Chapter 5: Apogee

> Thus, Mr. Vice President—[the s]olar system is opening up before us. With landing on the Moon we know that man can lay claim to the planets for his use. We know further that man will do this. The question is when? We know that [the] U.S. will take part. The question is how soon will we follow up on what we have begun with Apollo? It could be the early 1980s. (Thomas Paine, 1969)[1]

The Big Shot

In a November 1965 article on the next 20 years of space flight, Wernher von Braun sought to convey the Saturn V rocket's immense potential. "One Saturn V alone," he wrote, "will carry twice as much payload as the entire NASA space program up to this point in time. In fact, all the orbiters, all the deep space probes, and all the Mercurys and Geminis that have ever flown would only load the cargo compartment of one Saturn V to 50% of capacity."[2] With Saturn V available, the Moon, Mars, and indeed the entire solar system seemed within reach.

The first of fifteen Saturn V's ordered by NASA to support Project Apollo rolled out to Launch Pad 39A at Kennedy Space Center on 26 August 1967. Designated AS-501, the mighty rocket would launch Apollo 4, the first unmanned test of an Apollo CSM spacecraft. The 24-hour countdown commenced early on 8 November and reached T-0 at 7 a.m. Eastern Standard Time on 9 November. Seen from the KSC press site, three and one-half miles from the pad, the white and black rocket rose slowly at the summit of an expanding mountain of red flame and gray smoke. Thunder from "the Big Shot," as the news media nicknamed AS-501, drowned out television and radio reporters giving live commentary and threatened to collapse their temporary studios.

AS-501 stood 111 meters tall and weighed about 2,830 metric tons at liftoff. Its 10-meter-diameter S-IC first stage carried 2,090 metric tons of kerosene fuel and liquid oxygen oxidizer for its five F-1 rocket engines. They gulped 13.6 metric tons of propellants each second to develop a total of 3.4 million kilograms of thrust at liftoff. AS-501's first stage depleted its propellants in two and one-half minutes at an altitude of 56 kilometers, detached, and crashed into the Atlantic about 72 kilometers from Pad 39A.

The 10-meter-diameter S-II second stage carried 423 metric tons of liquid hydrogen and liquid oxygen for its five J-2 engines, which developed a total of 1 million pounds of thrust. The S-II depleted its propellants after six and one-half minutes at an altitude of 161 kilometers.

The 6.7-meter-diameter S-IVB third stage carried 105 metric tons of liquid hydrogen and liquid oxygen for its single restartable J-2 engine, which fired for two minutes to place the Apollo 4 CSM in a 185-kilometer parking orbit. For an Apollo lunar mission, the J-2 engine would ignite again after one orbit to place the Apollo spacecraft on course for the Moon. For Apollo 4, the third stage restarted after two Earth orbits, 3 hours and 11 minutes after liftoff, putting the stage and spacecraft into an Earth-intersecting ellipse with a 17,335-kilometer apogee (highest point above the Earth).

The Apollo 4 CSM separated from the S-IVB stage, then fired its engine for 16 seconds to nudge its apogee to 18,204 kilometers. The CSM engine ignited a second time 8 hours and 10 minutes into the flight to throw the CM at Earth's atmosphere at a lunar-return speed of about 40,000 kilometers per hour. The CM separated and positioned itself with its bowl-shaped heat shield forward. Heat shield temperature soared to 2,760 degrees Celsius, and CM deceleration reached eight times the pull of Earth's gravity. Three parachutes opened, and the Apollo 4 CM splashed into the Pacific Ocean 10 kilometers from the planned spot, 8 hours and 38 minutes after liftoff.

The success of AS-501/Apollo 4 helped rebuild confidence in NASA's ability to fulfill Kennedy's mandate following the January 1967 fire. President Johnson told reporters that the "successful completion of today's flight has shown that we can launch and bring back safely to Earth the space ship that will take men to the [M]oon." Von Braun told reporters that he regarded "this happy day as one of the three or four highlights of my professional life—to be surpassed only by the manned lunar landing."[3]

"To the Very Ends of the Solar System"

Apollo 4 also cheered Mars planners, for Saturn V had become their launch vehicle of choice following the end of post-Saturn rocket planning in 1964. NASA and AEC engineers developing the NERVA nuclear-thermal rocket engine saw special cause for celebration, for Saturn V was their brainchild's ride into space. The encouragement was well timed. NERVA, which stood for Nuclear Engine for Rocket Vehicle Application, still had no approved mission and had just survived a narrow scrape in a Congress ill-disposed toward funding technology for future space missions.

NERVA was a solid-core nuclear-thermal rocket engine. Hydrogen propellant passed through and was heated by a uranium nuclear reactor, which caused the propellant to turn to plasma, expand rapidly, and vent out of a nozzle, producing thrust. Unlike chemical rockets, no oxygen was required to burn the hydrogen in the vacuum of space. Nuclear-thermal rockets promised greater efficiency than chemical rockets, meaning less propellant was required to do the same work as an equivalent chemical system. This would reduce spacecraft weight at Earth-orbit departure, opening the door to a broad range of advanced missions.

Initial theoretical work on nuclear-thermal rockets began at Los Alamos National Laboratory (LANL) in 1946. The New Mexico laboratory operated under the aegis of the AEC. The joint AEC-U.S. Air Force ROVER nuclear rocket program began in 1955, initially to investigate whether a nuclear rocket could provide propulsion for a massive intercontinental missile. In 1957, the solid-core reactor engine design was selected for ground testing. The test series engine was appropriately named Kiwi, for it was intended only for ground testing, not for flight.

Citing LANL's nuclear rocket work, AEC supporters in the U.S. Senate, led by New Mexico Democrat Clinton Anderson, pushed unsuccessfully in 1958 for the commission to be given control of the U.S. space program. Anderson was a close friend of Senate Majority Leader Lyndon Johnson, who led the Senate Space Committee formed after Sputnik 1's launch on 4 October 1957.[4] In October 1958, the Air Force transferred its ROVER responsibilities to the newly created NASA, and ROVER became a joint AEC-NASA program. AEC and NASA set up a joint Space Nuclear Propulsion Office (SNPO). NASA Lewis—which at this time was performing the first NASA Mars study, an examination of the weight-minimizing benefits of advanced propulsion, including nuclear rockets (see chapter 2)—became responsible within NASA for technical direction of the ROVER program.

In July 1959, the first Kiwi-A test was carried out successfully using hydrogen gas as propellant at the Nuclear Rocket Development Station (NRDS) at Jackass Flats, Nevada, 90 miles from Las Vegas. Senator Anderson arranged for delegates to the Democratic National Convention to be on hand for the second Kiwi-A test in July 1960. At the Convention, Anderson arranged for a plank on nuclear rocket development to be inserted into the Democratic Party platform.[5] In October 1960, the third Kiwi-A test using hydrogen gas showed promising results, building support for a contract to be issued for development of a flight-worthy nuclear rocket engine.

The Democratic ticket of John Kennedy and Lyndon Johnson narrowly defeated Dwight Eisenhower's Vice President, Richard Nixon, in the November 1960 election. Anderson took over as head of the Senate Space Committee. President Kennedy embraced space after the Soviet Union helped end his White House honeymoon by launching the first human into space on 12 April 1961. He charged Johnson with formulating a visible, dramatic space goal the United States might reach before the Soviets. Johnson suggested landing an American on the Moon.

Before a special joint session of Congress on 25 May 1961, Kennedy called for an American astronaut on the Moon by the end of the 1960s. Then he asked for "an additional $23 million, together with $7 million already available, [to] accelerate development of the ROVER nuclear rocket. This gives promise of some day providing a means for even more exciting and ambitious exploration of space, perhaps beyond the Moon, perhaps to the very ends of the solar system . . . ."[6]

Because of Kennedy's speech, FY 1962 saw the real start of U.S. nuclear rocket funding. NASA and the AEC together were authorized to spend $77.8 million in FY 1962. Funding in the preceding 15 years had totaled about $155 million.

In July 1961, Aerojet-General Corporation won the contract to develop a 200,000-pound-thrust NERVA flight engine. NERVA Phase 1 occurred between July 1961 and January 1962, when a preliminary design was developed and a 22.5-foot NERVA engine mockup was assembled. At the same time, NASA Marshall set up the Nuclear Vehicle Projects Office to provide technical direction for the Reactor-In-Flight-Test (RIFT), a Saturn V-launched NERVA flight demonstration planned for 1967.

The first Kiwi-B nuclear-thermal engine ground test using liquid hydrogen (December 1961) ended early after the engine began to blast sparkling, melting bits of uranium fuel rods from its reactor core out of its nozzle. Though the cause of this alarming failure remained unknown, Lockheed Missiles and Space Company was made RIFT contractor in May 1962. In early summer 1962 the Marshall Future Projects Office launched the EMPIRE study, motivated in part by a desire to develop missions suitable for nuclear propulsion. Hence, early on NERVA became closely identified with Mars.

The second and third Kiwi-B ground tests (September 1962 and November 1962) failed in the same manner as the first. Failure cause remained uncertain, but vibration produced as the liquid hydrogen propellant flowed through the reactor fuel elements was suspected.

The PSAC and the White House Budget Bureau allied against the nuclear rocket program following the third Kiwi-B failure. They opposed funding for an early RIFT flight test because they saw it as a foot in the door leading to a costly piloted Mars mission, and because they believed the technology to be insufficiently developed, something the Kiwi-B failures seemed to prove. Kennedy himself intervened in the AEC-NASA/Budget Bureau-PSAC deadlock, visiting Los Alamos and the NRDS in December 1962.

On 12 December 1962, Kennedy decided to postpone RIFT until after additional Kiwi-B ground tests had occurred, explaining that "the nuclear rocket . . . would be useful for further trips to the [M]oon or trips to Mars. But we have a good many areas competing for our available space dollars, and we have to channel it into those programs which will bring a result—first, our [M]oon landing, and then consider Mars." Kennedy's decision marked the beginning of annual battles to secure continued nuclear rocket funding.[7]

At the May 1963 AAS Mars symposium in Denver, SNPO director Harold Finger pessimistically reported that nuclear rockets were not likely to fly until the mid-1970s.[8] However, the fourth Kiwi-B test, in August 1963, revealed that vibration had indeed produced the earlier core failures. The problem had a relatively easy solution, so NASA, AEC, and nuclear engine supporters in Congress became emboldened. They pressed Kennedy to reverse his December 1962 decision.

William House, Aerojet-General's Vice President for Nuclear Rocket Engine Operations, felt sufficiently optimistic in October 1963 to tell the British Interplanetary Society's Symposium on Advanced Propulsion Systems that a Saturn V would launch a 33-foot-diameter RIFT test vehicle to orbit in 1967. He predicted that one NERVA stage would eventually be able to inject 15 tons on direct course to Mars, or 3 tons on a three-year flight to distant Pluto.[9]

Kennedy never had the opportunity to reconsider his RIFT decision. Following the young President's November 1963 assassination, President Johnson took up the question. With an eye to containing government expenditures, he canceled RIFT in December 1963 and made NERVA a ground-based research and technology effort.

The year 1964 saw the successful first ground test of the redesigned Kiwi-B engine and the first NERVA start-up tests. It also marked the nuclear rocket program's peak funding year, with a joint AEC-NASA budget of $181.1 million. Though NERVA was grounded, work proceeded under the assumption that success would eventually lead to clearance for flight.

The nuclear rocket program budget gradually declined, dropping to $140.3 million in FY 1967. NERVA did not come under concerted attack, however, until the bitter battle over the FY 1968 NASA budget. In August 1967, Congress deleted all advanced planning and Mars Voyager funds from NASA's FY 1968 budget because it saw them as lead-ins to a costly piloted Mars program, and Johnson refused to save them (see chapter 4). NERVA funding was eliminated at the same time.

Voyager had to wait until FY 1969 to be resurrected as Viking. Through Anderson's influence, however, NERVA did better—the nuclear rocket program was restored with a combined AEC-NASA budget of $127.2 million for FY 1968. As if to celebrate Anderson's intervention, the NRX-A6 ground test in December 1967 saw a NERVA engine operate for 60 minutes without a hitch.

Boeing's Behemoth

In January 1968, the Boeing Company published the final report of a 14-month nuclear spacecraft study conducted under contract to NASA Langley. The study was the most detailed description of an interplanetary ship ever undertaken.[10] As shown by the EMPIRE studies, the propellant weight minimization promised by nuclear rockets tended to encourage big spacecraft designs. In fact, Boeing's 582-foot long Mars cruiser marked the apogee of Mars ship design grandiosity.

At Earth-orbital departure, Boeing's behemoth would include a 108-foot-long, 140.5-ton piloted spacecraft and a 474-foot-long propulsion section made up of five Primary Propulsion Modules (PPMs). The entire spacecraft would weigh between 1,000 and 2,000 tons, the exact weight being dependent upon the launch opportunity used. Each 33-foot-diameter, 158-foot-long PPM would hold 192.5 tons of liquid hydrogen. A 195,000-pound-thrust NERVA engine with an engine bell 13.5 feet in diameter would form the aft 40 feet of each PPM. The six-person piloted spacecraft would consist of a MEM lander, a four-deck Mission Module, and an Earth Entry Module.

Three PPMs would constitute Propulsion Module-1 (PM-1); two would constitute PM-2 and PM-3, respectively. PM-1 would push the ship out of Earth orbit toward Mars, then detach; PM-2 would slow the ship so that Mars' gravity could capture it into orbit, then it would detach; and PM-3 would push the ship out of Mars orbit toward Earth. At Earth, the crew would separate in the Apollo CM-based Earth Entry Module, reenter Earth's atmosphere, and splash down at sea.

Six uprated Saturn V rockets would place parts for Boeing's Mars ship in Earth orbit for assembly. Assembly crews and the flight crew would reach the spacecraft in Apollo CSMs launched on Saturn IB rockets. The 470-foot-tall uprated Saturn V, which would include four solid-fueled strap-on rockets, would

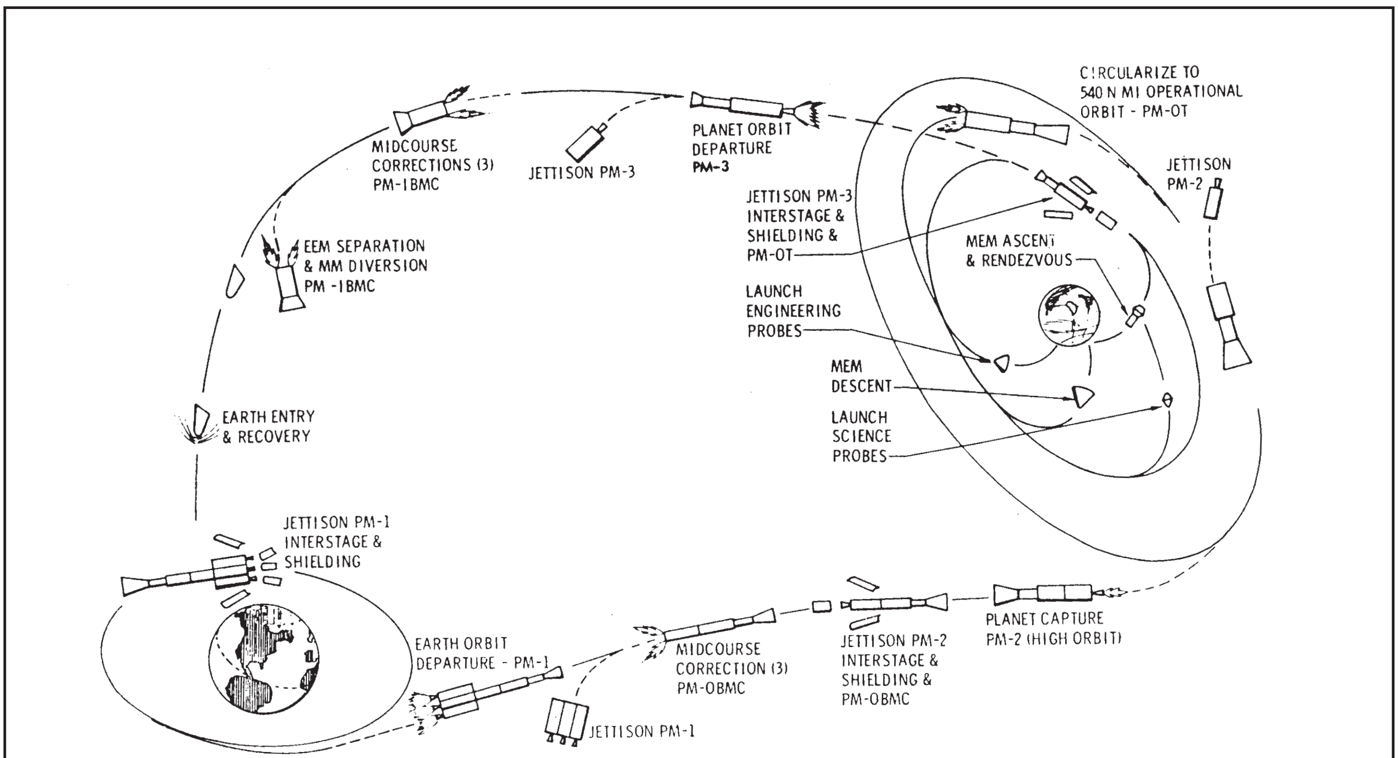

Figure 12—In January 1968, Boeing proposed this complex Mars expedition plan using nuclear rockets and an opposition-class trajectory. The company's Mars ship would measure nearly 200 meters long and support a crew of six. (Integrated Manned Interplanetary Spacecraft Concept Definition, Vol. 1, Summary, D2-113544-1, Boeing Company, Aerospace Group, Space Division, Seattle, Washington, p. 7.)

be capable of delivering 274 tons to a 262-mile circular Earth orbit. Boeing envisioned modifying KSC Saturn V launch pads 39A and 39B to launch the uprated Saturn V, and building a new Pad 39C north of the existing pads.

The company's report listed opportunities for nine Venus-swingby, one conjunction-class, and five opposition-class Mars expeditions between November 1978 and January 1998. The conjunction-class mission would last 900 days, while the Venus-swingby and opposition-class missions would last from 460 to 680 days.

Boeing envisioned using the MOR mission plan NASA Lewis used in its 1959-1961 studies. The MEM for descending to Mars from Boeing's orbiting Mars ship was designed for MSC between October 1966 and August 1967 by North American Rockwell (NAR), the Apollo CSM prime contractor.[11] NAR's MEM report, published the same month as the Boeing report, was the first detailed MEM study to incorporate the Mariner 4 results. Cost minimization was a factor in NAR's MEM design. The company proposed a 30-foot-diameter lander shaped like the conical Apollo CM. The Apollo shape, it argued, was well understood and thus would require less costly development than a novel design.

The lightest NAR MEM (33 tons) would carry only enough life support consumables to support two people on Mars for four days, while the heaviest (54.5 tons) was a four-person, 30-day lander. Like the Apollo Lunar Module (and many previous MEM designs), NAR's MEM design included a descent stage and an ascent stage. The MEM would contain two habitable areas—the ascent capsule and the descent stage lab compart-

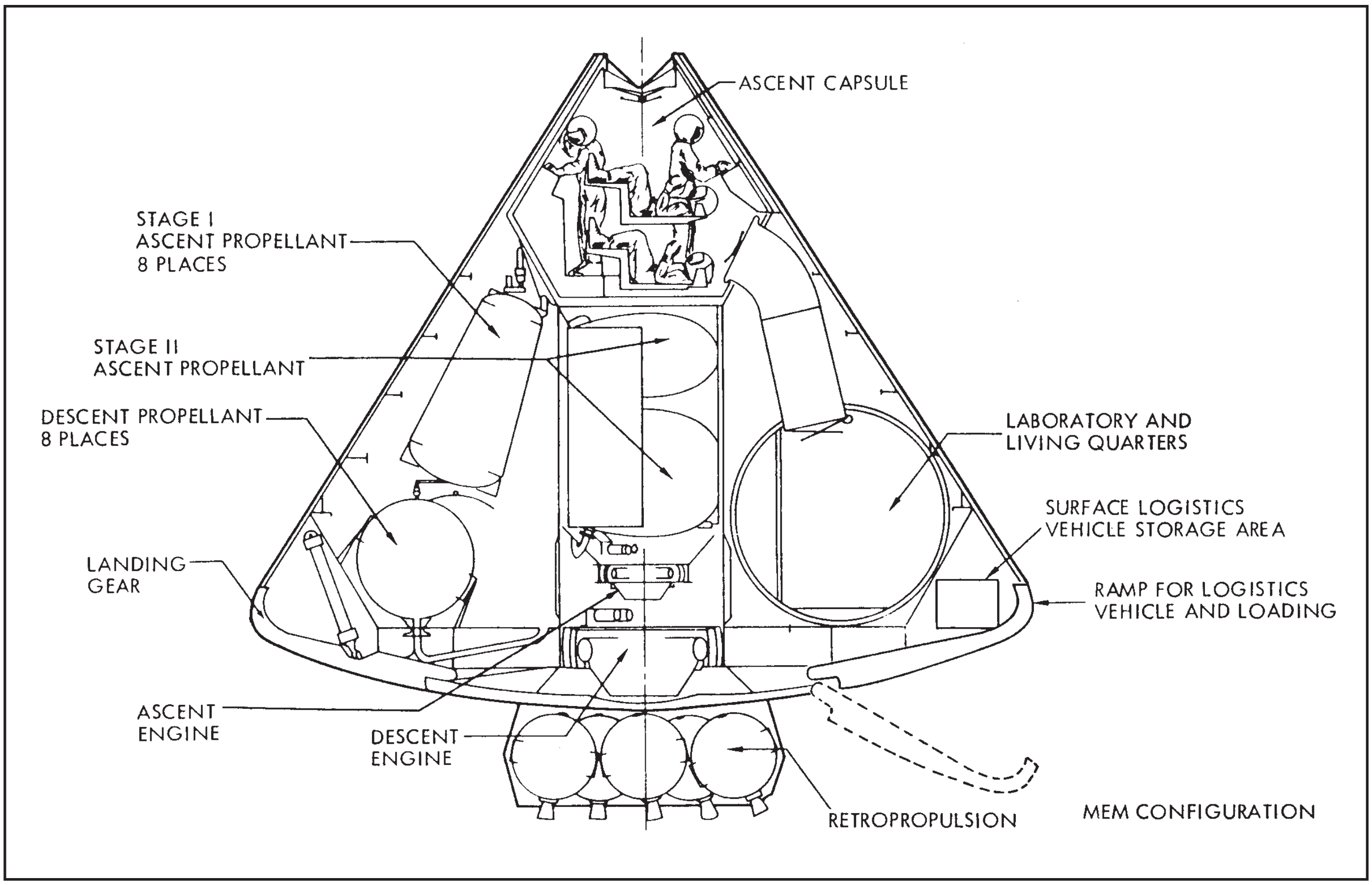

Figure 13—Cutaway of North American Rockwell's 1968 Mars lander. Based on the Apollo Command Module shape, its design incorporated new Mars atmosphere data gathered during the 1965 Mariner 4 automated Mars flyby. (Manned Exploration Requirements and Considerations, Advanced Studies Office, Engineering and Development Directorate, NASA Manned Spacecraft Center, Houston, Texas, February 1971, p. 5-3.)

ment. The ascent capsule would include an Apollo docking unit for linking the MEM to the mothership, and the lab compartment would include an airlock for reaching the Martian surface.

The MEM's Apollo-style bowl-shaped heat shield would protect it from friction heating during Mars atmosphere entry. To reduce cost, NAR proposed to develop a single heat shield design for both flight tests in Earth's atmosphere and Mars atmosphere entry. This meant, of course, that the shield would be more robust, and thus heavier, than one designed specifically for Mars atmosphere entry. During Mars atmosphere entry the crew would feel seven Earth gravities of deceleration.

After atmospheric entry, the MEM would slow its descent using a drogue parachute followed by a larger ballute (balloon-parachute). At an altitude of 10,000 feet the ballute would detach. The MEM's descent engine would fire; then two of the astronauts would climb from their couches to stand at controls and pilot the MEM to touchdown. The company proposed using liquid methane/liquid oxygen propellants that would

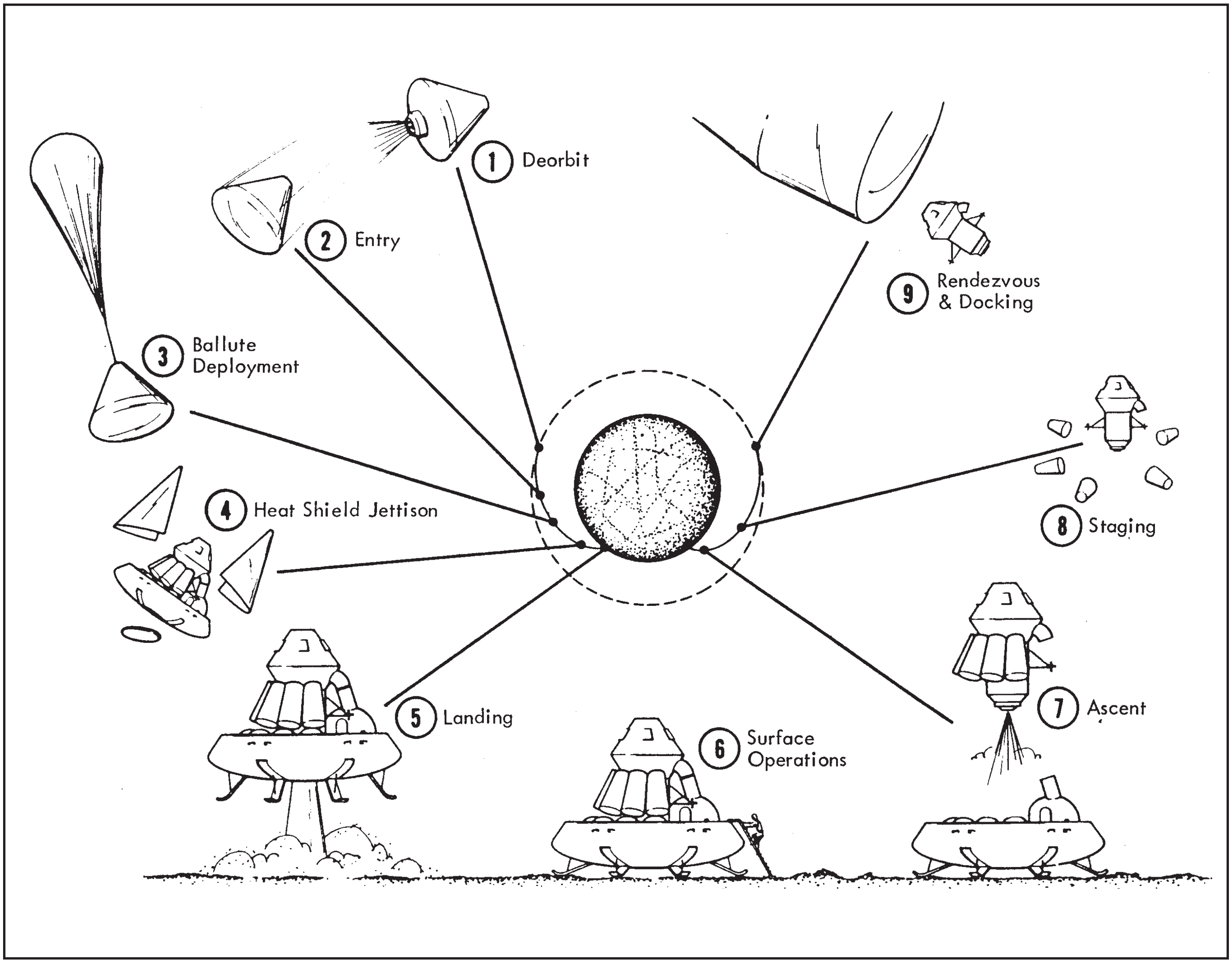

Figure 14—North American Rockwell's plan for landing on Mars and returning to Mars orbit. The company's lander, a two-stage design, would support up to four astronauts on Mars for up to 30 days and return to the orbiting mothership with up to 300 pounds of rocks. (Integrated Manned Interplanetary Spacecraft Concept Definition, Vol. 4, System Definition, D2-113544-4, Boeing Company, Aerospace Group, Space Division, Seattle, Washington, January 1968, p. 145.)

offer high performance but not readily boil off or decompose. The MEM would carry enough propellants for two minutes of hover. Its six landing legs would enable it to set down safely on a 15-degree slope.

For return to the mothership in Mars orbit, the crew would strap into the ascent capsule with their Mars samples and data. The ascent stage engine would ignite, burning methane/oxygen propellants from eight strap-on tanks. The ascent stage would blast away from the descent stage, climb vertically for five seconds, then pitch over to steer toward orbit. Once empty, the strap-on tanks would fall away; the ascent engine would then draw on internal tanks to complete Mars orbit insertion and rendezvous and docking with the mothership.

NAR had MEM development commencing in 1971 to support a 1982 Mars landing. The company envisioned a MEM flight test program using six MEM test articles and a range of rockets, including three two-stage Saturn Vs. The 1979 piloted MEM entry and landing test, for example, would have a fully configured MEM launched into Earth orbit on a two-stage Saturn V with a piloted CSM on top. In orbit the CSM would detach, turn, and dock with the MEM for crew transfer. The crew would then cast off the CSM and fly the MEM to landing on Earth.

Boeing scheduled the first Mars expedition for 1985-1986, with Mars expedition contract awards in 1976, and Mars hardware tests in low-Earth orbit beginning in 1978. NAR estimated development cost of its MEM at $4.1 billion, while Boeing's study placed total Mars program cost at $29 billion.

End of an Era

As Aerospace Technology magazine put it in May 1968, "If the political climate in Washington for manned planetary missions is as bleak as the initial congressional budget hearings indicate, the [NAR MEM] study is . . . likely to be the last of its type for at least a year."[12] In fact, it was the last until the late 1980s. As the battle over the FY 1968 budget during the summer of 1967 made abundantly clear, a $29-billion Mars program enjoyed support in neither the Johnson White House nor the Congress. Events in 1968 made even more remote the possibility that the U.S. might take on a new Apollo-scale space commitment.

On 30 January 1968, immediately after Boeing and NAR published their reports, North Vietnam invaded South Vietnam on the eve of Tet, the lunar new year. Though repulsed by U. S. and South Vietnamese forces, the large-scale offensive drove home to Americans and the Johnson White House that American involvement in Indochina would likely grow before it shrank.

At the end of May, the Defense Department asked for a $3.9-billion supplemental appropriation. Of this, $2.9 billion was earmarked to pay for the Tet Offensive—the Defense Department needed, for example, to replace 700 destroyed helicopters—while $1 billion would beef up U.S. defenses in South Korea following the Pueblo incident, in which North Korea seized a U.S. ship.[13] A total of 14,592 American soldiers had been killed in Vietnam by the close of 1968, by which time the total U.S. forces in Indochina stood at more than half a million.

There was also trouble at home. Johnson was a political casualty of Tet and other troubles shaking the nation. On 31 March 1968, he announced that he would not stand for reelection. On 4 April 1968, civil rights leader Martin Luther King Jr. was gunned down in Memphis, Tennessee; his death triggered racial violence across the country. That same month students at Columbia University in New York seized buildings to protest the Vietnam War in one of more than 200 major demonstrations at some 100 universities during the year. On 6 June 1968, Democratic Party front-runner Robert Kennedy was shot in Los Angeles. In August, antiwar protesters disrupted the Democratic National Convention.

Near the start of the FY 1969 budget cycle in early February 1968, as American and South Vietnamese forces pushed back the North Vietnamese, James Webb testified to the House Space Committee, where a $4 billion FY 1969 NASA budget was, according to one committee staffer, a "fait accompli." He reminded the Committee that

> NASA's 1969 authorization request, at the $4.37-billion level, is $700 million below the amount requested last year. NASA expenditures for Fiscal 1969 will be down $230 million

> from this year, $850 million from last year, and $1.3 billion less than in Fiscal 1966. The NASA program has been cut. I hope you will decide it has been cut enough . . . .[14]

In testimony to the Senate Appropriations Committee in May, after the House approved a $4-billion NASA budget, Webb told the Senators that President Johnson had directed him to acquiesce to the cut, then expressed concern over NERVA's future.[15] The nuclear rocket stayed alive in early June 1968 only after a lengthy Senate floor battle waged by Howard Cannon (Democrat-Nevada), whose state included the NRDS. Webb told the Senate Appropriations Committee later that month that the $4-billion NASA budget would require halting Saturn V production for a year and canceling NERVA. In an attempt to rally NERVA supporters to approve their engine's ride into space, he added that "to proceed with NERVA while terminating Saturn V cannot be justified."[16]

On 1 August 1968, Webb turned down George Mueller's request to make long lead-time purchases for manufacture of two more Saturn V's, the sixteenth and seventeenth in the series. He informed the OMSF chief that production would halt with the fifteen already allotted for the Apollo lunar program.[17] A week later Webb told Congress that "the future is not bright" for the Saturn rockets.[18]

At a White House press conference on 16 September 1968, Webb announced that he would step down after nearly 8 years as NASA Administrator. He told journalists that he left the Agency "well prepared . . . to carry out the missions that have been approved . . . . What we have not been able to do under the pressures on the budget has been to fund new missions for the 1970s . . . ."[19]

Thomas Paine Takes Charge

The final FY 1969 NASA budget was $3.995 billion, making it the first below $4 billion since 1963. This was more than $370 million below NASA's request, but almost exactly what Johnson had told Webb to accept in May. The Saturn V production line went on standby. The nuclear rocket program received $91.1 million, of which $33.1 million came from NASA funds.

NASA Deputy Administrator Thomas Paine became Acting NASA Administrator upon Webb's departure on 7 October. Webb, a 25-year veteran of Federal government service, had described Paine as one of a "new breed of scientist-administrators making their way into government."[20] Formerly director of General Electric's TEMPO think tank, he had entered government service through a program for recruiting managers from industry. Paine had become Webb's Deputy Administrator in March 1968, replacing Robert Seamans. When he took over NASA from Webb, Paine had seven months of Federal government experience.

Immediately after taking NASA's reins, Paine told the Senate Space Committee that he would seek a $4.5 billion NASA budget in FY 1970, followed by annual increases leading to a $5.5-billion budget in FY 1975. Paine said that he wanted a six- to nine-man space station serviced by Apollo CSMs in the mid-1970s. George Mueller also testified, calling for a $4.5-billion NASA budget in FY 1970. He said that this was necessary to avoid a gap in piloted flights after the Apollo lunar landings.[21]

On 30 October 1968, the Budget Bureau completed a "highlights" paper on "major aspects of National Aeronautics and Space operations which warrant attention at an early point in 1969" for President Johnson's successor. The paper noted that "pressure is mounting to budget significant sums for follow-on manned space flight activities." It stated that "the advantages of nuclear propulsion do not begin to approximate the costs for missions short of a manned Mars landing. No national commitment has been made to undertake this mission[,] which would cost $40-$100B[illion] . . . nevertheless, pressures are strong in NASA, industry, and Congress to undertake the development of the nuclear rocket."[22]

Republican Richard Nixon defeated Hubert Humphrey, Johnson's Vice President, for the White House in November. Though Apollo 7 had triumphantly returned NASA astronauts to orbit in October, space had been overshadowed as a campaign issue by the war, the economy, student revolt, and many other "down-to-Earth" issues. Nixon had promised a tax cut, which promised to place yet more pressure on Federal agencies to cut spending.

Six weeks after the election, in the Johnson Administration's twilight days, space flight won back the front page. On 21 December 1968, Apollo 8 astronauts Frank Borman, James Lovell, and William Anders became the first people to launch into space on a Saturn V rocket and the first humans to orbit a world other than Earth. The Apollo 8 CSM dropped behind the Moon early on 24 December and fired its engine for four minutes to slow down and allow the Moon's gravity to capture it into lunar orbit.

Thirty-five minutes after the spacecraft passed beyond the Moon's limb, it emerged from the other side. As it did, Earth rose into view over the hilly lunar horizon, and the crew snapped their planet's picture. Lovell described the Moon to people on Earth as "essentially gray, no color; looks like plaster of Paris or sort of grayish deep sand."[23] Later, in one of the most memorable moments of the space age, the crew took turns reading to the world from the biblical book of Genesis. Early on Christmas Day 1968, after 10 lunar orbits, the Apollo 8 crew fired their CSM's engine to escape the Moon's gravitational pull and fall back to Earth.

Originally Apollo 8 was intended as an Earth-orbital test of the Saturn V and the Lunar Module Moon lander, but the Lunar Module was not ready. Sending Apollo 8 to orbit the Moon was first proposed in August 1968 by George Low, director of the Apollo Spacecraft Program Office at MSC, and was eagerly promoted by Tom Paine despite initial skepticism from NASA Administrator Webb.[24] Because the crew lacked a Lunar Module, they lacked the backup propulsion and life support systems it could provide. These would come in handy during James Lovell's next flight to the Moon on Apollo 13 in April 1970.

The image of Earth rising into view over the pitted gray Moon featured prominently on end-of-year magazines and newspapers. It formed a counterpoint of fragile beauty and bold human achievement that accentuated the war, dissent, and assassinations of 1968. This was reflected in Nixon's first inaugural speech on 20 January 1969:

> We have found ourselves rich in goods, but ragged in spirit; reaching with magnificent precision for the Moon, but falling into raucous discord on Earth. We are caught in war, wanting peace. We are torn by divisions, wanting unity.[25]

Democrat Paine submitted his resignation pro forma when Republican Nixon took office. Surprisingly, Nixon did not accept it. Though Aviation Week & Space Technology reported that Nixon was impressed by the job Paine had done since coming to NASA, the real reasons were apparently less meritorious.[26] Nixon had never shown much interest in space and could find no ideologically suitable replacement who wanted to head NASA. He may also have desired to have a Democrat in place to blame if the Kennedy/Johnson Apollo program failed.[27] Paine was confirmed as NASA Administrator in March 1969.

Being a Democrat in a Republican administration was enough to leave Paine in a weak position. On top of that, however, Paine was a Washington neophyte. Webb had been wily, a Washington insider given to deal-making; Paine was an idealist given to emotive arguments. Paine was, according to NASA Historian Roger Launius, "every bit as zealous for his cause as had been his namesake." Furthermore, he was "unwilling to compromise and . . . publicly critical of the [Nixon] administration's lack of strong action" with regards to space.[28] He excoriated his Center directors for lacking boldness. He considered this disloyal to his view of America, the expansive country, ready to tackle any challenge.[29]

To Paine, the late 1960s was not a time to try men's souls. He complained to the Washington Evening Star of "what I would call almost a national hypochondria . . . in many ways crippling some of the forward-looking things we're able to do . . . I feel that one of the very highest priority matters is the war on poverty and the problems of the cities. But in the meantime we're making . . . a lot of progress in the civil rights area and really, this nation is a good deal healthier than we're giving it credit for today."[30]

Paine tried to use the excitement generated by Apollo 8 as a lever to gain Nixon's commitment to an expansive post-Apollo future for NASA. His efforts were countered by voices counseling caution. Nixon had appointed "transition committees" to help chart a course for his new Administration. On 8 January 1969, the Task Force on Space transition committee, chaired by Charles Townes, handed in its report. The Task

Force, made up of 13 technologists and scientists, recommended against new starts and proposed a steady NASA budget of $4 billion per year "a rather frugal amount" equivalent to "three-quarters of one percent of GNP [Gross National Product]."[31]

The Task Force counseled continued lunar exploration after the initial Apollo Moon landings and advised Nixon to postpone a decision on a large space station and the reusable shuttle vehicle needed to resupply it economically. The primary purpose of the station was, it said, "to test man's ability for an extended spaceflight over times of a year or more, so that the practicality of a manned planetary mission could be examined. However, the desirability of such a mission is not yet clear . . . ."[32]

The Task Force recommendations resembled those in the February 1967 PSAC report, and with good reason—the membership lists of the two groups were almost identical. One new addition was Robert Seamans, Secretary of the Air Force, who had been NASA Deputy Administrator when the PSAC had submitted its 1967 report.

Even as the Task Force presented its recommendations to Nixon, Paine's optimistic plans for NASA's FY 1970 budget foundered. President Johnson's FY 1970 budget request for NASA, released 15 January 1969, was $3.88 billion—$800 million less than the $4.7 billion "optimum" figure Paine had given the Budget Bureau in November and more than $100 million less than what Paine had said was the "minimum acceptable." When Nixon's Budget Bureau chief, Robert Mayo, asked agency heads a week later to further trim the Johnson budget, Paine pushed for a $198-million increase. Mayo quickly rebuffed Paine's request.[33] Nixon's FY 1970 budget went to Congress on 15 April. NASA's share was $3.82 billion, of which Congress eventually appropriated $3.75 billion.

Space Task Group

Paine pointed to the Task Force on Space report as an example of what he did not want for NASA's future.[34] At a NASA meeting on space stations held in February at Langley, Paine invoked instead von Braun's Collier's articles.[35] Following the meeting, Aviation Week & Space Technology magazine reported that NASA planned a 100-person space station by 1980, with first 12-person module to be launched on a modified Saturn V in 1975.[36]

Nixon's science advisor, Lee Dubridge, tried to get authority to set NASA's future course, in part because he sensed Paine's aims were too expansive, but Paine protested. On 13 February 1969, President Nixon sent a memorandum to Dubridge, Paine, Defense Secretary Melvin Laird, and Vice President Spiro Agnew, asking them to set up a Space Task Group (STG) to provide advice on NASA's future.[37] On 17 February, Nixon solicited Paine's advice on the agency's direction. Paine's long, detailed letter of 26 February sought to step around the STG process and secure from Nixon early endorsement of a space station.[38] In his response, Nixon politely reminded Paine of the newly formed STG.[39]

STG meetings began on 7 March 1969. In addition to the four voting members, the group included observers: Glenn Seaborg of the AEC; U. Alexis Johnson, Under Secretary of State for Political Affairs; and, most influential, the Budget Bureau's Mayo. Robert Seamans stood in for Melvin Laird. The STG chair was Agnew, another Washington neophyte. Misreading the Vice President's importance within the Nixon Administration, Paine focused his efforts on wooing Agnew to his cause. Much of the STG's work was conducted outside formal STG meetings, which occurred infrequently.

NASA's STG position became based on the Integrated Program Plan (IPP) developed by Mueller's OMSF, which was first formally described to Paine in a report dated 12 May.[40] Mueller attributed many of its concepts to a NASA Science and Technical Advisory Council meeting held in La Jolla, California, in December 1968. Though concerned mostly with Earth-orbital and cislunar missions, the report proposed that "the subsystems, procedures and even vehicles" for such missions "be developed with a view towards their possible use in a future planetary program . . . ."[41]

The IPP schedule was aggressive even by 1960s Moon race standards. Between 1970 and 1975, NASA would conduct a dozen Apollo lunar expeditions and launch and operate three AAP space stations—two in Earth orbit and one in lunar polar orbit. The year 1975 would see the debut of the reusable Earth-orbital Space

Shuttle, which could carry a 25-ton, 40-foot-long, 22-foot-wide payload in its cargo bay.

Shuttle payloads would include a standardized space station module housing up to 12 astronauts, a propulsion module usable as a piloted Moon lander or Space Tug, and tanks containing liquid hydrogen propellant for the NERVA-equipped Nuclear Shuttle, which would first reach Earth orbit on an uprated Saturn V in 1977. Significantly, Mueller's IPP gave NERVA a non-Mars mission as part of a larger reusable transportation system in cislunar space. Up to 12 astronauts would conduct a Mars flight simulation aboard the Space Station in Earth orbit from 1975 to 1978, and 1978 would see establishment of a Lunar Base.

By 1980, 30 astronauts would live and work in cislunar space at any one time. Four Nuclear Shuttle flights and 42 Space Shuttle flights per year would support the Space Station Program. Six Nuclear Shuttle flights, 48 Space Shuttle flights, and eight Space Tug Moon lander flights per year would support the Lunar Base Program.

NASA's Big Gun

Paine liked Mueller's ambitious IPP. He asked Wernher von Braun to make it even more expansive by building a Mars mission concept onto it in time for a 4 August presentation to the STG. The presentation was timed to capitalize on the enthusiasm and excitement generated by the first Apollo Moon landing mission, which was set to lift off on 16 July 1969.

Paine saw von Braun as "NASA's big gun." He believed that the space flight salesmanship for which the German-born rocketeer was famous could still help shape the future of American space flight as it had in the previous two decades. According to Von Braun, "it was an effort of a very few weeks to put a very consistent and good and plausible story together."[42]

Meanwhile, Paine's efforts to woo Agnew were, it appeared, beginning to pay off. At the Apollo 11 launch, the Vice President spoke of his "individual feeling" that the United States should set "the simple, ambitious, optimistic goal of a manned flight to Mars by the end of the century."[43]

On 20 July, Apollo 11 Commander Neil Armstrong and Lunar Module Pilot Edwin "Buzz" Aldrin landed the spider-like Lunar Module Eagle on the Moon's Sea of Tranquillity. At the start of humanity's first two-hour Moon walk, Aldrin described the landscape as a "magnificent desolation." The astronauts remained at Tranquillity Base for 21 hours before rejoining Command Module Pilot Michael Collins aboard the CSM Columbia in lunar orbit. On 24 July 1969, they splashed down safely in the Pacific Ocean, achieving the goal Kennedy had set eight years before.

In reporting the Apollo 11 landing, the Los Angeles Herald-Examiner pointed to space-age spin-offs, such as "new paints and plastics," then predicted that "the Mars goal should bring benefits to all mankind even greater than the . . . [M]oon program."[44] The Philadelphia Inquirer anticipated opposition to a Mars program; it asked, "will the inspiration be abandoned before the veiled censure of those who seem to suggest the solution of all human dilemmas lies in turning away from space to other priorities?"[45]

Aviation Week & Space Technology reported that "[s]pace officials sense that public interest is near an all-time high . . . ."[46] Yet polls taken at the time did not indicate strong public support for Mars exploration. A Gallup poll showed that the majority of people polled aged under 30 years favored going on to Mars; however, a larger majority of those over 30 opposed. Taken together, 53 percent of Americans opposed a Mars mission, 39 percent favored it, and 8 percent had no opinion.[47]

In addition to the polls, new automated probe data supplied Mars mission detractors with ammunition. The Mariner 6 spacecraft had left Earth on 24 February, just before STG meetings began. On 31 July 1969, as Paine and von Braun put the finishing touches on their 4 August pitch, it flew over the southern hemisphere of Mars, snapping 74 grainy images of a forbidding landscape pocked by craters. A feature known to Earth-based telescopic observers as Nix Olympica ("the Olympian Snows") appeared as a 300-mile crater with a bright central patch.

The spacecraft's twin, Mariner 7, had left Earth on 26 March. It flew over Mars' southern hemisphere on 5 August 1969, snapping 126 images of the smooth-floored Hellas basin, the heavily cratered Hellespontus region, and the south pole ice cap. The probes seemed

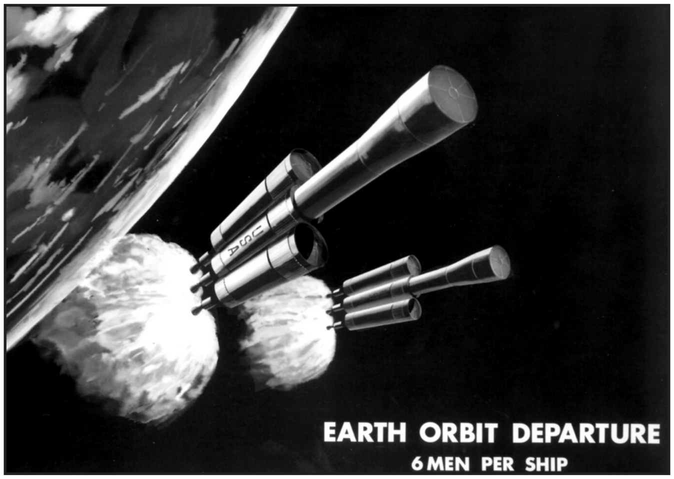

Figure 15—Twin Mars ships blast their all-male crews from Earth orbit using NERVA nuclear rocket stages. In August 1969, Wernher von Braun used images such as this to present NASA's vision of a Mars expedition in the 1980s to the Space Task Group and to Congress. (NASA Photo MSFC-69-PD-SA-176)

to confirm the pessimistic picture painted by Mariner 4 in 1965. The New York Times noted that NASA had "begun drumming up pressure to spend huge sums required to send men to Mars in the early 1980s . . . . But the latest Mariner information makes the possibility of life on Mars much less than it seemed even a week ago, thus removing much of the original motivation for such a project."[48]

NASA's 4 August STG presentation had three parts, lasted 55 minutes, and took into account neither the opinion polls nor the new Mars data. In the first part, Paine spent 20 minutes describing the "mystery, challenge, rich potential, and importance to man of the solar system" and "how the United States can move from [the] start represented by Apollo to exploration of the entire solar system with a program requiring only a modest investment of our national resources."[49]

Von Braun followed Paine and spent 30 minutes describing a piloted Mars expedition in 1982. His presentation formed the heart and soul of NASA's STG pitch.[50] In retrospect, it also marked the apogee of von Braun's career.

Von Braun drew on a sizable library of conceptual Mars spacecraft art generated in the Marshall Future Projects Office to show Mayo, Dubridge, Seamans, Johnson, Seaborg, and Agnew vehicles similar to the Boeing Mars cruiser and the NAR MEM. In his IPP-based plan, the MEM was the only piece of hardware applicable only to Mars flight. All other vehicle elements would, he explained, be developed for cislunar roles. MEM go-ahead in 1974 would mark de facto commitment to a 1982 Mars expedition. The first space station module, the design of which would provide the basis for the Mars ship Mission Module, would fly in 1975, as would the first Earth-orbital Space Shuttle. The year 1978 would see the MEM test flight; then, in 1981, the first Mars mission would depart Earth orbit for a Mars landing in 1982.

The Mars mission would employ two Mars spacecraft consisting of three Nuclear Shuttles arranged side by side and a Mission Module. The complete spacecraft would measure 100 feet across the Nuclear Shuttles and 270 feet long. All modules would reach orbit on upgraded Saturn V rockets. After the twin expedition ships were assembled, reusable Space Shuttles would launch water, food, some propellant, and two six-person crews to the waiting Mars ships. At Earth-orbit launch,

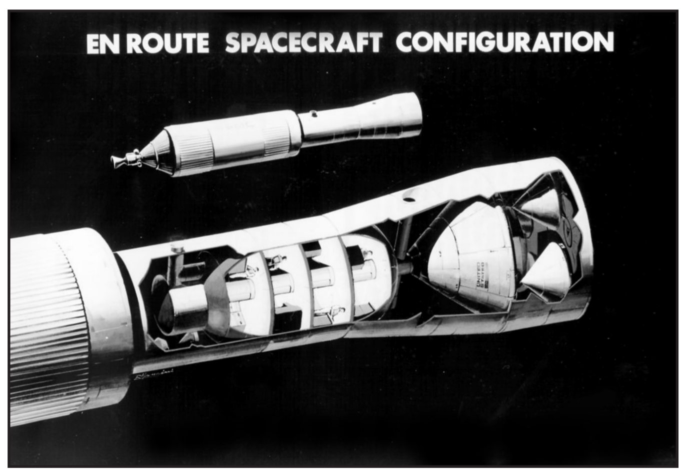

Figure 16—Compared with cramped Apollo spacecraft, the lodgings proposed for NASA's 1980s Mars ships were palatial. In this cutaway, note the four-deck Mission Module (center) and large conical Mars lander (right). (NASA Photo S-69-56295)

each ship would mass 800 tons, of which 75 percent was hydrogen propellant.

Von Braun targeted Mars expedition departure for 12 November 1981. The port and starboard Nuclear Shuttles would then fire their NERVA engines, achieve

Trans-Mars Injection, and shut down and separate from the center Nuclear Shuttle and Mission Module. They would turn around and fire their engines again to slow down and enter elliptical Earth orbit. A few days later they would reach perigee (lowest point above the Earth) at the original assembly orbit altitude, fire their engines to circularize their orbits, and rendezvous with the Space Station for refurbishment and re-use. The ships would weigh 337.5 tons each after port and starboard Nuclear Shuttle separation.

As in the Planetary JAG piloted flyby missions, the nine-month coast to Mars would be "by no means an idle phase." The ships each would serve as "a manned laboratory in space, free of the disturbing influences of the Earth." According to von Braun, "[t]he fact that there will be two observation points, Earth and spacecraft, permits several possible experiments." In addition, "as yet unidentified comets might be observed for the first time."[51]

Von Braun had the twin Mars ships reaching Mars on 9 August 1982. Each would fire the NERVA engine on its remaining Nuclear Shuttle to slow down and enter Mars orbit. At Mars Orbit Insertion each spacecraft would weigh 325 tons. The crews would then spend two days selecting landing sites for the expedition's 12 automated Sample Return Probes. The probes would land, retrieve samples uncontaminated by human contact, and lift off, then deliver the samples automatically to sterilized bio-labs on the ships for study.

If the samples contained no hazards, a three-man landing party would descend to the surface in one of the 47.5-ton MEMs. The other would be held in reserve—von Braun explained that "capability is provided for one man to land a MEM and bring a stranded crew back to the ship." He promised that "Man's first step on Mars will be no less exciting than Neil Armstrong's first step on the Moon."[52]

The astronauts would then spend between 30 and 60 days on Mars. Von Braun listed objectives for Martian exploration, including the following:

- Understand Martian geology "because Mars probably closely paralleled the earth in origin and . . . development."

- Search for life—von Braun stated that "preliminary data indicate that some lower forms of life can survive in the Martian environment . . . in isolated areas higher forms . . . may exist. Man on Mars will [also] be able to study . . . the behavior of terrestrial life forms transplanted to the Martian environment."

- "Drilling for . . . water will be an early objective . . . and its discovery would open many possibilities . . . . For example, it might become possible to produce rocket fuel for the return trip on later missions."[53]

The landing party would lift off in the MEM ascent stage using the descent stage as a launch pad. The ascent stage would dock with the orbiting ship and the crew would transfer 900 pounds of samples and equipment, then would discard the expended ascent stage. The ships would ignite their center Nuclear Shuttles to leave Mars on 28 October 1982, after 80 days near the planet. The ships would weigh 190 tons each prior to Mars orbit departure.

Von Braun told the STG that the twin Mars ships would fly by Venus on 28 February 1983, to use the planet's gravity to slow their approach to Earth, thereby reducing the amount of braking propellant needed to enter Earth orbit. During swingby the astronauts would map Venus' cloud-shrouded surface with radar and deploy four automated probes.

Von Braun scheduled return to Earth for 14 August 1983. He noted that an Apollo-style direct reentry was possible; however, until "a better assessment can be made of the back contamination hazard (the return by man of pathogens that might prove harmful to earth inhabitants), a more conservative approach has been planned, i.e., the return of the crew to earth orbit for a quarantine period."[54] The center Nuclear Shuttles would place the Mission Modules in Earth orbit and perform rendezvous with the Space Station, where doctors would examine the astronauts. The Mars ships would weigh 80 tons each at mission's end, one-tenth of their Earth-departure weight. Following their quarantine period, the crew would return to Earth aboard a Space Shuttle. The center Nuclear Shuttles, meanwhile, would be refurbished and reused.

He then looked beyond the first expedition, stating that additional flights to Mars could occur during the periods 1983-84, 1986-87, and 1988-89. The 50-person Mars Base might be established in 1989, in time for the 20th anniversary of von Braun's presentation. Von Braun told the STG that NASA's budget would peak at $7 billion per year in 1975, or about 0.6 percent of GNP, and that it would level out at $5 billion in 1989, at which time its share of GNP would be 0.3 percent.[55] This assumed steady 4 percent annual growth in the U.S. economy. In his closing remarks, Paine put the cost a little higher than had von Braun; he told the other STG members that "[t]his kind of program would be possible for the United States with a budget rising to about $9 billion [per year] in the last half of the decade."[56]

"Now Is Not the Time . . ."

NASA's vision was breathtaking, but stood little chance of acceptance in 1969 America. Robert Seamans appears to have been generally sympathetic to Paine's vision, yet cognizant of political and economic realities. He arrived at the 4 August meeting with a letter for Agnew laying out a less expansive view of America's future in space—one similar to the recommendations made by the transition Task Force in January. Seamans wrote, "I don't believe we should commit this Nation to a manned planetary mission, at least until the feasibility and need are more firmly established. Experience must be gained in an orbiting space station before manned planetary missions can be planned." Then he recommended against early commitment to a space station.

Seamans advised instead that NASA should expand AAP and continue lunar exploration "on a careful step-by-step basis reviewing scientific data from one flight before going to the next." He differed from the transition Task Force by recommending "a program to study by experimental means including orbital tests the possibility of a Space Transportation System that would permit the cost per pound in orbit to be reduced by a substantial factor (ten times or more)."[57] Aviation Week & Space Technology had by this time already predicted that the STG would recommend a reusable Space Shuttle as NASA's post-Apollo focus.[58]

On 5 August, the day Mariner 7 flew past Mars, Paine and von Braun presented their pitch to the Senate Space Committee. Clinton Anderson, its chair, had in effect already responded to the presentation; on 29 July 1969, he said that "now is not the time to commit ourselves to the goal of a manned mission to Mars."[59] Coming from Anderson, this was ominous and somewhat puzzling. The New Mexico Senator had backed NASA since its birth, in large part because the Agency gave the nuclear rocket program he supported funding and a raison d'être. His rejection of Mars placed him in a dilemma—how could he back nuclear propulsion yet not support what was widely seen as its chief mission? Other Space Committee members had similar reactions to NASA's presentation. Senator Mark Hatfield (Republican-Oregon) told Paine and von Braun that he supported the space program, but was "not really ready, at this point . . . to make commitments . . . to meet a deadline to get a man to Mars." Senator Margaret Chase Smith (Republican-Maine) named Paine's game, saying that the government "should avoid making long-range plans during this emotional period [following Apollo 11] . . . otherwise we may become involved in a crash program without the justification we had for Apollo—and therefore without the full support of Congress."[60]

Despite the clear signals from Congress, the STG remained split between Washington neophytes and old hands, with the former stubbornly preaching Mars and the latter counseling something less expansive. Robert Mayo broke the deadlock when he proposed that the group offer the President several pacing options contingent on available funds.[61]

Paine and Mueller then took their case to the public with a presentation to the National Press Club. Mueller painted a picture of NASA's space activities in 1979, when, he said, more than 200 people would work in space at one time. Most would be scattered in facilities between Earth orbit and the lunar surface; however, 12 would be en route to Mars in two ships.[62] Aviation Week & Space Technology editor Robert Hotz attended the Press Club talks and became swept up in NASA's vision. In his editorial following the talks he took a page from Paine's book, writing that

> the Apollo 11 mission has opened an endless frontier which mankind must explore. Man is extending his domain from the 8,000-mile-diameter of his home planet earth to the 8-billion-mile diameter of the solar system . . . . Hopefully [the President] will note that only by setting extremely high goals have extraordinary results been achieved . . . . We think Dr. Paine made a telling point when he warned against establishing future goals too low.[63]

Congress, meanwhile, voiced more reservations. George Miller (Democrat-California), chair of the House Committee on Science and Astronautics, did not want "to commit to a specific time period for setting sail to Mars." Miller was not opposed to going to Mars on principle; in fact, he believed it "highly probable that five, perhaps 10 years from now we may decide that it would be in the national interest to begin a carefully planned program extending over several years to send men to Mars."[64]

J. W. Fulbright (Democrat-Arkansas), Committee on Foreign Relations chair, sought to put Apollo in proper perspective as an element of 1960s realpolitik: "The [Apollo 11] landing called forth a great deal of poetizing about the human spirit bursting earthly bounds . . . . In all this I perceive not humbug . . . but rather more sententiousness than plain hard truth. Americans went to the Moon for a number of reasons of which, I am convinced, the most important by far was to beat the Russians."[65] Sending American astronauts on to Mars had nothing to do with beating the Russians. Therefore, Fulbright saw little cause to support such a mission.

America's Next Decades in Space

NASA released its report America's Next Decades in Space: A Report to the Space Task Group on 15 September 1969.[66] Paine was the principal author of the report, which aimed to promote NASA's STG position. In retrospect the report marked the apogee of NASA Mars expedition planning. With a note of pride it pointed out that, in NASA's first decade,

> the American space program progressed from the 31-pound Explorer 1 in earth orbit to Apollo spacecraft weighing 50 tons sent out to the moon [and] from manned flights of a few thousand miles and 15-minute duration to the 500,000 mile round-trip 8-day [Apollo 11] mission which landed men on the [M]oon and returned them safely to [E]arth.[67]

The NASA report then appealed to President Nixon to think of his place in history, and to see his decision as an unprecedented opportunity:

> At the moment of its greatest triumph, the space program of the United States faces a crucial situation. Decisions made this year will affect the course of space activity for decades to come . . . . This Administration has a unique opportunity to determine the long-term future of the Nation's space progress. We recommended that the United States adopt as a continuing goal the exploration of the solar system . . . . To focus our developments and integrate our programs, we recommend that the United States prepare for manned planetary expeditions in the 1980s.[68]

Not surprisingly, the NASA report's program closely resembled the one Paine and von Braun described in their 4 August STG presentation. Continued piloted lunar exploration after Apollo would, the NASA report proclaimed, "expand man's domain to include the [M]oon" by establishing a lunar base. This would lay groundwork for a piloted Mars expedition in the 1980s. As Mayo had proposed, the NASA report described different program rates, each with a different date for reaching Mars, the ultimate goal of all the programs. The "maximum rate," in which money was no object and only the pace of technology could slow NASA's rush to Mars, scheduled the first Mars expedition for 1981. Program I launched the first expedition in 1983, while Program II, the pacing option favored by Agnew, put it in 1986. Program III was identical to Program II, except that no date was specified for the first Mars expedition.

The STG report proper, The Post-Apollo Space Program: Directions for the Future, was also published on 15 September 1969. It had a split personality.[69] The main body closely followed NASA's America's Next Decades in Space report—not surprisingly, since Paine was again the principal author. The introductory "Conclusions and Recommendations" section, however, differed markedly in tone and emphasis from the NASA-authored section. This was because it was added in early September at the insistence of senior White House staffers who did not want to provide President Nixon with only ambitious objectives from which to choose.[70]

The "Conclusions and Recommendations" section acknowledged that NASA had "the demonstrated organizational competence and technology base . . . to carry out a successful program to land man on Mars within 15 years"; however, it failed to advocate an aggressive Mars program, recommending instead sending humans to Mars "before the end of this century." At the same time, it cautioned that "in a balanced program containing other goals and activities, this focus should not assume over-riding priority and cause sacrifice of other important activity in times of severe budget constraints."[71]

New space capabilities would be developed in a three-phase program, to which the introductory section attached no firm schedule. Phase 1 would see "exploitation of existing capability and development of new capability, maintaining program balance within available resources." This would include continued "Apollo-type" lunar missions. New development would be based on the principles of "commonality, reusability, and economy." Phase 2 was an "operational phase" using new systems in cislunar space with emphasis on "exploitation of science and applications" aboard space stations. In Phase 3, "manned exploration missions out of [E]arth-[M]oon space" would occur, "building upon the experience of the earlier two phases."[72] The "Conclusions and Recommendations" section cautioned,

> Schedule and budgetary implications within these three phases are subject to Presidential choice and decision . . . with detailed program elements to be determined in a normal annual budget and program review process. [73]

Nixon's Response

Shortly after the Apollo 11 lunar landing, von Braun told space policy analyst John Logsdon that

> the legacy of Apollo has spoiled the people at NASA . . . . I believe that there may be too many people in NASA who at the moment are waiting for a miracle, just waiting for another man on a white horse to come and offer us another planet, like President Kennedy.[74]

Von Braun might have placed his boss in that category. Paine placed great stock in the effect the NASA section of the STG report would have on President Nixon. Another document—a lengthy memorandum by Mayo dated 25 September 1969—apparently had greater effect, however. Mayo told the President that NASA had requested $4.5 billion for FY 1971 despite a $3.5-billion cap imposed by his office. He then recommended that Nixon "hold an announcement of your space decision until after you have reviewed the [STG] report recommendations specifically in the context of the total 1971 budget problem . . . ." Mayo added that he believed the NASA sections of the STG report "significantly underestimated" the costs of future programs.[75]

In late September, Aviation Week & Space Technology reported that NASA was hopeful that it might receive a supplemental appropriation in FY 1970 to begin work toward Mars.[76] In October this optimism led Mueller to establish the Planetary Missions Requirements Group (PMRG), which included representatives from NASA Headquarters and several NASA field centers. The PMRG, the successor to the Planetary JAG, first met formally in December 1969. Its purpose was to blueprint Mars mission concepts in the context of the STG integrated plan.[77]

By the time the PMRG met for the first time, however, NASA had received bad news. On 13 November 1969, Mayo's Office of Management and Budget (OMB) (formerly the Budget Bureau) had informed Paine that NASA's FY 1971 request would be $1 billion shy of his request—just $3.5 billion. Paine called the figure "unacceptable" and told Mayo that "the proposed rationale" for this budget figure "ignores and runs counter to the conclusions reached by the Space Task Group . . . the OMB staff proposals would force the President to reject the Space Program as an important continuing element of his Administration's total program."[78]

Paine was compelled to acquiesce, however. On 13 January 1970, he briefed newsmen on NASA's budget ahead of Nixon's FY 1971 budget speech. He termed the $3.5 billion budget "solid," and announced that the Saturn V rocket production line, already dormant, would close down permanently.[79] This was a serious blow to the nuclear rocket program. It meant that, in addition to having no approved mission, it now had no way to get into space. NASA subsequently began study of using the Earth-orbital Space Shuttle to place NERVA-equipped rocket stages into Earth orbit.

Paine also canceled the planned tenth lunar landing mission, Apollo 20, so that its Saturn V could launch the Skylab space station, and announced that the Viking Mars probe would slip to a 1975 launch with a 1976 Mars landing. In an apparent effort to raise alarm and fend off further cuts, Paine released a list of NASA Center closures in order of priority. First to go would be

Ames, in Nixon's California stronghold, and the last three in order would be MSC, Marshall, and KSC.[80]

In late January, just before Nixon unveiled his Federal budget for FY 1971, NASA took another cut. When sent to Capitol Hill on 2 February 1970, NASA's portion of the budget had fallen to $3.38 billion. In announcing NASA's budget, Nixon said that "[o]ur actions make it possible to begin plans for a manned mission to Mars."[81] In fact, the 1970-71 period would see NASA's last formal piloted Mars plan until the 1980s.

Nixon did not use his 22 January 1970 State of the Union address to plot the way forward in space as some in NASA had hoped that he might. His first priority, he said, was to "bring an end to the war in Vietnam." He also proposed to "begin to make reparations for the damage we have done to our air, to our land, and to our waters."[82] Apollo 8 pictures of blue Earth rising over the barren Moon had become a rallying point for the environmental movement—not, as Paine had hoped, for space exploration. Paine was unimpressed by Nixon's environmentalist slant. He told an industry group that "[w]e applaud the increase in sewage disposal plants. But we certainly hope this doesn't mean the nation has taken its eyes off the stars and put them in the sewers."[83]

Nixon finally issued his policy on the post-Apollo space program on 7 March 1970. Unlike Kennedy's 1961 Moon speech, Nixon's statement was broad and vague, with no specifics about NASA funding. Rather than endorse a specific target date for a piloted Mars mission, he said that "we will eventually send men to explore the planet Mars." The British weekly The Economist reported that people at NASA "looked like children who got the jigsaw puzzle they were expecting rather than the bicycle they were dreaming of."[84]

PSAC Recommends Shuttle

At the same time Nixon issued his space policy, his PSAC issued The Next Decade in Space, a report extolling the possibilities of a Space Shuttle-based space program. The presidential advisory body acknowledged that "[e]normous technological capabilities have been built up in the Apollo Program," but recommended "a civilian space effort about half the magnitude of the present level."[85] The PSAC emphasized the military and direct economic benefits of piloted space travel, which it said could only be accrued by replacing virtually all expendable rockets with a reusable Space Transportation System (STS). This would include the Space Shuttle and a reusable orbital tug.

The STS would allow "orbital assembly and ultimately radical reduction in unit cost of space transportation," the PSAC stated, quoting a NASA/Defense Department study that placed the cost per flight of the STS at $5 million, or 1 percent of the Saturn V cost.[86] At the time the PSAC released its report, the U.S. could launch four Saturn V rockets per year, each with a payload of about 100 tons. The PSAC reasoned that "[s]ince only ten flights of the STS can in principle fulfill the role of two Saturn V launches/year, this capability might be reached soon after initial operation of the STS."[87]

The PSAC then addressed piloted Mars exploration, writing that "[p]rudence suggests that the possibility of undertaking a manned voyage to Mars be kept in mind but that a national commitment to this project be deferred at this time."[88] The STS, it expected, "could place the equipment needed for the Mars mission in orbit with one or two dozen launches and at a cost substantially below that of a single Saturn V." It also recommended that the permanent space station it said should precede a piloted Mars mission be deferred until after the STS could be used to assemble it.[89] Despite the heavy reliance it placed on the STS, the PSAC recommended deferring a decision to build it until FY 1972.

In July 1970, Paine submitted his resignation. On 15 September the first anniversary of the release of the STG and NASA reports, George Low took over as Acting NASA Administrator. In February 1971, Presidential Assistant Peter Flanigan was ordered to find a NASA Administrator who would "turn down NASA's empire-building fervor and turn his attention to . . . work[ing] with the OMB and White House."[90]

The Last Mars Study

The PMRG, meanwhile, continued low-level Mars expedition planning. NASA's post-Apollo Mars aspirations died with a whimper—a call to NASA Centers participating in the PMRG for reports summing up their work. PMRG work at MSC resided in the Engineering and Development Directorate's Advanced Studies Office

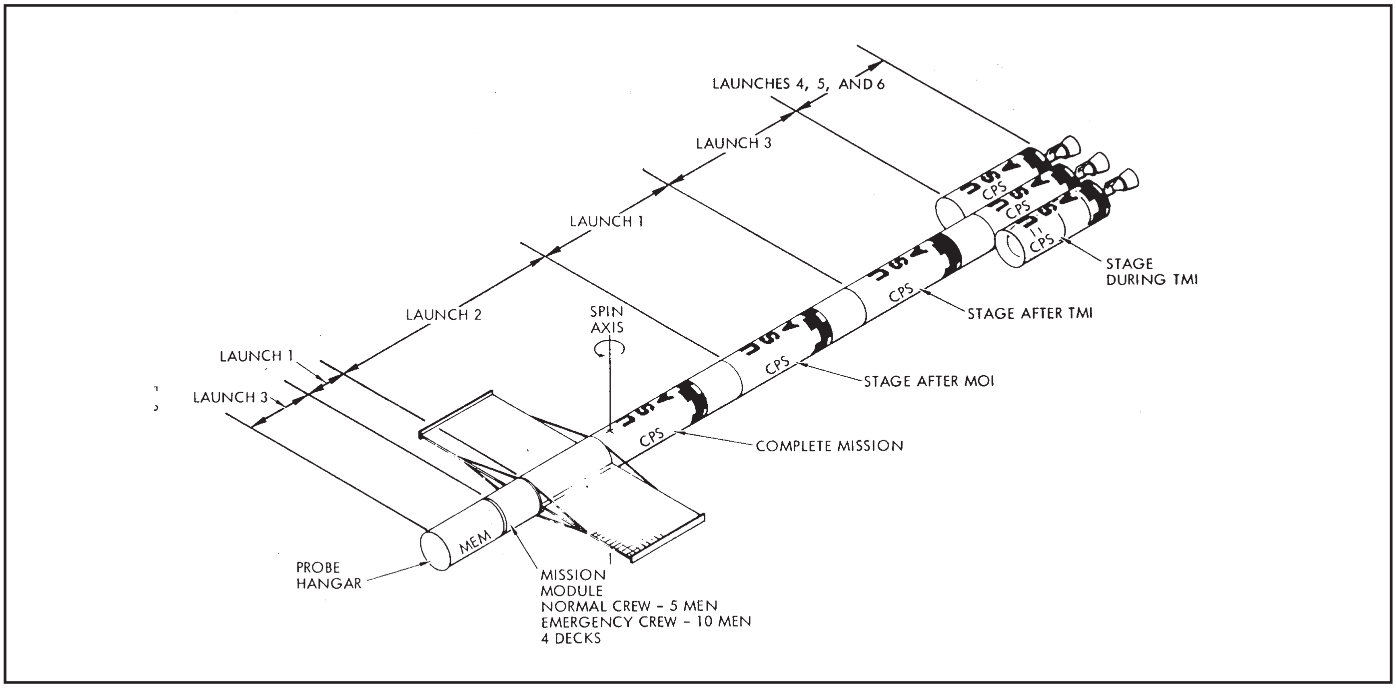

Figure 17—Last gasp (for a while): NASA's 1971 Mars spaceship design, the last until the 1980s, proposed to reduce cost by using projected Space Shuttle technology and rejecting nuclear engines in favor of cheaper chemical propulsion. (Manned Exploration Requirements and Considerations, Advanced Studies Office, Engineering and Development Directorate, NASA Manned Spacecraft Center, Houston, Texas, February 1971, p. 5-2.)

under Morris Jenkins. MSC Associate Director of Engineering Maxime Faget reviewed Jenkins' February 1971 report. In his introduction, Jenkins explained,

> Official statements regarding the manned Mars mission have always been conditioned by an emphasis that there was no set time frame for it. This together with problems of budget constraints on the more immediate future programs and the overall posture of the space program, influenced formal support for this study. Justifiably, the formal support was always very small and . . . non-continuous . . . .[91]

The guiding principle of MSC's PMRG study was austerity. In general configuration its Mars ship resembled Boeing's 1968 behemoth, but chemical propulsion stood in for nuclear. According to Jenkins, "everything [was] done to make [this study] a useful point of departure when national priorities and economic considerations encourage the mounting of a manned Mars expedition."[92] MSC targeted its 570-day Mars expedition for the 1987-88 launch opportunity, following an 11-year development and test period beginning in the mid-1970s.

MSC assumed availability of a fully reusable Space Shuttle based on Max Faget's "flyback" design. The flyback shuttle would include a winged orbiter launched on a winged booster. Both booster and orbiter would carry astronauts. MSC envisioned a booster the size of a 747 and an orbiter on the scale of a DC-9.

The study rejected launching Mars spacecraft components in the 15-foot-diameter payload bay of the orbiter because as many as 30 modules would have to be launched separately and brought together in orbit, necessitating a "complex and lengthy assembly and checkout process."[93] Instead, MSC proposed launching the Mars ship's three 24-foot-diameter modules on the back of the Shuttle booster with the aid of Chemical Propulsion System (CPS) stages. Three CPS stages would be launched into orbit without attached modules.

The Shuttle booster would carry the CPS and attached module (if any) partway to orbit, then separate to return to the launch site. The CPS would then ignite to achieve Earth orbit. Each CPS would weigh 30 tons empty and hold up to 270 tons of liquid hydrogen/liquid oxygen propellants. In keeping with the principle of austerity, the CPS stages would use the same rocket engine and propellant tank designs as the Shuttle booster and orbiter, and do double duty as Mars ship propulsion stages. Assembling the expedition's single ship would need 71 Shuttle booster launches. Six would launch the ship (three modules and six CPS stages), and the remainder would carry Shuttle orbiters serving as tankers for loading the CPS stages with propellants.

The assembled Mars ship would include a hangar for automated probes and a MEM based on the 1968 NAR design. For redundancy, its 55-ton, four-deck Mission Module would be split into two independent pressurized volumes, each containing a duplicate spacecraft control station. Deck four would be the ship's solar flare radiation shelter. The 65-foot-long Electrical Power System module would contain pressurized gas storage tanks and twin solar arrays. The crew would rotate the Mars ship end over end about twice per minute to produce artificial gravity in the Mission Module equal to one-sixth Earth's gravity (one lunar gravity).

Earth departure would require a series of maneuvers. Maneuver 1 would expend two CPS stages to place the Mars ship in elliptical "intermediate orbit." Maneuver 2 and Maneuver 3 would use one CPS stage—the first would place the ship in elliptical "waiting orbit," and the second would adjust the plane of the departure path. Space tugs would later recover the three discarded CPS stages for reuse. Maneuver 4 would place the ship on a 6-month trajectory to Mars. The fourth CPS would enter solar orbit after detaching from the Mars ship and would not be recovered.

Slowing the ship so that Mars' gravity could capture it into a 200-mile by 10,000-mile orbit would expend the fifth CPS. The elliptical orbit would require less propellant to enter and depart than a circular one. The five-person crew would spend 15 days in orbit studying Mars and preparing the MEM for landing; then three crewmembers would separate in the MEM, leaving behind two to watch over the mothership.

The MEM crew would explore their landing site using a pair of unpressurized electric rovers resembling the Apollo Lunar Roving Vehicle, which was slated to be driven on the Moon for the first time on Apollo 15 in July 1971. During Mars surface excursions, one crewmember would remain in the MEM while the other two took out one rover each. This "tandem convoy" arrangement would allow the Mars explorers to avoid the "walk back" limit imposed on single-rover traverses in the Apollo program. Walk back distance was limited less by astronaut stamina than by the amount of water and air the space suit backpacks could hold. If one Mars rover failed, the functional rover would return both astronauts to the MEM. Each rover would include a hook for towing the failed rover back to the MEM for repairs.

Rover maximum speed would be 10 miles per hour, and total area available to two rovers would amount to 8,000 square miles, compared to only 80 square miles for a single rover. Once every 15 days, a 36-hour traverse of up to 152 miles would occur, with the astronauts sleeping through the frigid Martian night on the parked rovers in their hard-shelled aluminum space suits. Jenkins did not attempt to estimate the amount of sleep the astronauts might actually be able to achieve during their overnight camping trips.

The astronauts would collect samples of rock and soil with emphasis on finding possible life. According to the MSC report, "[t]he potential for even elementary life to exist on another planet in the solar system may . . . be the keystone to the implementation of a manned planetary exploration program . . . man's unique capabilities in exploration could . . . have a direct qualitative impact on life science yield."[94]

After 45 days of surface exploration, the crew would blast off in the MEM ascent stage and dock with the mothership. Any specimens of Mars life collected would be transferred to a Mars environment simulator. The crew would discard the ascent stage; then the sixth and final CPS would ignite to push the ship back toward Earth. The MEM astronauts would remain quarantined in one pressurized volume until the danger of spreading Martian contagion to the other astronauts was judged to be past.

The MSC PMRG report received only limited distribution within NASA and virtually none outside the Agency. Formal studies within NASA aimed at sending humans to Mars would not occur again until the Manned Mars Missions exercise in 1984 and 1985.

NERVA Falls, Shuttle Rises

The OMB's FY 1972 request for NASA was $3.31 billion. The budget slashed NERVA funding in favor of continued Space Shuttle studies. Combined AEC-NASA nuclear rocket funding plummeted to $30 million split evenly between the two agencies. NASA and the AEC had together requested $110 million. The allotted budget threatened to place the NRDS on standby and was considered by many sufficient only to shut down the program.

In February 1971, Clinton Anderson held a hearing on the cut in NASA's NERVA funding. In his introductory remarks, he lauded the nuclear rocket program as "one of the most successful space technology programs ever undertaken" and pointed to the $1.4-billion investment in nuclear propulsion technology since 1955.[95] Senator Alan Bible (Democrat-Nevada) then pointed out that the STG report called for nuclear rockets.[96]

Acting NASA Administrator George Low took his marching orders from the highest levels of the Nixon White House. The Earth-orbital Shuttle had to come first, he said—without it NERVA had no ride to space. He told the Senators that, "NERVA needs the Shuttle, but the Shuttle does not need NERVA."[97]

Low denied that the funding cut would kill the program, explaining that "useful work on long lead-time items" could be accomplished.[98] There would, however, be no technical progress during FY 1972, and possibly none in FY 1973. "We have not, as yet, been able to look forward beyond that," Low added.[99]

Two months later, in May 1971, 21 members of Congress wrote to President Nixon requesting more funds for NERVA in FY 1972. When the White House failed to respond, Congress of its own accord budgeted $81 million for nuclear rockets, of which NASA's portion was $38 million. In October, however, the OMB refused to release more than the $30 million the Administration had requested. In November the OMB stood by its FY 1972 nuclear propulsion request despite protests from the Senate floor.[100]

On 5 January 1972, President Nixon met with James Fletcher, Tom Paine's successor as NASA Administrator, at the "Western White House" in San Clemente, California. Afterward, Fletcher read out Nixon's statement calling for an FY 1973 new start on the Shuttle. The announcement's venue was significant—California, a state of many aerospace firms, was vital to Nixon's 1972 reelection bid.[101] Nixon pointed out that "this major new national enterprise will engage the best efforts of thousands of highly skilled workers and hundreds of contractor firms over the next several years." Fletcher added that it was "the only meaningful new manned program that can be accomplished on a modest budget."[102] First flight was scheduled for 1978.

Nixon sent his FY 1973 budget to Capitol Hill on 24 January 1972. As its supporters had feared, the budget contained no funds for NERVA. Anderson, nuclear propulsion's greatest champion, was ill and could not defend it. The last NERVA tests occurred in June and July of 1972. Anderson retired from the Senate at the end of 1972. The FY 1974 budget terminated what remained of the U.S. nuclear rocket program.[103]

With both NERVA and Saturn V gone—the last Saturn V flew in May 1973—NASA's piloted space flight ambitions collapsed back to low-Earth orbit. Yet the Agency did not cease to strive toward Mars. As we will see in the next chapter, NASA's robot explorers conducted the first in-depth Mars exploration in the 1970s, holding open the door for renewed piloted Mars planning.