Chapter 2: Earliest NASA Concepts

> Now it is time to take longer strides—time for a great new American enterprise—time for this nation to take a clearly leading role in space achievement . . . I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the [M]oon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space . . . it will not be one man going to the [M]oon—it will be an entire nation. For all of us must work to put him there. (John F. Kennedy, 1961)[1]

NASA's First Mars Study

As early as November 1957—a month after Sputnik 1 became Earth's first artificial moon—about 20 researchers at Lewis Research Center, a National Advisory Committee on Aeronautics (NACA) laboratory in Cleveland, Ohio, commenced research into nuclear-thermal and electric rocket propulsion for interplanetary flight.[2] (Lewis was renamed Glenn Research Center at Lewis Field in 1999.) Such advanced propulsion systems required less propellant than chemical rockets, thus promising dramatic spacecraft weight savings. This meant fewer costly launches from Earth's surface and less Earth-orbital assembly.

Soon after the Lewis researchers began their work, Congress and the Eisenhower administration began to work toward the creation of a U.S. national space agency in response to Soviet space challenges. President Dwight Eisenhower wanted a civilian agency to ensure that headline-grabbing space shots would not interfere with the serious business of testing missiles and launching reconnaissance satellites. Senator Clinton Anderson (Democrat-New Mexico) led a faction that wanted the Atomic Energy Commission (AEC) to run the space program, citing as justification its nuclear-thermal rocket experiments. Others supported expansion of NACA, the federal aeronautics research organization founded in 1915. On 29 July 1958, Eisenhower signed into law legislation creating the National Aeronautics and Space Administration (NASA) from NACA and various Department of Defense space organizations.[3]

When NASA opened its doors on 1 October 1958, Lewis became a NASA Center. The Lewis researchers sought to justify and expand their advanced propulsion work. In April 1959—two years before any human ventured into Earth orbit—they testified to Congress about their work and solicited funding for a Mars expedition study in Fiscal Year (FY) 1960. Congress granted the request, making the Lewis study the first Mars expedition study conducted under NASA auspices.[4]

The Lewis researchers sought to develop weight estimates for Mars ships using their advanced propulsion systems. For their nuclear-thermal rocket analysis, the Lewis researchers assumed a Mars mission profile that would, by the end of 1960s, come to be virtually the standard NASA model:

> The mission begins with the vehicle system in an orbit about the Earth. Depending on the weight required for the mission, it can be inferred that the system has been delivered as a unit to orbit—or that it has been assembled in the orbit from its major constituents . . . the vehicle containing a crew of seven men is accelerated by a high-thrust nuclear rocket engine onto the transfer trajectory to Mars. Upon arrival at Mars, the vehicle is decelerated to establish an orbit about the planet . . . a Mars Landing Vehicle containing two men descends to the Martian surface . . . . After a period of exploration these men take off from Mars using chemical-rocket power and effect a rendezvous with the orbit party. The . . . vehicle then accelerates onto the return trajectory; and, upon reaching Earth, an Earth Landing Vehicle separates and . . . decelerates to return the entire crew to the surface.[5]

For analysis purposes, the Lewis researchers targeted the 1971 launch opportunity, when Mars' close proximity to Earth minimized the amount of energy (and thus propellant) needed to reach it. They cautioned, however, that "[t]his is not meant to imply that actual trips are contemplated for this period."[6] They opted for a 420-day round trip with a 40-day stay at Mars, and found that the optimum launch date was 19 May 1971.

As might be expected, fast Mars trips generally require more propellant (typically liquid hydrogen in the case of a nuclear rocket) than slow trips. The more propellant required, the greater the spacecraft's weight at Earth-orbit departure. Thus, longer missions appear preferable if weight minimization is the dominant consideration in a Mars mission plan. The Lewis team noted, however, that crew risk factors had to be considered in calculating spacecraft weight. These were hard to judge because much about conditions in interplanetary space and on Mars remained unknown. In particular, they cautioned that "[c]urrent knowledge of radiation hazards is still not completely satisfactory."[7]

Explorer 1 and Explorer 3 (launched 26 March 1958) detected the Van Allen Radiation Belts surrounding Earth. Their discovery was the first glimpse of an unsuspected reef, rock, or shoal menacing navigators in the new ocean of space. It raised the profile of ionizing radiation as a possible threat to space travelers.

No longer were the thin-skinned personnel spheres of von Braun's 1950s Mars ships judged adequate. Von Braun had made little provision for limiting crew radiation exposure, though he had expressed the hope that "by the time an expedition from earth is ready to take off for Mars, perhaps in the mid-2000s . . . researchers will have perfected a drug which will enable men to endure radiation for comparatively long periods."[8]

The Lewis team did not place its trust in pharmacology. For their study, they assumed the following ionizing radiation sources: the Van Allen belts at Earth and Mars (in reality, Mars lacks radiation belts), continuous cosmic ray bombardment, solar flares, and, of course, the ship's nuclear-thermal rocket engine. Their spacecraft crew compartment, an unshielded two-deck cylinder providing 50 square feet of floor space per crewmember ("between that provided for chief petty officers and commissioned officers on submarines"), contained a heavily shielded cylindrical "vault" at its center, into which the crew would retreat during passage through the Van Allen belts, nuclear rocket operation, and large solar flares.[9] Crewmembers would also sleep in the vault; this would reduce their cosmic ray exposure during approximately one-third of each day.

Not surprisingly, the weight of radiation shielding required depended on how much radiation exposure for the crew was allowed. If major solar flares could be avoided during the 420-day voyage and a total radiation dose of 100 Roentgen Equivalent Man (REM) were permissible, then 23.5 tons of shielding would suffice, the Lewis researchers found. If, however, one major flare could not be avoided, shielding weight jumped to 82 tons to keep the total dose below 100 REM. If only 50 REM were considered permissible and one major flare could not be avoided, shielding weight would become "enormous"—140 tons.[10] "These data," they wrote, served "to underscore . . . the importance of determining more precisely the nature and virulence of the radiation in space."[11]

The Lewis researchers determined that "short trips are as, or more, economical, in terms of weight, than long-duration missions," even though they generally required more propellant, because long trips required more heavy shielding to keep the crew within the radiation dose limit.[12] They estimated that a nuclear-thermal spaceship for a 420-day round trip in 1971 with a maximum allowable total radiation dose of 100 REM would weigh 675 tons at Earth-orbit launch.

Twirling Ion Ships to Mars

Just as the creation of NASA was prompted by the Cold War clash between the United States and the Soviet Union, so was the goal that dominated NASA's first decade. On 12 April 1961, Soviet cosmonaut Yuri Gagarin became the first person to orbit Earth. His Vostok 1 spacecraft completed one circuit of the planet in about 90 minutes. Gagarin's flight was a blow to the new administration of President John F. Kennedy, who had narrowly defeated Eisenhower's Vice President, Richard M. Nixon, in the November 1960 elections. Gagarin's flight coincided with the embarrassing failure of a Central Intelligence Agency (CIA)-sponsored invasion of Cuba at the Bay of Pigs (17-19 April 1961).[13]

The tide of Kennedy's political fortunes began to turn on 5 May 1961, when astronaut Alan Shepard rode the Freedom 7 Mercury capsule on a suborbital hop into the Atlantic Ocean. On 25 May 1961, Kennedy capitalized on this success to seize back the political high ground. Before a special Joint Session of Congress, he called for an American to land on Earth's Moon by the end of the 1960s.

NASA had unveiled a 10-year plan in February 1960 that called for a space station and circumlunar flight before 1970, and a lunar landing a few years later. The

Agency believed that this constituted a logical program of experience-building steps.[14] Mars planners were torn over Kennedy's new timetable. On the one hand, it put Mars work on the back burner by making the Moon NASA's primary, overriding goal. On the other hand, it promised to make launch vehicles and experience needed for Mars available all the sooner.[15]

Two contenders led the pack of Apollo lunar mission modes in mid-1961—Earth-Orbit Rendezvous (EOR) and Direct Ascent. Both stood to benefit piloted Mars missions. In EOR, two or three boosters launched Moon ship modules into Earth orbit. The modules docked; then the resultant ship flew to the Moon and landed. Mars planners knew that experience gained through Moon ship assembly could be applied to Mars ship assembly. In Direct Ascent, the spacecraft flew directly from Earth's surface to the lunar surface and back. This called for an enormous launch vehicle which could be used to reduce the number of launches needed to put Mars ship parts and propellants into orbit.

NASA's Marshall Space Flight Center in Huntsville, Alabama, was responsible for developing the rockets required for lunar flight. Marshall began as the ABMA's Guided Missile Development Division. In the 1950s, the von Braun rocket team had developed some of the first U.S. missiles, including the intermediate-range Redstone, the "Americanized" version of the V-2. A Redstone variant called Jupiter-C launched the Explorer 1 satellite.

Just as Saturn was next after Jupiter among the planets, the Saturn series of rockets was next after Jupiter-C. Saturn I and Saturn IB used a cluster of Redstone/Jupiter tanks in their first stages. The engineers in Huntsville envisioned yet larger rockets. NASA's 1960 master plan called for development of an enormous "post-Saturn" rocket called Nova. Either Saturn or Nova could be used to carry out an EOR Moon mission; Nova was required for Direct Ascent.

Marshall might have performed the first NASA Mars study, but when the Lewis advanced propulsion engineers testified to Congress in 1959, the Huntsville organization was still not a part of NASA. Ernst Stuhlinger's group within the ABMA Guided Missile Development Division had commenced work on electric propulsion in 1953 and considered Mars expeditions in its design process.

In electric propulsion, a thruster applies electricity to propellant (for example, cesium), converting its atoms into positive ions. That is, it knocks an electron off each cesium atom, giving it an electric charge. The thruster then electrostatically "grips" the cesium ions and "throws" them at high speed. Electric propulsion provides constant low-thrust acceleration while expending much less propellant than chemical or nuclear-thermal propulsion, consequently reducing spacecraft weight. Low thrust, however, means low acceleration.

Stuhlinger presented a paper in Austria in 1954 describing a solar-powered electric-propulsion spacecraft with dish-shaped solar concentrators.[16] Walt Disney had contacted von Braun after reading the Collier's articles; this contact led to three space flight television programs from 1955 to 1957. Disney's Mars and Beyond, which premiered on 4 December 1957, featured Stuhlinger's distinctive umbrella-shaped nuclear-electric Mars ships, not von Braun's sphere-and-girder chemical ships.[17]

The U.S. Army, eager to retain its foothold in missilery, was loath to release the von Braun team to NASA as required by President Eisenhower. Army resistance prevented von Braun, Stuhlinger, and their colleagues from officially joining the new space agency until 1 July 1960. However, they had by then worked directly with NASA for some time—hence their input to NASA's February 1960 master plan.[18] Wernher von Braun became Marshall's first director, and Ernst Stuhlinger became director of Marshall's Research Projects Division.

Stuhlinger's 1962 piloted Mars mission design, targeted for launch in the early 1980s, would include five 150-meter long Mars ships of two types—"A" and "B"—each carrying three astronauts.[19] As in von Braun's The Mars Project, risk to crew was minimized through redundancy. The expedition could continue if as many as two ships were lost, provided they were not of the same type. One ship could return the entire 15-person expedition to Earth under crowded conditions.

The three "A" ships would carry one 70-ton Mars lander each. At Mars, an unpiloted cargo lander would detach; if it landed successfully, the explorers would land in the second lander. If the cargo lander failed, the second lander would become an unpiloted cargo lander, and the third lander would deliver the surface team. The lander crew would stay on Mars for 29 days. If the crew lander ascent stage failed to fire, the explorers could return to Mars orbit in the cargo lander ascent stage.

Stuhlinger's ships would each include a nuclear reactor producing 115 megawatts of heat. The reactor would heat a working fluid which would drive a turbine; the turbine in turn would drive a generator to supply 40 megawatts of electricity to two electric-propulsion thrusters. To reject the heat it retained after leaving the turbine, the working fluid would circulate through radiator panels with a total area of 4,300 square meters before returning to the reactor. The ship would move through space with its radiator panels edge-on to the Sun. Radiator tubes would be designed to be individually closed off to prevent a meteoroid puncture from releasing all of the ship's working fluid into space.

Each flat, diamond-shaped ship would weigh 360 tons when it switched on its electric thrusters in Earth orbit at the start of the Mars voyage—a little more than half as much as the NASA Lewis nuclear-thermal Mars ship. Of this, 190 tons (for the "B" ships) or 120 tons (for the "A" ships) would be cesium propellant. As already indicated, the price of low spacecraft weight was low acceleration—Stuhlinger's fleet would need 56 days to spiral up and out of Earth orbit; then, after a 146-day Earth-Mars transfer, it would require 21 days to spiral down to low-Mars orbit.

Stuhlinger's ships would rotate 1.3 times per minute to produce acceleration equal to one-tenth of Earth's gravity in the crew cabin. The reactor, located at the opposite end of the ship from the crew cabin, would act as an artificial gravity counterweight. Thus, the separation needed to keep the crew away from the reactor would also serve to increase spin radius.

Engineers designing artificial gravity systems must endeavor to make the spin radius as long as possible. This is because an artificial gravity system with a short spin radius must rotate more rapidly than one with a long spin radius to generate the same level of acceleration, which the crew feels as gravity. A short-radius, fast-spinning rotating system produces pronounced coriolis effects. For example, water leaving a faucet curves noticeably. Similarly, a person moving toward or away from the center of such a rotating system tends to veer sideways. Turning the head tends to produce nausea. In addition, a troublesome gravity gradient occurs vertically along the body—the head experiences less acceleration than the feet.

Stuhlinger's electric thrusters would be mounted at the ship's center of rotation on stalks. These would rotate against the ship's spin to remain pointed in the required direction. In addition to aiding the crew, Stuhlinger noted, artificial gravity would prevent gas pockets from forming in the working fluid.[20]

Stuhlinger's design included a 50-ton, graphite-clad radiation shelter (about 15 percent of the entire weight of the ship) in the ship's crew compartment. Drinking water, propellant, oxygen cylinders, and equipment would be arranged around the shelter to provide additional shielding. The 2.8-meter-diameter, 1.9-meter-high shelter would hold a three-person ship's complement comfortably and would protect the entire 15-person expedition complement in an emergency. The crew would live in the shelter for 20 days during the outbound Van Allen belt crossing.

The Moon Intervenes

Stuhlinger wrote that it "is generally accepted that a manned expedition to . . . Mars will be carried out soon after such an ambitious project becomes technically feasible . . . [it is] the natural follow-on project to be undertaken after the lunar program."[21] Mars planners took Kennedy at his word when he said that reaching the Moon was "important for the long-range exploration of space."

On 11 July 1962, however, NASA announced that it had selected Lunar Orbit Rendezvous (LOR) over EOR and Direct Ascent as the Apollo mission mode. Attention had turned from EOR and Direct Ascent to LOR early in 1962. LOR, a concept zealously promoted by NASA Langley Research Center engineer John Houbolt, promised the lowest lunar spacecraft weight. This enabled a lunar expedition with only a single Saturn rocket launch, making LOR the fastest, cheapest way of meeting Kennedy's end-of-decade deadline.[22]

In LOR, the lunar spacecraft—which consists of a small lander and a command ship—blasts off directly from Earth with no Earth-orbital assembly. The lander lands on the Moon, leaving the large command ship in lunar orbit. Surface exploration completed, the lander blasts off from the Moon and returns to the orbiting command ship. Spacecraft weight is reduced because only the small, light-weight lander must burn propellant to land and lift off.

It should be noted that the NASA Lewis and Stuhlinger Mars plans used the same general approach for the same reason. Landing the entire massive ship on Mars and launching it back to Earth would require impossible amounts of propellant or an impossibly small interplanetary vehicle. The standard NASA Mars plan can thus be dubbed Mars Orbit Rendezvous (MOR).

The LOR decision impacted post-Apollo ambitions. The reduction in lunar expedition mass promised by LOR removed the need for a post-Saturn Nova rocket, as well as the need to learn how to assemble large modular vehicles in Earth orbit. It thus reduced Apollo's utility as a technological stepping stone to Mars. The need to create a new justification for big rockets influenced Marshall's decision to start a new Mars study in early summer 1962. As will be seen in the next chapter, this study, known as EMPIRE, kicked off the most intense period of piloted Mars mission planning in NASA's history.