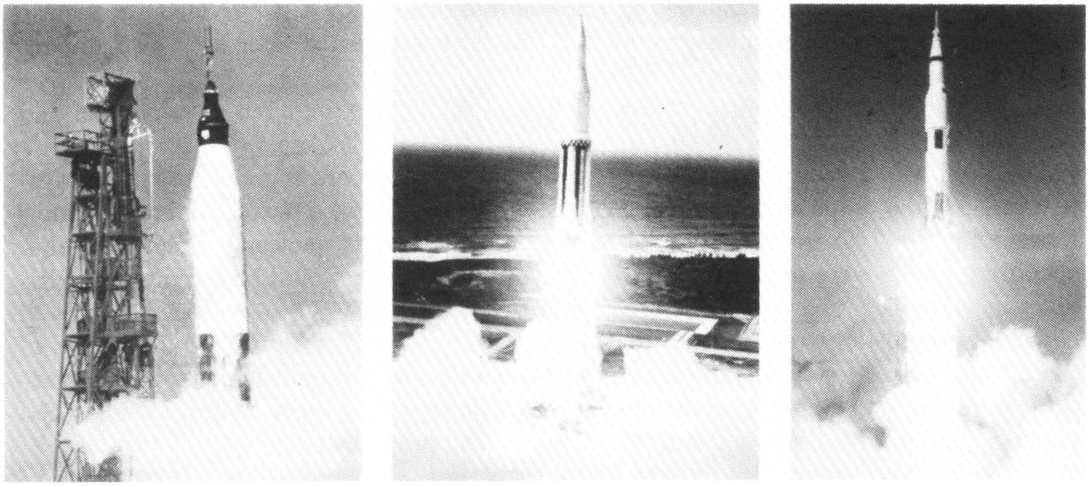

Figure 23 Hardware base for the future manned missions; Mercury Atlas; Saturn I; Saturn V.

Conclusion

Although confidence was much higher on the feasibility of manned planetary mission accomplishment, the reality of budget pressures caused a deferral from a 1982 landing to the 2004 to 2008 time period. This effectively interrupted the concentrated efforts, and 1968 brought a focus on whether there should be a Space Shuttle or a Space Station as the next major step for NASA. With the leadership of Charles J. Donlan, OMSF Deputy Associate Administrator, and Charles W. Mathews, Director, Apollo Applications Program, the studies brought a focus on the decision, and the Space Shuttle was selected. Mueller hoped to sustain the evolution with a Space Station and then manned planetary missions beyond lunar activities. With deferral of the Space Station, my assignment as Director, Advanced Manned Spacecraft, with Earth orbit, lunar extensions, and planetary missions to be considered, had lost a key element in the schedule for these technologically challenging steps. As shown in Figure 23, by 1969 the foundations were laid. Briefly, a strong base was built with evolving capability. We had the Mercury, Saturn, and Apollo experiences and hardware base. The Saturn V with Apollo gave a basic capability (Figure 24). The foundation seemed good, with the advanced chemical and nuclear rocket and power technology program then underway. The literature was full of detailed examinations of future missions.

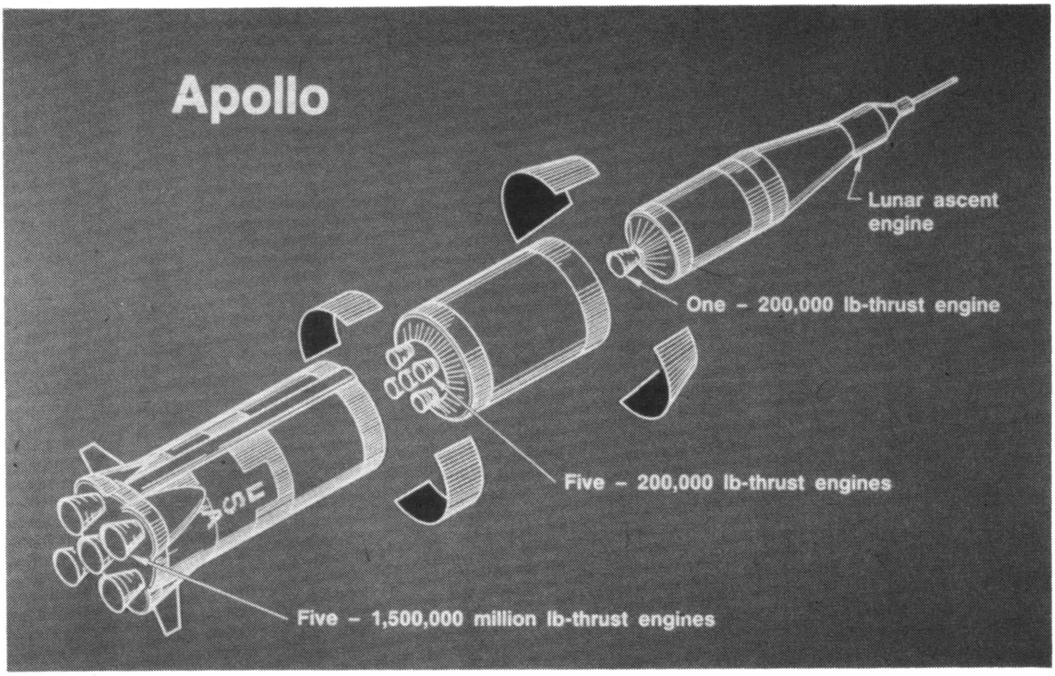

Figure 24 Apollo, Manned mission experience base and foundation for the future.

The focus on manned Mars missions bypassed the Moon as a requirement. Earth orbit to Mars, with propulsive nuclear stages at Earth departure, Mars capture, and Mars departure, and return with high speed entry, had become the baseline for 1982 to 1986. There was a strong hope for zero-gravity operations to be practical to simplify the interplanetary observations and operations, and the technology for development had been identified. The key to any long duration spaceflight for the future would be the environment control and life support demonstrations for manned safety, and the 1 to 3 years of near-Earth operations to verify operational capabilities for Mars capture and surface exploration. The unmanned Mariner and Voyager and the Viking plans were pointed in the right beginning directions. The future was at a confident point. Only later, after Apollo was successful, would it become clear that a continuation to Mars, or even the Space Station, would be deferred for nearly 20 years in the 1970s. Wernher von Braun gave it his best, but The Mars Project would have to wait at least one synodic cycle from 1982 until 2006, or later.

In October 1968, as I left NASA Headquarters for a position in Europe, the changes were evident, but a deferral this long was not really expected. It is only now, 20 years after the first Apollo lunar landing, that the spirit of space exploration is being revived. The need for international cooperation has been stated by many. The importance to all nations is being re-examined. I believe that it will take a program of all the advanced technology the world can cooperatively assemble to be successful with this adventure for all mankind. The required resources will be significant, but the planning started in 1961 at the MSFC, and focused many times by 1968, will provide direction and excitement for effective visions of the future—even into the 21st century, in the framework of current manned space exploration planning.