Chapter 3: EMPIRE and After

> Manned exploration of Mars is the key mission in interplanetary space flight. Man must play a key role in the exploration of Mars because the planet is relatively complex, remote, and less amenable to exploration by unmanned probes than is the [M]oon . . . serious interest in the Manned Mars Mission is springing up . . . with many planning studies being performed by several study teams within [NASA] and within industry . . . . Perhaps the most important result emerging from the present studies is the indication that the Manned Mars Mission can be performed in the relatively near future with equipment and techniques that will for the most part be brought into operation by the Apollo Project . . . the Manned Mars Mission is rapidly taking shape as the direct follow-on to the Apollo Project. (Robert Sohn, 1964)[1]

EMPIRE

Ernst Stuhlinger's Research Projects Division was the smaller of two advanced planning groups in ABMA. The larger, under Heinz Koelle, became the Marshall Space Flight Center's Future Projects Office. Until 1962, Koelle's group focused primarily on lunar programs—Koelle was, for example, principal author of the U.S. Army's 1959 Project Horizon study, which planned a lunar fort by 1967. Koelle's deputy, Harry Ruppe, also supervised a limited number of Mars studies. Ruppe had come from Germany to join the von Braun team in Huntsville in 1957.

In the 1962-1963 period, however, the Future Projects Office spearheaded NASA's Mars planning efforts. As discussed in the last chapter, Marshall's primary focus was on launch vehicles. Advanced planning became important at Marshall in part because of the long lead times associated with developing new rockets. Marshall director von Braun foresaw a time in the mid-1960s when his center might become idle if no goals requiring large boosters were defined for the 1970s. As T. A. Heppenheimer wrote in his 1999 book The Space Shuttle Decision,

> The development of the Saturn V set the pace for the entire Apollo program. This Moon rocket, however, would have to reach an advanced state of reliability before it could be used to carry astronauts. The Marshall staff also was responsible for development of the smaller Saturn IB that could put a piloted Apollo spacecraft through its paces in Earth orbit. Because both rockets would have to largely complete their development before Apollo could hit its stride, von Braun knew that his [C]enter would pass its peak of activity and would shrink in size at a relatively early date. He would face large layoffs even while other NASA [C]enters would still be actively preparing for the first mission to the Moon.[2]

Mars was an obvious target for Marshall's advanced planning. Von Braun was predisposed toward Mars exploration, and landing astronauts on Mars provided ample scope for his Center to build new large boosters. The timing, however, was not good. The Moon would, if all went well, be reached by 1970—but NASA would certainly not be ready to land astronauts on Mars so soon. For one thing, planners needed more data on the Martian environment before they could design landers, space suits, and other surface systems. What Marshall needed was some kind of short-term interim program that answered questions about Mars while still providing scope for new rocket development.

A 1956 paper by Italian astronomer Gaetano Crocco, presented at the Seventh International Astronautical Federation Congress in Rome, offered a possible way out of Marshall's dilemma.[3] Crocco demonstrated that a spacecraft could, in theory, fly from Earth to Mars, perform a reconnaissance Mars flyby, and return to Earth. The spacecraft would fire its rocket only to leave Earth—it would coast for the remainder of the flight. The Mars flyby mission would require less than half as much energy—hence propellant—as a minimum-energy Mars stopover (orbital or landing) expedition. This meant a correspondingly reduced spacecraft weight. Total trip time for a Crocco-type Mars flyby was about one year; for the type of mission von Braun employed in The Mars Project (1953), trip time was about three years.

Flyby astronauts would be like tourists on a tour bus, seeing the sights from a distance in passing but not getting off. Crocco wrote that they would use "a telescope of moderate aperture . . . to reveal and distinguish natural [features] of the planet . . . ." He found, however, that Mars' gravity would deflect the flyby spacecraft's course so it missed Earth on the return leg if it flew closer to Mars than about 800,000 miles. Such a distant flyby would, of course, "frustrate the exploration scope of the trip."

To permit a close flyby without using propellant, Crocco proposed that the close Mars flyby be followed by a Venus flyby to bend the craft's course toward Earth. The Venus flyby would be an exploration bonus, Crocco wrote, allowing the crew to glimpse "the riddle which is concealed by her thick atmosphere." Crocco calculated that an opportunity to begin an Earth-Mars-Venus-Earth flight would occur in June 1971.[4]

From a vantage point at the start of the twenty-first century, a piloted planetary flyby seems a strange notion, yet in the 1960s NASA gave nearly as much attention to piloted Mars flybys as it did to piloted Mars landings. Piloted Mars flybys are now viewed from the perspective of more than three decades of successful automated flyby missions (as well as orbiters and landers). Of the nine planets in the solar system, only Pluto has not been subjected to flyby examination by machines. Robots can do flybys, so why entail the expense and risk to crew of piloted flybys?

Indeed, there were critics at the time the Future Projects Office launched its Early Manned Planetary-Interplanetary Roundtrip Expeditions (EMPIRE) piloted flyby/orbiter study. For example, Maxime Faget, principal designer of the Mercury capsule, coauthored an article in February 1963 which pointed out that a piloted Mars flyby would "demand the least [propulsive] energy . . . but will also have the least scientific value" because of the short period spent near Mars. He added that data on Mars gathered through a piloted flyby would be "in many ways no better than those which might be obtained with a properly operating, rather sophisticated unmanned probe."[5]

The key phrase in Faget's criticism is, of course, "properly operating." When the Future Projects Office launched EMPIRE in May-June 1962, robot probes did not yet possess a respectable performance record. The Mariner 2 probe carried out the first successful flyby exploration of another planet (Venus) in December 1962, midway through the EMPIRE study, but the other major U.S. automated effort, the Ranger lunar program, was off to a shaky start. That series did not enjoy its first success until Ranger 7 in July 1964. The first successful Mars flyby did not occur until a year after that. In fact, one of the early justifications for piloted flybys was that the astronauts could act as caretakers for a cargo of automated probes to keep them healthy until just before they had to be released at the target planet.

Faget also believed that the "overall planning of a total spaceflight program should be based on a logical series of steps." Mercury and Gemini would provide basic experience in living and working in space, paving the way for Apollo, which would, Faget explained, "have the first real mission." After that, NASA should build an Earth-orbiting space station and possibly a lunar base.[6]

For Faget, a piloted Mars flyby mission in the 1970s was a deviation from the model von Braun popularized in the 1950s, which placed the first Mars expedition a century or more in the future. Faget avoided mentioning, however, that he had already been compelled to rationalize Kennedy's politically motivated drive for the Moon. Going by von Braun's logical blueprint, piloted lunar flight should have been postponed until after the Earth-orbiting space station was in place.

For the EMPIRE study, three contractors studied piloted flyby and "capture" (orbiter) expeditions to Mars and Venus. Aeronutronic studied flybys[7]; Lockheed looked at flybys and, briefly, orbiters[8]; and General Dynamics focused on orbiter missions.[9] Aeronutronic's study summed up EMPIRE's three goals:

- Establish a requirement for the Nova rocket development program.
- Provide inputs to the joint AEC-NASA nuclear rocket program, which had been established in 1960 and included a flight test program over which Marshall had technical direction.
- Explore advanced operational concepts necessary for flyby and orbiter missions.[10]

The first two goals were contradictory as far as spacecraft weight minimization was concerned. Seeking justification for a new large rocket provided little incentive for weight minimization, while one of the great attractions of nuclear-thermal rockets was their increased efficiency over chemical rockets, which helped minimize weight. The contractors' tendency not to tightly control spacecraft weight assisted them with crew risk minimization. For example, all three contractors saw fit to include in their

EMPIRE designs heavy spacecraft structures for generating artificial gravity.

Lockheed identified two main Mars flyby trajectory classes, which it nicknamed "hot" and "cool." In the former, the piloted flyby spacecraft would drop inside Earth's orbit (in some launch windows Venus flyby occurred), reach its farthest point from the Sun (aphelion) as it flew by Mars, and return to Earth about 18 months after launch. In the latter, the flyby spacecraft would fly out from Earth's orbit, pass Mars about 3 months after launch, reach aphelion in the Asteroid Belt beyond Mars, and return to Earth about 22 months after launch.

The Aeronutronic team opted for a "hot" trajectory. They assumed a Nova rocket capable of lifting 250 tons to Earth orbit. For comparison, the largest planned Saturn rocket, the Saturn C-5 (as the Saturn V was known at this time) was expected to launch around 100 tons. One Nova rocket would thus be able to launch the entire 187.5-ton Aeronutronic flyby spacecraft into Earth orbit.

Aeronutronic's "design point mission" had the flyby spacecraft leaving Earth orbit between 19 July 1970 and 16 August 1970, using a two-stage nuclear-thermal propulsion system. Aeronutronic's design retained the empty second-stage hydrogen propellant tanks to help shield the command center in the ship's core against radiation and meteoroids. Two cylindrical crew compartments would deploy from the core on booms; then the ship would rotate to provide artificial gravity. An AEC-developed radioisotope power source would deploy on a boom behind the ship. At the end of the flight the crew would board a lifting body Earth-return vehicle and separate from the ship. A two-stage retrorocket package would slow the lifting body to a safe Earth atmosphere reentry speed while the abandoned flyby ship sailed by Earth into orbit around the Sun.

Lockheed also emphasized a rotating design for its EMPIRE spacecraft. In the company's report, the flyby crew rode into orbit on a Saturn C-5 in an Apollo Command and Service Module (CSM) perched atop a folded, lightweight flyby spacecraft. A nuclear upper stage would put the CSM and flyby ship on course for Mars. The CSM would then separate and the flyby spacecraft would automatically unfold two long booms from either side of a hub. The CSM would dock at the end of one boom to act as counterweight for a cylindrical habitation module at the end of the other boom. When the ship rotated, the CSM and habitation module would experience acceleration the crew would feel as gravity.

The weightless hub at the center of rotation would contain chemical rockets for course correction propulsion, a radiation shelter, automated probes, and a dish-shaped solar power system. At Mars, the crew would stop the spacecraft's rotation and release the probes. At journey's end, the crew would separate from the flyby craft in the CSM, fire its rocket engine to slow down, discard its cylindrical Service Module (SM), and reenter Earth's atmosphere in the conical Command Module (CM). The abandoned flyby craft would fly past Earth into solar orbit. Lockheed's report mentioned briefly how a Mars orbiter mission might investigate the Martian moons Phobos and Deimos.[11]

The General Dynamics report was by far the most voluminous and detailed of the three EMPIRE entries, reflecting a real passion for Mars exploration on the part of Krafft Ehricke, its principal author. Ehricke commanded tanks in Hitler's attack on Moscow before joining von Braun's rocket team at Peenemünde. He came to the U.S. in 1945 with the rest of the von Braun team but left in 1953 to take a job at General Dynamics in San Diego, California. There he was instrumental in Atlas missile and Centaur upper-stage development. In the late 1950s he became involved in General Dynamics advanced planning.

Ehricke's team looked at piloted Mars orbiter missions. These would permit long-term study of the planet from close at hand, thus answering critics who complained that piloted flybys would spend too little time near Mars. General Dynamics' 450-day Mars orbiter mission was set to launch in March 1975.

Modularized Mars ships would travel in "convoys" made up of at least one crew ship and two automated service ships. Ship systems would be "standardized as much as practical" so that the crew ship could cannibalize the service ships for replacement parts. If a meteoroid perforated a propellant tank, for example, the crew would be able to replace it with an identical tank from a service ship. The ships would carry small "tugboat" spacecraft for moving propellant tanks and other bulky spares.[12] This approach—providing many spares—helped minimize risk to crew, but would dramatically boost overall expedition weight.

General Dynamics described many possible ship configurations; what follows was typical. The company allotted a nuclear propulsion stage for each major maneuver. After performing its assigned maneuver, the stage would be cast off. Ehricke's team estimated that nuclear engine flight testing would have to occur between May 1968 and April 1970 to support a March 1975 expedition. The M-1 engine system would perform Maneuver-1 of the Mars expedition, escape from Earth orbit (hence its designation). The M-2 engine system would slow the ship so Mars' gravity could capture it into Mars orbit, and M-3 would launch the spacecraft out of Mars orbit toward Earth. The M-4 engine system would slow the ship at Earth at the expedition's end.

Attached to the front of the M-4 stage would be the 10-foot-diameter, 75-foot-long spine module, or "neck," which served two functions: in addition to separating the astronauts from the nuclear engines to minimize crew radiation exposure, it would place distance between the crew and the ship's center of gravity, making the artificial gravity spin radius longer.

General Dynamics opted arbitrarily for providing artificial gravity equal to 25 percent of Earth's surface gravity and estimated that five rotations per minute was the upper limit for crew comfort. As engine systems were cast off, however, the ship's center of rotation would shift forward. For example, before the M-1 maneuver it would be at the aft end of the M-2 engine system, 420 feet from the ship's nose, and at the start of the M-2 maneuver it would be at the front of the M-2 system, 265 feet from the nose. As the ship grew progressively shorter, the spin radius would decrease, forcing faster rotation to maintain the same artificial gravity level. The report proposed joining the aft end of the crew vehicle to the end of a service vehicle during return to Earth, after the M-3 engine system was cast off, in order to place the center of rotation at the joint between the two vehicles and permit an acceptable rotation rate.

The General Dynamics crew ship design included the Life Support Section (LSS) for the eight-person crew. The LSS, which would be tested attached to an Earth-orbital space station beginning in November 1968, again illustrated the intense modularity of the General Dynamics design. The 10-foot-diameter central section would be attached to the front of the spine module and would house the repair shop, food storage, and radiation-shielded Command Module (not to be confused with the Apollo CM). The Command Module would serve double duty as the ship's radiation shelter and "last redoubt" if all other habitable modules were destroyed. Crewmembers would sleep in the Command Module's lower level to reduce their overall radiation exposure. The top level would serve as the crew ship's bridge and the "blockhouse" from which the service vehicles would be remote-controlled.

Two-level, 10-foot-diameter Mission Modules would cluster around the central section to provide additional living space. Individual levels could be sealed off if penetrated by meteoroids, and entire Mission Modules could be cast off if the crew had to reduce spacecraft mass to permit return to Earth—for example, if a large amount of propellant were lost and could not be replaced from the service vehicles. The LSS would also include the Earth Entry Module, an Apollo CM-style conical capsule. In addition to carrying the astronauts through Earth's atmosphere at voyage's end, it would serve as emergency abort vehicle during the M-1 maneuver. The service vehicles would each carry a spare Earth Entry Module.

On the service ships, a hangar for robot probes would replace the LSS. Unlike the Lockheed and Aeronutronic reports, the General Dynamics report treated its automated Mars probes in some detail. They would include the Returner Mars sample collector, a Mars Lander based on technology developed for NASA's planned Surveyor lunar soft-landing probes, Deimos Probe (Deipro) and Phobos Probe (Phopro) Mars moon hard landers based on technology developed for NASA's Ranger lunar probes, the Mars Environmental Satellite (Marens) orbiter, and Floater balloons.[13]

General Dynamics' EMPIRE statement of work specified that it should study piloted Mars-orbital missions; however, enthusiastic Ehricke could not resist inserting an option to carry a small piloted Mars lander. A piloted Mars orbiter must, after all, enter and depart Mars orbit, thus performing all the major maneuvers required of a Mars Orbit Rendezvous landing mission except the landing itself. The Mars Excursion Vehicle lander, which would be based on the automated Returner, would be carried in a service vehicle probe hangar. It would support two people for seven days on Mars.[14] Ehricke's team proposed that a crew test it on the Moon in November 1972.

To get its ships into Earth orbit, Ehricke's team invoked a very large post-Saturn heavy-lift rocket capable of launching 500 tons. Two of these giants would be able to place parts for one ship into orbit so that only one rendezvous and docking would be required to complete assembly. By contrast, if the Saturn C-5 were used, eight launches and seven rendezvous and docking maneuvers would be needed to launch and assemble each General Dynamics Mars ship. The Ehricke team targeted post-Saturn vehicle development to commence in July 1965; the giant rocket would be declared operational in August 1973.

Mars in Texas

NASA's Manned Spacecraft Center (MSC) (renamed the Johnson Space Center in 1973) began as the Space Task Group (STG) at NASA Langley Research Center in Hampton, Virginia, where it was formed in late 1958 to develop and manage Project Mercury. Following Kennedy's May 1961 Moon speech, the STG's responsibilities expanded, so it needed a new home. The STG became the MSC and moved to Houston, Texas.

Maxime Faget became MSC's Assistant Director for Research and Development. He launched the first MSC piloted Mars mission study in mid-1961, but it remained in-house and at a minimal level of effort until late 1962, after Marshall kicked off EMPIRE. MSC's study was supervised by David Hammock, Chief of MSC's Spacecraft Technology Division, and Bruce Jackson, one of his branch chiefs. Chief products of MSC's study were a Mars mission profile unlike any proposed up to that time and the first detailed Mars Excursion Module (MEM) piloted Mars lander design.

Jackson and Hammock presented MSC's Mars plan at the first NASA intercenter meeting focused on interplanetary travel, the Manned Planetary Mission Technology Conference held at Lewis from 21 to 23 May 1963. The NASA Headquarters Office of Applied Research and Technology organized the meeting, which focused mainly on specific technologies, many with applications to missions other than Mars. The "Mission Examples" session, chaired by Harry Ruppe, was relegated to the afternoon session on the last day of the meeting.

Hammock and Jackson presented MSC's mission design publicly for the first time at the American Astronautical Society (AAS) Symposium on the Manned Exploration of Mars in Denver, Colorado, the first non-NASA conference devoted to piloted Mars travel.[15] George Morgenthaler of Martin Marietta Corporation in Denver organized the symposium. As many as 800 engineers and scientists heard 26 papers and a banquet address by Secretary of the Air Force Eugene Zuckert. It was the first time so many individuals from Mars-related disciplines came together in one place, and the last Mars conference as large until the 1980s. Sky & Telescope magazine reported that the "Denver symposium . . . helped narrow the gaps between engineer, biologist, and astronomer."[16]

Hammock and Jackson called Mars "perhaps the most exciting target for space exploration following Apollo . . . because of the possibility of life on its surface and the ease with which men might be supported there."[17] Two of their plans used variations on the MOR mode, but the third, dubbed the Flyby-Rendezvous mode, was novel—it would accomplish a piloted Mars landing while still accruing the weight-minimization benefits of a Crocco-type flyby.

The Flyby-Rendezvous mode would use two separate spacecraft, designated Direct and Flyby. They would reach Earth orbit atop Saturn V rockets. The unpiloted Flyby craft would depart Earth orbit 50 to 100 days ahead of the piloted Direct craft on a 200-day trip to Mars. The Direct craft, which would include the MEM lander, would reach Mars ahead of the Flyby craft after a 120-day flight. The astronauts would then board the MEM and abandon the Direct craft. The MEM would land while the Direct craft flew past Mars into solar orbit. Forty days later the Flyby craft would pass Mars and begin the voyage back to Earth. The crew would lift off in the MEM ascent vehicle and set out in pursuit, boarding the Flyby craft about two days after leaving Mars. Near Earth the astronauts would separate from the Flyby spacecraft in an Earth-return capsule, enter Earth's atmosphere, and land.

One of MSC's MOR plans used aerobraking, while the other relied on propulsive braking. In aerobraking, the lifting-body-shaped Mars spacecraft would skim through Mars' upper atmosphere to use drag to slow down and enter orbit. The Mars surface explorers would separate from the orbiting ship in the MEM and land for a surface stay of 10 to 40 days. They would then lift off in the MEM ascent stage, dock with the orbiting ship, and leave Mars orbit. Earth atmosphere reentry would occur as in the Flyby-Rendezvous mode. Hammock and Jackson's propulsive-braking MOR mission resembled the aerodynamic-braking mode design, except that a chemical or nuclear propulsion stage would place the ship in Mars orbit.

Hammock and Jackson found that the chemical all-propulsive spacecraft design would weigh the most at Earth-orbit departure (1,250 tons), while the nuclear aerobraking design would weigh the least (300 tons). The Flyby-Rendezvous chemical and aerobraking chemical designs would weigh about the same (1,000 tons).

The MEM design for the Houston Center's MOR plans—the first detailed design for a piloted Mars lander—was presented in June 1964 at the next major meeting devoted to Mars exploration, the Symposium on Manned Planetary Missions at Marshall.[18] Philco (formerly Ford) Aeronutronic performed the study between May and December 1963. Franklin Dixon, the presenter, was Aeronutronic's manager for Advanced Space Systems. The design, which the company believed could land on Mars in 1975, was first described publicly in Houston in November 1964 at the American Institute of Astronautics and Aeronautics (AIAA) 3rd Manned Space Flight Conference.

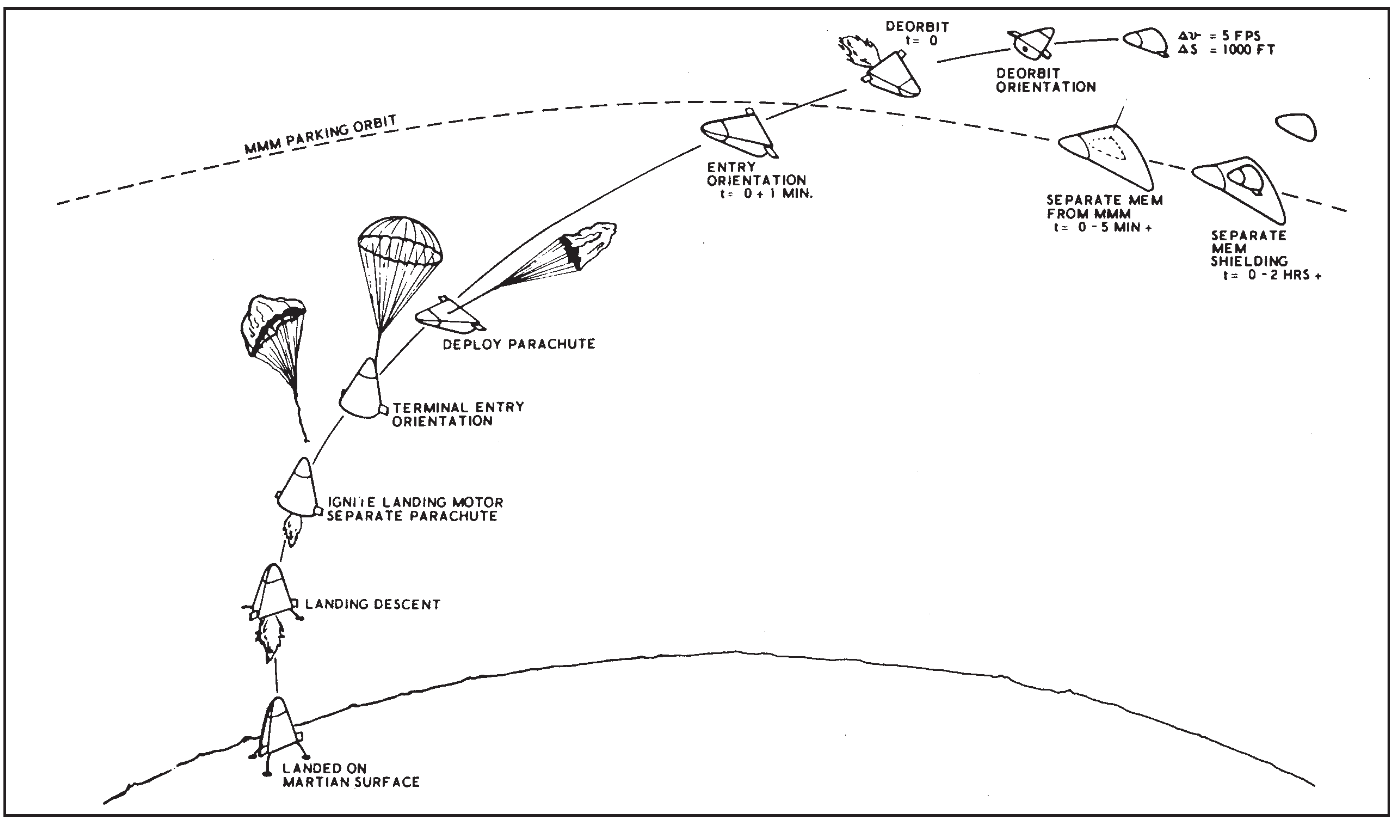

Figure 1—Landing on Mars. Aeronutronic's Mars lander, a lifting body glider, relied on aerodynamic lift to minimize required propellant. The design was based on optimistic estimates of Martian atmospheric density. ("Summary Presentation: Study of a Manned Mars Excursion Module," Franklin Dixon, Proceeding of the Symposium on Manned Planetary Missions: 1963/1964 Status, NASA TM X-53049, Future Projects Office, NASA George C. Marshall Spaceflight Center, Huntsville, Alabama, June 12, 1964, p. 467.)

Dixon pointed out that the chief problem facing Mars lander designers was the lack of reliable Mars atmosphere data, noting that "two orders of magnitude variations in density at a given altitude were possible when comparing Mars atmosphere models of responsible investigators." Aeronutronic settled on a Martian atmosphere comprising 94 percent nitrogen, 2 percent carbon dioxide, 4 percent argon, and traces of oxygen and water vapor, with a surface pressure of 85 millibars (about 10 percent of Earth sea-level pressure). For operation in this atmosphere, Aeronutronic proposed a "modified half-cone" lifting body with two stubby winglets. The Aeronutronic MEM would measure about 30 feet long and 33 feet wide across its tail. The 30-ton MEM would ride to Mars on its mothership's back under a thermal/meteoroid shield which the crew would eject two hours before the Mars landing. The three-person landing party, which would consist of the captain/scientific aide, first officer/geologist, and second officer/biologist, would don space suits and enter the small flight cabin in the MEM's nose. Five minutes before planned deorbit, the MEM would separate from its mothership and retreat to a distance of 1,000 feet. There it would point its tail forward and fire its single descent engine to begin the fall toward Mars' surface.

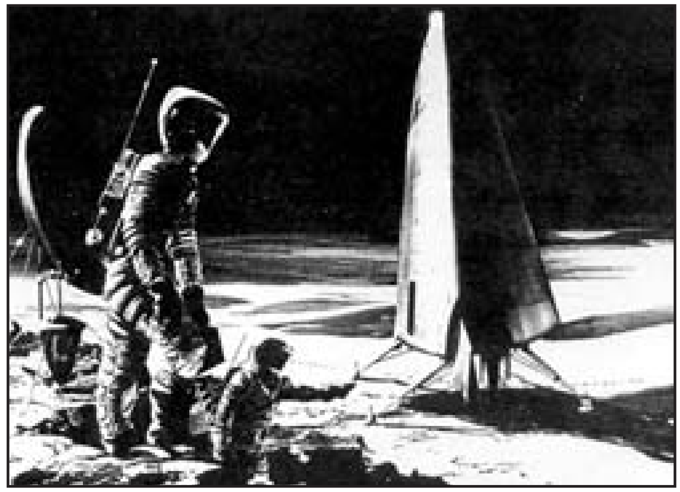

Figure 2—Astronauts exploring Mars near Aeronutronic's lander would take pains to collect biological specimens before terrestrial contamination made study impossible. A large dish antenna (left) would let them share their discoveries with Earth. ("Summary Presentation: Study of a Manned Mars Excursion Module," Franklin Dixon, Proceeding of the Symposium on Manned Planetary Missions: 1963/1964 Status, NASA TM X-53049, Future Projects Office, NASA George C. Marshall Spaceflight Center, Huntsville, Alabama, June 12, 1964, p. 470.)

The MEM's heat-resistant hull would be made largely from columbium, with nickel-alloy aft surfaces. Aeronutronic calculated that friction heating would drive nose temperature to 3,050 degrees Fahrenheit. At Mach 1.5, between 75,000 and 100,000 feet above Mars, a single parachute would be deployed and the MEM would assume a tail-down attitude. The engine would then ignite a second time and the parachute would separate. Aeronutronic's design included enough propellant for an estimated 60 seconds of hover before touchdown on four landing legs with crushable pads.

Aeronutronic attempted to select a MEM landing site using photographs taken by Earth-based telescopes. Theorizing that living things might follow the retreating edge of the melting polar cap in springtime, they suggested that NASA target the MEM to Cecropia at 65 degrees north latitude (this corresponds to Vastitas Borealis north of Antoniadi crater on modern Mars maps).[19] Upon landing, the astronauts would eject shields covering the MEM windows and look out over their landing site to evaluate "local hazards," including any "unfriendly life forms."[20] Mars surface access would be through a cylindrical airlock that lowered like an elevator from the MEM's tail.

Dixon stated that "biological evaluation of life forms is essential for the first purely scientific effort to allow pre-contamination studies before man alters the Mars environment,"[21] implying that little effort would be made to prevent the astronauts from introducing terrestrial microorganisms. Aeronutronic listed "investigate life forms for possible nutritional value"[22] among the tasks of the Mars biology study program. The crew would explore Mars for between 10 and 40 days, spending about 16 man-hours outside the MEM each day.

Aeronutronic's MEM was envisioned as a two-stage vehicle. For return to Mars orbit, the ascent motor would fire, blasting the flight cabin free of the descent stage. Two propellant tanks would be cast off during ascent. After docking with the orbiting mothership, the MEM flight cabin would be discarded.

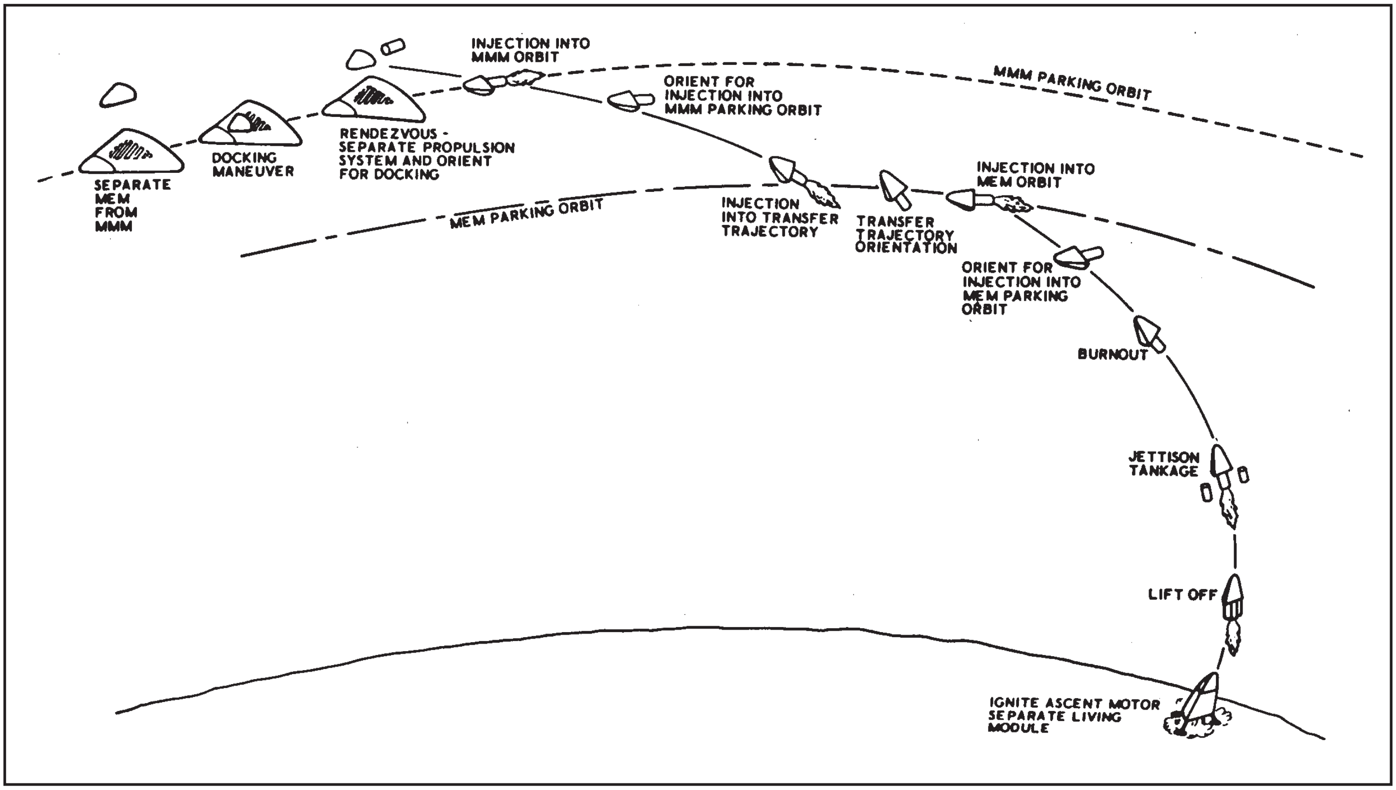

Figure 3—Returning to Mars orbit: Like the Apollo Lunar Module, Aeronutronic's lander design used its descent stage as a launch pad for its ascent stage. Unlike the Lunar Module, it cast off spent propellant tanks as it climbed to orbit. ("Summary Presentation: Study of a Manned Mars Excursion Module," Franklin Dixon, Proceeding of the Symposium on Manned Planetary Missions: 1963/1964 Status, NASA TM X-53049, Future Projects Office, NASA George C. Marshall Spaceflight Center, Huntsville, Alabama, June 12, 1964, p. 468.)

UMPIRE

Every 26 months, an opportunity occurs for a short (six-month) minimum-energy transfer from Earth to Mars. In some opportunities the planet is farther from Earth than in others. This means that in some opportunities the minimum energy necessary to reach Mars is greater than in others. The most difficult Mars opportunities require about 60 percent more energy than the best opportunities. The more energy required to reach Mars, the more propellant a spacecraft must expend. Because of this, a spacecraft launched in a poor Mars opportunity will weigh more than twice as much as one launched in a good Mars opportunity.

The quality of Mars launch opportunities runs through a continuous cycle lasting about 15 years. Not surprisingly, this corresponds to the cycle of astronomically favorable oppositions described in Chapter 1. The EMPIRE studies showed that the best Mars opportunities since 1956 would occur in 1969 and 1971, just as the Apollo lunar goal was reached. Opportunities would become steadily worse after that, hitting a peak in 1975 and 1977, then would gradually improve. The next set of favorable oppositions would occur in 1984, 1986, and 1988.

The Marshall Future Projects Office contracted with General Dynamics/Fort Worth and Douglas Aircraft Company in June 1963 to "survey all the attractive mission profiles for manned Mars missions during the 1975-1985 time period, and to select the mission profiles of primary interest." The study, nicknamed "UMPIRE" ("U" stood for "unfavorable"), was summed up in a Future Projects Office internal report in September 1964.[23]

General Dynamics and Douglas worked independently, but each found that the "best method of alleviating the cyclic variation of weight required in Earth orbit is to

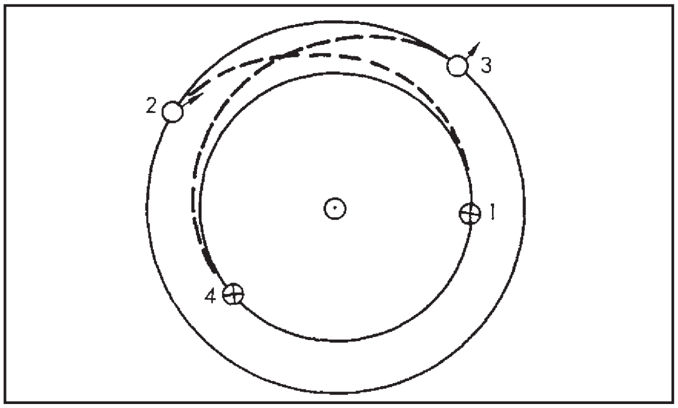

Figure 4—Conjunction-class Mars missions include a low-energy transfer from Earth to Mars, a long stay at Mars, and a low-energy transfer from Mars to Earth. 1 - Earth departure. 2- Mars arrival. 3 - Mars departure. 4 - Earth arrival. (Manned Exploration Requirements and Considerations, Advanced Studies Office, Engineering and Development Directorate, NASA Manned Spacecraft Center, Houston, Texas, February 1971, p. 1-7.)

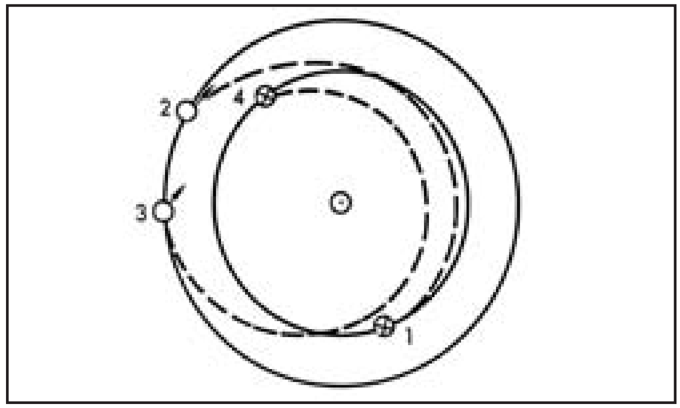

Figure 5—Opposition-class Mars missions offer a short Mars stay but require one high-energy transfer, so they demand more propellant than conjunction-class missions. 1 - Earth departure (low-energy transfer). 2 - Mars arrival. 3 - Mars departure (high-energy transfer). 4 - Earth arrival. (Manned Exploration Requirements and Considerations, Advanced Studies Office, Engineering and Development Directorate, NASA Manned Spacecraft Center, Houston, Texas, February 1971, p. 1-8.)

plan long (900-1100 days) missions."[24] The companies advised that "serious consideration . . . be given to the concept of the first manned landing on Mars being a long term base" rather than a short visit.[25] That is, the two companies recommended making the first Mars expedition conjunction class, not opposition class.

The terms "conjunction class" and "opposition class" refer to the position of Mars relative to Earth during the Mars expedition. In the former, Mars moves behind the Sun as seen from Earth (that is, it reaches conjunction) halfway through the expedition; in the latter, Mars is opposite the Sun in Earth's skies (that is, at opposition) at the expedition's halfway point.

Conjunction-class expeditions are typified by low-energy transfers to and from Mars, each lasting about six months, and by long stays at Mars—roughly 500 days. Total expedition duration thus totals about 1,000 days. The long stay gives Mars and Earth time to reach relative positions that make a minimum-energy transfer from Mars to Earth possible. Von Braun opted for a conjunction-class expedition in The Mars Project.

Opposition-class Mars expeditions have one low-energy transfer and one high-energy transfer separated by a short stay at Mars—typically less than 30 days. Total duration is about 600 days. This was the approach Lewis used in its 1959-1961 study. In the 1960s, most Mars expedition plans were opposition class.

Because they require more energy, opposition-class expeditions demand more propellant. All else being equal, a purely propulsive opposition-class Mars expedition can need more than 10 times as much propellant as a purely propulsive conjunction-class expedition. This adds up, of course, to a correspondingly greater spacecraft weight at Earth-orbit departure.

Therefore, the conjunction-class plan is attractive. However, the long mission duration is problematical, for it demands great endurance and reliability from both machines and astronauts, exposes any crew left in Mars orbit to risk from meteoroids and radiation for a longer period, and requires complex Mars surface and orbital science programs to enable productive use of the 500-day Mars stay.

Mars in California

NASA's Ames Research Center, a former NACA laboratory in Mountainview, California, also became involved in piloted Mars planning in the EMPIRE era. In 1963, Ames contracted with the TRW Space Technology Laboratory to perform a non-nuclear Mars landing expedition study emphasizing weight reduction. Robert Sohn supervised the study for TRW and presented the study's results at the 1964 Huntsville meeting.[26] Sohn's team targeted 1975 for the first piloted Mars landing.

TRW found that the biggest potential weight-saver was aerobraking. For its aerobraking calculations, it used the Rand Corporation's August 1962 "Conjectural Model III Mars Atmosphere" model, which posited a Martian atmosphere consisting of 98.1 percent nitrogen and 1.9 percent carbon dioxide at 10 percent of Earth sea-level pressure. This atmospheric density and composition dictated the spacecraft's proposed shape—a conical nose with dome-shaped tip, cylindrical center section, and skirt-shaped aft section. This shape was based on an Atlas missile nose cone. The TRW team's two-stage, 12.5-ton MEM would also use the nose-cone shape. All else being equal, a version of TRW's spacecraft for the 1975 Mars launch opportunity that used braking rockets at Mars and Earth would weigh 3,575 tons, while the company's aerobraking design would weigh only 715 tons.

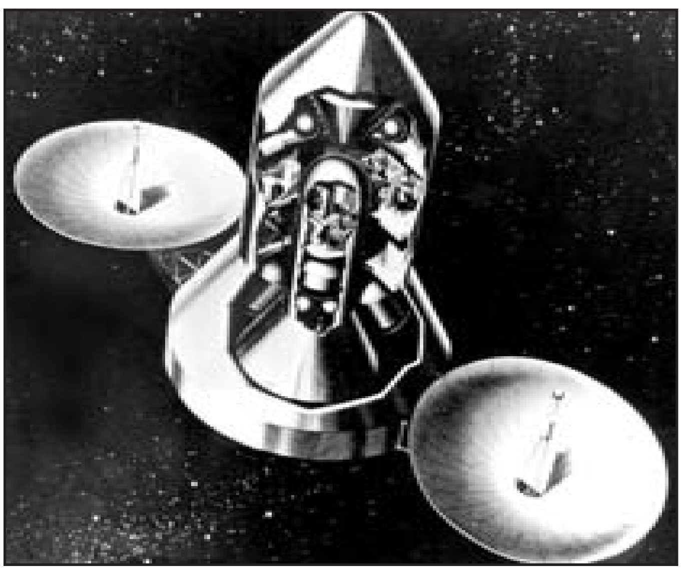

Figure 6—TRW's 1964 Mars ship design, shaped like a missile warhead, sought to minimize required propellant by aerobraking in the Martian atmosphere. This cutaway shows the Mars lander and Earth Return Module inside the spacecraft. ("Summary of Manned Mars Mission Study," Robert Sohn, Proceeding of the Symposium on Manned Planetary Missions: 1963/1964 Status, NASA TM X-53049, Future Projects Office, NASA George C. Marshall Spaceflight Center, Huntsville, Alabama, June 12, 1964, p. 150.)

TRW's Earth aerobraking system was the Earth Return Module, a slender half-cone lifting body carried inside the main spacecraft. A few days before Earth encounter the crew would enter the Earth Return Module and separate from the main spacecraft. The Earth Return Module would enter Earth's atmosphere as the main spacecraft flew past Earth into solar orbit.

The TRW study proposed a lightweight artificial gravity system—a 500-foot tether linking the main spacecraft to the expended booster stage that pushed it from Earth orbit—which would, it calculated, add less than 1 percent to overall spacecraft weight. The resultant assemblage would spin end over end to produce artificial gravity. TRW reported that NASA Langley had used computer modeling to confirm this design's long-term rotational stability.[27]

TRW found that Earth-Mars trajectories designed to reduce spacecraft weight at Earth departure would result in high reentry speeds at Earth return. For example, an Earth Return Module would reenter at 66,500 feet per second at the end of a 1975 Mars voyage, while one returning after a 1980 mission would reenter at almost 70,000 feet per second. TRW found that available models for predicting atmospheric friction temperatures broke down at such speeds.[28] For comparison, maximum Apollo lunar-return speed was "only" 35,000 feet per second.

Reentry speed could be reduced by using rockets. TRW found, however, that including enough propellant to slow the entire spacecraft from 66,500 feet per second to 60,000 feet per second would boost spacecraft weight from 715 tons to 885 tons. Slowing only the Earth Return Module by the same amount would increase overall spacecraft weight to 805 tons.

The study proposed a new alternative—a Venus swing-by at the cost of a modest increase in trip time. A ship returning from Mars in 1975 could, the study found, cut its Earth reentry speed to 46,000 feet per second by passing 3,300 kilometers over Venus's night side. A Venus swingby during flight to Mars in 1973 would allow the ship to gain speed without using propellant and thus arrive at Mars in time to take advantage of a slower Mars-Earth return trajectory. According to TRW's calculations, Venus swingby opportunities occurred at every Mars launch opportunity.[29]

Building on Apollo

By the end of the June 1964 Marshall Mars symposium, early flyby detractor Maxime Faget had come to see some merit in the concept. In a panel discussion chaired by Heinz Koelle, Faget declared that "we should, I think, consider a flyby . . . if we undertake a flyby we really have to face the problems of man flying out to interplanetary distances . . . . I think we have to undertake a program that will force the technology, otherwise we will not get [to Mars] in my lifetime . . . ."[30]

Von Braun, also a panel member, added, that "I think [piloted] flyby missions, particularly flybys involving [automated] landing probes . . . would be invaluable . . . . One such flight, giving us more information on what to expect . . . on the surface of Mars, will be extremely valuable in helping us in laying out the equipment for the landing . . . that would follow the first flyby flight." [31]

Von Braun then implicitly announced an impending shift in NASA advanced planning. "I am also inclined to believe," he said, "that our first manned planetary flyby missions should be based on the Saturn V as the basic Earth-to-orbit carrier. The reason is that, once the production of this vehicle is established and a certain reliability record has been built up, this will be a vehicle that will be rather easy to get." Von Braun's statement acknowledged that a post-Saturn rocket appeared increasingly unlikely.[32] In an outline of future plans submitted to President Lyndon Johnson's Budget Bureau in late November 1964, NASA stated that the post-Saturn rocket should receive low funding priority, and called for post-Apollo piloted spaceflight to be focused on Earth-orbital operations using technology developed for the Apollo lunar landing.[33]

The 1964 decision to use Apollo technology for missions after the lunar landing could be seen as a rejection of post-Apollo piloted Mars missions. Historian Edward Ezell wrote in 1979 that the "determinism to utilize Apollo equipment for the near future was very destructive to the dreams of those who wanted to send men to Mars."[34] As if to emphasize this, the amount of funding applied to piloted planetary mission studies took a nose dive after November 1964. In the 17 months preceding November 1964, $3.5 million was spent on 29 piloted planetary mission studies. Between November 1964 and May 1966, NASA contracted for only four such studies at a cost of $465,000.[35]

Mars planners were not so easily discouraged, however. After EMPIRE, and concurrent with UMPIRE, a Marshall Future Projects Office team led by Ruppe commenced an in-house study to look at using Apollo hardware for Mars exploration. Ruppe's study report, published in February 1965, found that piloted Mars flyby missions would be technically feasible in the mid- to late-1970s using Saturn rockets and other Apollo hardware. [36] The report's flyby spacecraft design used hardware already available or in an advanced state of development. Two RL-10 engines would provide rendezvous and docking propulsion, for example, and an Apollo Lunar Module descent engine would perform course corrections.

A pressurized hangar would protect a modified Apollo CSM during the interplanetary voyage. The hangar would also provide a shirt-sleeve environment so that the astronauts could act as in-flight caretakers for five tons of automated probes, including "landers, atmospheric floaters, skippers, orbiters, and possibly probes . . . to perform aerodynamic entry tests [of] designs and materials."[37] The last of these would, Ruppe wrote, provide data to help engineers design the piloted Mars landers to follow. His report drew on the UMPIRE conclusions when it stated that

> significant reduction of initial mass in Earth orbit is possible if we can use aerodynamic braking at Mars or refueling there, but these methods assume a knowledge about . . . the Martian atmosphere, or about Mars surface resources which just is not available. The first venture, still assuming that we are not very knowledgeable . . . would probably transport 2 or 3 men to the surface of Mars for a few days . . . [at a cost of] a billion dollars per man-day on Mars. If the physical properties of Mars were well known, we could think . . . of the first landing as a long-duration base, reducing cost to less than 10 million dollars per man-day.[38]

The three-person flyby crew would live in a spherical habitat containing a radiation shelter and a small centrifuge for maintaining crew health (the study rejected artificial gravity systems that rotated the entire craft as being too complex and heavy). Twin radioisotope power units on extendible booms would provide electricity.

The mission would require six Saturn V launches and one Saturn IB launch. Saturn V rocket 1 would launch the unpiloted flyby spacecraft; then Saturn V rockets 2 through 5 would launch liquid oxygen tankers. The sixth Saturn V would then launch the Earth-departure booster, a modified Saturn V second stage called the S-IIB, which would reach orbit with a full load of 80 tons of liquid hydrogen but with an empty liquid oxygen tank. Ruppe wrote that solar heating would cause the liquid hydrogen to turn to gas and escape; to ensure that enough remained to boost the flyby craft toward Mars, the S-IIB would have to be used within 72 hours of launch from Earth.

The three astronauts would launch in the modified Apollo CSM on the Saturn IB rocket and then board the flyby spacecraft. They would use the RL-10 engines to guide the flyby craft to a docking with the S-IIB. The oxygen tankers would then dock in turn and pump their cargoes into the S-IIB's empty oxygen tank. Ruppe's flyby craft and booster would weigh 115 tons at Earth-orbit departure. The S-IIB would then ignite, burn to depletion, and detach, placing the flyby craft on course for Mars.

During the flight, the astronauts would regularly inspect and service the automated probes. As they approached Mars, the astronauts would release the probes and observe the planet using 1,000 pounds of scientific equipment. The flyby spacecraft would relay radio signals at a high data rate between the Mars probes and Earth until it passed out of range; then direct communication between Earth and the probes would commence at a reduced data rate.

As Earth grew large again outside the viewports, the flyby astronauts would enter the modified Apollo CSM and abandon the flyby craft. The CSM's propulsion system would slow it to Apollo lunar return speed, then the CM would separate from the SM, reenter, and land. Depending on the launch opportunity used, total mission duration would range from 661 to 691 days.

Even as Ruppe's report was published, the "robot caretaker" justification for piloted Mars flybys was becoming increasingly untenable. On 31 July 1964, the Ranger 7 Moon probe snapped 4,316 images of one corner of Mare Nubium before smashing into the lunar surface as planned. The images showed the Moon to be sufficiently smooth for Apollo landings, and gave the credibility of robot explorers a vital boost. As Ruppe published his report, Mariner 4, launched on 28 November 1964, was making its way toward Mars. Not long after Ruppe published his report, on 20 February 1965, Ranger 8 returned 7,137 images as it plunged toward the Sea of Tranquillity. A month later, Ranger 9 returned 5,148 breathtaking images of the complex 112-kilometer crater Alphonsus.

Beyond providing engineering and scientific justifications for the piloted flyby mission, Ruppe's report tendered a political justification. He wrote:

> From the lunar landing in this decade to a possible planetary landing in the early or middle 1980s is 10 to 15 years. Without a major new undertaking, public support will decline. But by planning a manned planetary [flyby] mission in this period . . . the United States will stay in the game.[39]

That Ruppe felt it necessary in early 1965 to attempt to justify a piloted Mars flyby mission in terms of probable impact on the U.S. domestic political environment is telling, as will be seen in the next chapter.