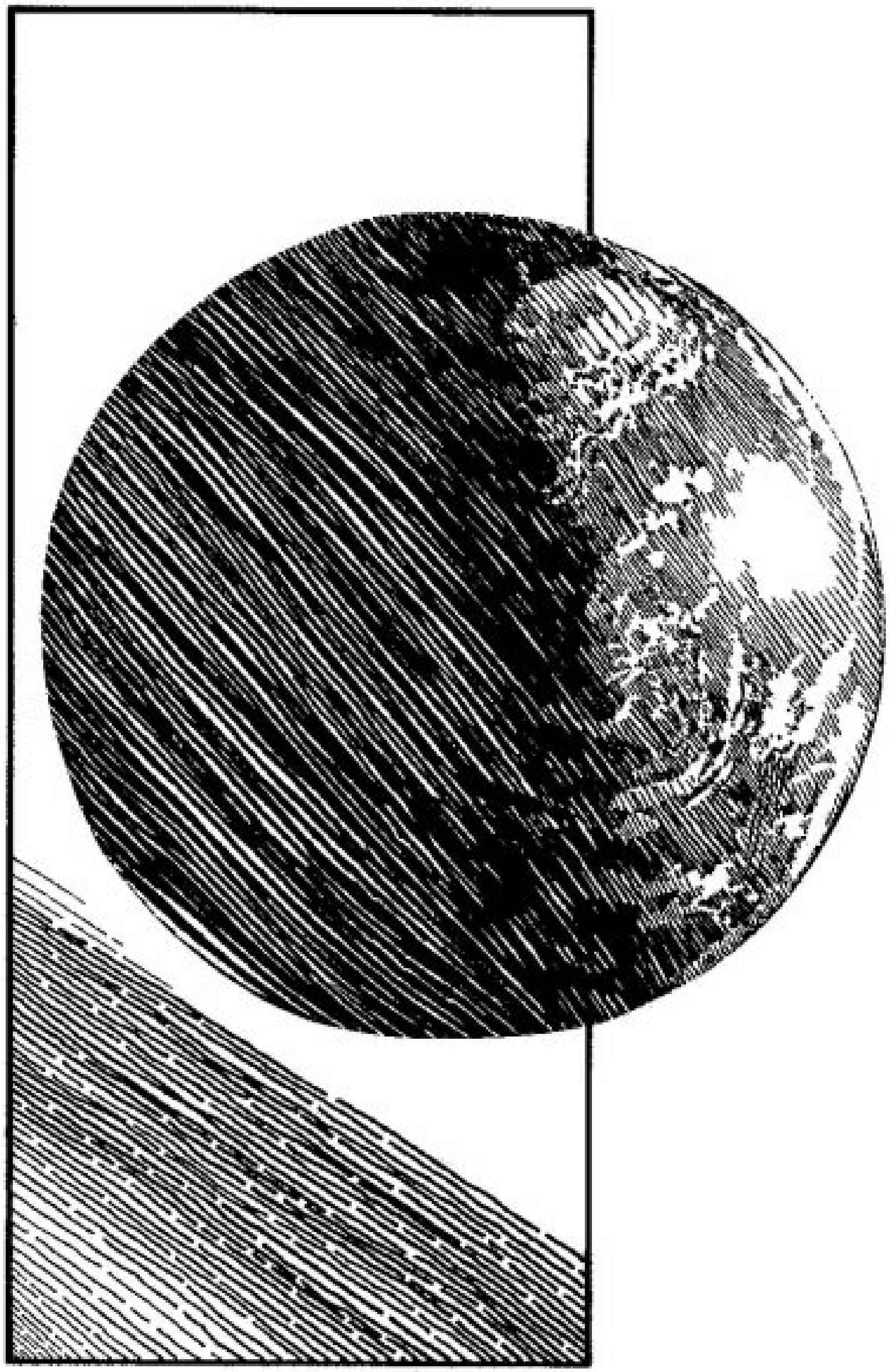


CHAPTER 17: *Space Station Earth*

Children in kindergartens in Texas in the 1980's began to sing new lyrics to the old song "Farmer in the Dell." They went like this: "We're blasting off to space, We're blasting off to space, Fly high away from Earth, We're blasting off to space." And the round continued—"We're going to the Moon . . . We're going to the planets . . . We're going to the stars . . . Fly high away from Earth, we're going to the stars." It meant that human spaceflight had become a part of the folklore. Whatever the pros and cons of putting humankind in space might have been over the past three decades, or the costs, or the real or imagined benefits for present and future generations, spaceflight had become as ingrained in the American mystique as "Farmer in the Dell."[1]

People could leave the planet Earth. They could fly in space. They had flown in space. They could walk on the Moon. They had walked on the Moon. They could fly a vehicle into an Earth orbit and return safely to Earth. They had done so many times. And they were now building a permanent space station for working and living in space. These things had been conceived, designed, constructed, and flown in part through the work of the National Aeronautics and Space Administration and Lyndon B. Johnson Space Center and its contractors. Because of these things Earth and its peoples would never be the same again.

With the return to flight, activity and energy-levels at NASA and JSC quickened. Congress began firming up a NASA budget for 1989 that contained a 30-percent increase over the 1988 budget, including a $6 billion, 3-year commitment to space station funding and a 27-percent increase in Shuttle program funding. The improved budget rejuvenated work on the space station, which had experienced budget cuts late in 1988 that resulted in delaying plans to have a fully operational station in Earth orbit from 1995 to 1997. Budget and design problems would continue to cause "slippages" in the space station program, but it had for a time developed a new life and a new name—Space Station *Freedom*.[2]

While *Discovery* orbited the Earth in September 1988, NASA began negotiating development contracts for the four, 10-year space station work packages to be handled respectively by Boeing Aerospace, McDonnell Douglas, General Electric's Astro Space Division, and Rockwell International's Rocketdyne Division. JSC, as manager of the McDonnell Douglas $2.6 billion package, had responsibility for the space station's integrated truss structure, mobile servicing system transporter, airlocks, and hardware and software data management (relating to guidance, navigation and control, and communications and tracking). Boeing, under Marshall Space Flight Center direction, would develop the laboratory and habitation module, while Goddard Space Flight Center managed contracts for an unmanned polar-orbiting platform and a flight telerobotic system, and Lewis Research Center directed work on an electrical power and distribution system. JSC anticipated increasing its civil service employees from a near all-time low of about 3340 to about 3460, with support contractor employment remaining stable at approximately 9000. Human Resources Director Jack Lister noted that since 1970, JSC's civil service force had been in a precipitous decline which strained the center's "in-house, civil service technological strength." Things were now looking up.[3] Employee and contractor morale began to rise more than proportionately.

But long-term budget and space policy awaited decisions by a higher authority. Governor Michael Dukakis of Massachusetts, the Democratic candidate for President, ran on a ticket with Texas Senator Lloyd Bentsen. The latter, if not professedly pro-space, had a proud history of being supportive of government programs that helped Houston and Texas. George Bush, the Republican candidate for President, who claimed Houston as his hometown, supported an invigorated space program, as did incumbent Republican President Ronald Reagan. Reagan visited the crew of *Discovery* and personnel at JSC just days before the countdown began for the return to space. "You don't launch rockets," he told the crowd of government employees and contractors, "you launch dreams. . . . America's going to space again, and we are going there to stay." STS-26 commander Rick Hauck told the President they would like to take him with them on the flight, but being unable to do that, would carry his personal name tag and a flight patch for the jacket he then presented the President.[4]

Certainly one spin-off of the *Discovery* flight was to help focus the voters' attention on NASA and space. It was, in fact, an unusually well-informed electorate who over the past 2-1/2 years had been exposed to numerous blue-ribbon committee studies and reports, and to a relentless media scrutiny that, in the words of Administrator James Fletcher, "sought to question every action and to uncover its every perceived blemish and wart."[5] For example, *Apollo: The Race to the Moon* by Charles Murray and Catherine Bly Cox suggested that the Apollo successes derived from a brilliant, "old-boy" network that produced an organization based on reliability and trust, but which in time became an "incestuous buddy-buddy bureaucracy" that had experienced "hardening of the arteries." Political scientist Howard E. McCurdy observed that NASA "lost touch with many Apollo precepts, including the importance of testing, the need for hands-on activity, and a commitment to recruitment of exceptional people." Historian Alex Roland thought that the Agency had fallen into a vicious cycle in repeatedly trying to outdo Apollo. "NASA simply wouldn't face the evidence that their plans were too expensive."[6]

A *New York Times* article, reprinted in a NASA newsletter, suggested that while the dream might still be alive, it was an impoverished dream. "Like the Shuttle, the space station is not an end but a means, infrastructure, built for when a President someday decides what to do with it. No wonder the space program has become a yawn." The writer thought that the space station should be scrapped and that the United States should seek a joint mission with Russia to Mars.[7]

And while *Discovery* orbited the Earth, James Van Allen, the professor of physics who in the Explorer experiments discovered the "Van Allen" radiation belt, raised the old cry that NASA's emphasis on manned spaceflight prevented spending on constructive scientific work that might be done with unmanned vehicles. An unidentified NASA "top administrator" is supposed to have said that "we made Van Allen famous, and he's been kicking us in the butt ever since."[8]

Although a poll by the Associated Press in August 1988, just before the return to flight, indicated that a large portion of the population had lost confidence in NASA over the past few years, a remarkable 58 percent said that the Agency had done a good or excellent job, with most of those polled favoring a budget at least equal to or greater than that for the past years.

But a similar Gallup Poll a year later suggested that public commitment to the space program was lukewarm. Roughly one-fourth of those polled favored raising the NASA budget, while an equal number would cut the budget. There was little sense of urgency about being the first to land on Mars, and no strong opinions about whether space exploration should concentrate on manned or unmanned missions.[9]

In October 1988, as NASA celebrated its 30th birthday and the return to flight, most Americans could not recall a time when there had been no NASA. For them, the Apollo program and lunar landing were history, nothing more. And the cold war which had triggered the turn to space was dissipating rapidly and would virtually evaporate. The polarized cold war world helped keep the space race alive. Could peace and international cooperation do the same? Did space ventures, in fact, offer an institutional and intellectual framework for international cooperation that might in and of itself justify a continued commitment to space? Whereas the cold war and international competition brought Soviets and Americans into space, and in the process threatened to destroy them all either through military conflict or economic collapse, could peace and international cooperation sustain an effort in space, or was technological advancement somehow dependent upon international rivalry and war or the threat of war? American goals in space, whatever the motivations of the past decades, entered a new conceptual framework in the last decade of the 20th century because of the changing world order reflected by the demise of the cold war. For those under the age of 30, the rationale for an American presence in space would not be quite the same as for those of the cold war generation.

In the realization that NASA had not fully communicated its accomplishments and its purposes to the general public, JSC and individuals in the private sector for some years had been interested in improving the center's visitor complex and educational information facilities. In October 1988, Aaron Cohen signed a Memorandum of Understanding with the Manned Space Flight Educational Foundation for a privately endowed visitor center on site. Approximately one million visitors came through the gates of JSC each year; and although there were Mercury and Apollo rockets, lunar modules and astronaut flight suits on display, the center was really not equipped, nor did it have the personnel or time, to commit the kind of energies to public education and information that did seem to be justified. In cooperation with community leaders and retirees, JSC officers—prominently William R. (Bill) Kelly (Director of Administration) and Harold S. Stall (Director of Public Affairs)—organized a nonprofit corporation as a vehicle for raising funds to operate a planned $40 million (or more) visitor center.[10]

Kelly, who signed the Memorandum of Understanding with Cohen, was Chairman of the Foundation. Stall was President and Chief Operating Officer. Six more JSC officials including Dr. Carolyn Huntoon (Director of Space and Life Sciences), Harvey Hartman (Deputy Director of Human Resources), Paul J. Weitz (JSC Deputy Director), John W. O'Neill (Assistant Director of Mission Operations), and Grady McCright (Deputy Director of Center Operations) joined five board members from the private sector. In November, the Foundation kicked off an $8 million fund-raising campaign for "Space Center Houston," seeking to procure one-half of the total from aerospace contractors and the remainder from Houston-area civil and philanthropic organizations. An additional $42 million was to be raised from revenue bonds funded by admission charges. The Foundation also entered into a preliminary

Space Center Houston: Built to be an "adventure of the mind," the visitor center is expected to relieve JSC of the difficult obligation of hosting the general public and at the same time produce a better informed, more aware, and more supportive public.

agreement with Walt Disney Imagineering for the design and development of the visitor complex.[11]

The economic down-turn, oil price collapse, and banking and savings and loan crises resulted in long delays and failed commitments to the Foundation and difficulty in obtaining funding for the proposed revenue bonds; but by early 1991, "Space Center Houston" was back on track. The complex had been enlarged to a 180,000 square foot facility that would cost about $70 million and host an anticipated 2.3 million visitors per year. Hal Stall said that the new center sought to dispel the myth of space and explain its realities. "It is not to be," he said, "a theme park or a museum, but an experience center where visitors can see, touch and feel. It is to be an adventure of the mind."[12] The visitor center is expected to have a great impact on the local economy, relieve JSC of the difficult obligation of hosting the general public, and produce a much better informed, more aware, and presumably more supportive public. Thus, September, October, and now November 1988, marked a turning point in the affairs of NASA and JSC in yet another way.

The newly elected President, George Bush, interpreted his victory at the polls as at least in part a vote for a sustained and somewhat enhanced space program. A transition team began the search for a new NASA Administrator. Among those being considered were Gerald Griffin and Chris Kraft, former JSC directors; H. Ross Perot, a businessman from Dallas; Hans Mark, Chancellor of the University of Texas; Richard H. Truly, NASA's Associate Administrator and a former astronaut; Frank Borman, a former astronaut and President of Eastern Airlines; and former astronauts Bill Anders, Tom Stafford, and Frederick H. (Rick) Hauck, who commanded the *Discovery* in its September flight.[13] Although the list of candidates suggested a strong JSC representation and certainly the President's personal interest in space (and in Houston) boded well for JSC, center personnel were preoccupied with more pressing things than the politics of succession.

Technicians and flight crews began final preparations for the launch of *Atlantis* (STS-27) scheduled for late November or early December. In November, JSC unveiled its new $4.8 million space station mockup and trainer building and facilities, and soon after,

A mockup of the new Space Station Freedom *is housed in Building 9 at JSC to provide training and design experience for the space station scheduled to be placed in permanent orbit about Earth near the close of the decade of the 1990's.*

the *Atlantis* crew flew to Kennedy Space Center for a "dry" test launch. On December 2, after a delay for bad weather, the Shuttle lifted off on a classified DoD mission. There were now two successful returns to flight. Following *Atlantis*' return, JSC employees and contractors received a total of 158 individual and 43 group return-to-flight NASA awards. JSC remembered that 20 years earlier Apollo 8 made the historic translunar orbital flight. Relatively few of the personnel on board then were still at the center. It seemed appropriate to begin planning a reunion—a 20th anniversary celebration of the Apollo 11 lunar landing to be held at JSC in July, 1989.[14]

Discovery entered the Vehicle Assembly Building at Kennedy in late January 1989, for mating with the STS-29 Shuttle components in preparation for a March 1989 lift-off. On March 13, pretty much on schedule, *Discovery* rode into orbit. In a telephone call to the orbiting vehicle, President Bush congratulated the crew and NASA: ". . . you have our strong support," he said, "We're living in tough budgetary times, but I am determined to go forward with a strong, active space program." And on the ground at JSC, in his farewell tour of NASA facilities, Administrator Fletcher congratulated JSC employees and predicted revisits to the Moon, lunar bases, and manned missions to Mars.[15]

As a reflection of his commitment to space, President Bush resurrected the National Space Council which had fallen into disuse during previous administrations. Soon after the return of *Discovery*, its head, Vice President Dan Quayle, visited JSC in company with Rear Admiral Richard H. Truly, NASA Associate Administrator for Space Flight. The Vice President told a lunch crowd in the Building 11 cafeteria that President Bush told him there were three things he would love about Houston, "the weather, the barbecue, and the Johnson Space Center." The National Space Council, he said, would look beyond the traditional divisions of space interests (the civil, commercial and national security interests), and would seek to formulate policies regarding the privatization of space and the promotion of educational opportunities "to ensure an abundant supply of qualified scientists and aerospace engineers."[16]

Within days, President Bush nominated Admiral Truly to the post of NASA Administrator. The Senate approved the nomination in late June, and in July Richard H. Truly became the first administrator with astronaut experience. A Navy pilot, Truly joined the Air Force Manned Orbiting Laboratory Program in 1965 and transferred to NASA's astronaut corps in 1969 when the Air Force program was canceled. He piloted the STS-2 flight and commanded the STS-8 flight. He then served as commander of the Naval Space Command before going to NASA Headquarters as Associate Administrator for Space Flight. Henry Hartsfield, Deputy Director of Flight Crew Operations at JSC, said that because Truly had flown in space and "managed the return to flight (of the Shuttle), he understands how to sell the budgets and how to develop sound ideas." But not all were so supportive. George Henry Elias, author of *Breakout Into Space: Mission for a Generation*, thought that Truly was too much the specialist (an astronaut, military officer and technician) when what NASA needed was a "generalist with broad vision and deep experience."[17] Generally, however, JSC felt good about having one of its own at the NASA helm.

It felt good too to get *Atlantis* back into orbit on May 4, carrying the unmanned Magellan spacecraft to be launched from the Shuttle for an orbital exploring mission to the planet Venus. A month later the Magellan probe had traveled 3.735 million miles from Earth and was moving at a velocity of 5500 miles per hour.[18] The space program seemed to be back on track.

NASA scheduled 4 more Shuttle flights for 1989, 9 for 1990, 8 in 1991, and 12 in 1992 (including the introduction to the Shuttle fleet of the new *Endeavour*—replacing the *Challenger*). The flight manifest planned 14 Shuttle flights in 1993, 13 in 1994, and 10 through September of 1995. In addition, NASA began scheduling launches using Titan IV expendable rockets. Like Magellan, two more unmanned planetary probes, Galileo to Jupiter and Ulysses to the Sun, were scheduled for 1989 and 1990, respectively. The program office slipped the scheduled launch of the Hubble Space Telescope from December 1989 to March 1990 in order to retrieve a Long Duration Exposure Facility (LDEF) deployed in 1984 and originally scheduled for retrieval in 1985. That retrieval time was now long past due and the LDEF satellite was in danger of plunging back to Earth. There were to be many Earth science missions and experiments, a number of cooperative missions and experiments with foreign nations, and in 1995, the first assembly missions for components of Space Station *Freedom*.[19] There was much to do—much to look forward to.

Aaron Cohen remarked: ". . . Our number one job (at JSC) is still to fly the Shuttle and fly it safely." In the Technical Services Division, machining, sheetmetal and welding fabrication, sculpturing, electronics and computer devices were produced on order for the Shuttle and space station. Here JSC engineers fabricated the mockups, models, and government-supplied equipment where ideas and designs became tangible artifacts, and technicians manufactured everything from "soup to nuts." Here hands-on management began. Many of the specialty fabrications for the new ship *Endeavour,* scheduled for a 1992 maiden flight, came out of the JSC shops. Much of the center's energy and talent continued to be directed to maintaining and flying the Shuttle fleet.[20] JSC also made a number of administrative changes affecting the management of both the Shuttle and the space station.

Daniel M. Germany assumed direction of the Orbiter and GFE (Government-Furnished Equipment) Projects Office at JSC, replacing Richard A. Colonna who headed for the outback to become NASA's representative to Australia. Work on *Endeavour* now consumed more of the orbiter office's attention. Rockwell International's Space Construction Division increased its workforce on the *Endeavour* construction project from 600 to 850. Roger Hicks, JSC's orbiter project operations officer stationed at the construction site in Palmdale, reported that everything was on schedule, if not a bit ahead, but that the crucial work would come in 1990 when the various components and fuselage, wings, tail, and crew modules were assembled and electronic systems were integrated and tests began.[21]

Leonard Nicholson replaced Richard Kohrs as Deputy Director of the Space Shuttle Program Office, and that office was moved from Headquarters to JSC to better mesh the technical work with management—thus ameliorating (in the minds of JSC engineers) the separation of Level II management from the center technical expertise that had occurred with the scrapping of the lead center system and the reorganizations following the *Challenger* disaster. Nicholson, who joined the Spacecraft Integration Branch in the Engineering and Development Directorate at JSC in 1963, rose through the ranks to become technical assistant to the Manager of the Apollo Program Office, then manager of the Space Transportation System (STS) Operations Office, and manager of STS Integration and Operations. Jay Greene, who had a diverse background at JSC in flight dynamics, as chief of the Mission Operations Branch, flight director, and chief of the Safety Division, became deputy manager of the National Space Transportation System Program Office (which would soon be renamed the Space Shuttle Program Office). Larry Williams, who joined NASA in 1962, became manager of the Engineering Integration Office. C. Harold (Hal) Lambert, a 1957 Langley Research Center veteran who went to JSC's Propulsion and Power Division in 1962, became manager of the Shuttle Integration and Operations Office.[22]

There were also management changes and program changes for the space station. Richard Kohrs left JSC for Headquarters where he would direct the Space Station Freedom Program Office. Kohrs, like Nicholson, began his NASA career at MSC in 1963 and was STS systems integration manager and deputy manager of the STS Program Office before moving to space station work. Kohrs assigned Richard A. Thorson to JSC as deputy manager for Space Station Freedom Program Integration. This assignment helped reestablish the essential association between the Level B (Level II after 1987) program management and technical expertise.[23] Thus, the new space station Level B and Shuttle Level II management structures attempted to establish a bridge between the old lead center system and the post-*Challenger* organization that had effectually isolated the technical integration management from its technical resources.

Another bridge between project and program management involved simply the transfer of personnel between Headquarters and JSC. Thus, Arnold D. Aldrich, who joined the Langley Space Task Group soon after its formation and became a member of the staff of MSC, moved to Headquarters in 1987 as Director of the National STS Office. Aldrich managed the STS through his deputy director and colleague, Leonard Nicholson at JSC. Nicholson, of course, had replaced Richard Kohrs as deputy director. About the time that Kohrs went to Headquarters, John W. Aaron, who was managing the Lunar and Mars Exploration Activity Office in Washington, D.C., transferred to Houston to head the Space Station Projects Office. Aaron, who joined the JSC task force in 1964 as a flight controller, had been assistant and then chief of the Spacecraft Software Division (1979-1984) and a special assistant to Aaron Cohen. Clarke Covington, who formerly headed the Space Station Projects Office, now became a technical assistant to the JSC Director. But because the project office reported directly to the Center Director, rather than through the program office as had occurred under the lead center style of management, the interface between the program office and the project office was not as close as it had been under the lead center system.[24] However, no management system had been perfect and the vital ingredient in effective project/program management involved the proper "people" and experience mix. It did appear that insofar as JSC and the Shuttle were concerned, the old "collegial" management mix that had provided an interface between Headquarters and JSC and had served NASA so well during the Mercury, Gemini, and Apollo/George Low era had been reinstated.

Aaron Cohen defined project management as "the business of creating—through a sensible sequence of efforts that utilize to best advantage the resources available—a product that achieves the objective." JSC's product:

> . . . is putting men and women into space, keeping them alive and productive while they're there and returning them safely to Earth. We design, develop and operate manned spacecraft and train the crews that use them. We conduct scientific and medical experiments that help us understand how space affects our astronauts and spacecraft . . .

Cohen thought that the key to effective project management was to nurture the environment and culture that motivated people to strive for technical excellence above all else. After intensive in-house studies, JSC initiated a Total Quality Management program that sought to continually enhance performance at all levels through cooperative contractor-manager team planning and collaboration. Regarded as a strategic approach to change, the new processes sought to produce real savings and better performance (earning JSC a Quality Improvement Prototype award from OMB in 1990).[25]

Cohen had learned that hands-on experience was essential to controlling the three classical elements of project management—performance, cost, and schedule. Schedules drive costs, and costs determine what can be produced. Performance is a product of costs and schedules. Contract management and project control are as important to management as technical expertise. Decisions must not only be made, they must be timely. Compromise is both acceptable and necessary. Not all problems can be solved. Product development involves selecting that which is best or better, not that which is perfect. And finally, project management is a people-oriented business. Patience, communication, honesty and fair treatment are necessary elements of effective management.[26] Thus, space projects were people projects, and the culture and environment of space project management, to be sure, extended far beyond the confines of JSC. The President, Congress, Headquarters, all of the NASA centers, the contractors and their employees, and even the media and electorate contributed to the culture that had formed about space and its technology.

Space was a complex business that required a sustained level of activity, careful scheduling, continual testing and development, cost controls, a relentless attention to detail and quality in product and performance. An event such as the launch of *Columbia* (STS-28) in August 1989 on a DoD mission reflected not only a triumph in technology, but a significant accomplishment in very large-scale project and systems management, as well as a real achievement of the human spirit. Glenn Lunney sensed that the 25 years he spent at JSC had been a time memorable for extraordinary events, a "Camelot, a magic time, . . . when what we did was more than the sum of all of us."[27]

Although none said so in so many words, Lunney's sense of things seemed to reflect the sentiments of most of those gathered at JSC to celebrate the 20th anniversary of the lunar landing. "Were you there? . . . Yes, I was there." They meant, of course, not that they were on the Moon, but that they shared that time as one of the several thousand scientists, technicians, engineers, flight controllers, and staff of JSC. Comments from speakers included: "Think about what humans have done the past 100 years, when you think about the possibilities for the future." "There was a sense of trying to accomplish something that had not been done before." "What we did was nothing short of fantastic," another commented. "We had more responsibility at age 30 than most people have in a lifetime." "This was an enormously successful and dedicated organization." "The door's been opened . . ." "The things we thought were not important . . . really are." "This was a pause as one climbed the mountain . . ." "This was done by ordinary people!"[28] And with each Shuttle launch, each placement of a satellite, or each design, development and testing of a space station component, that magic continued.

While JSC and NASA celebrated the Apollo Lunar Landing 20th Anniversary, President George Bush announced a new "Space Exploration Initiative."

> We must commit ourselves anew to a sustained program of manned exploration of the solar system and, yes, the permanent settlement of space . . .
>
> First, for the coming decade—for the 1990's—Space Station *Freedom*, our critical step in all our space endeavors. Next, for the new century, back to the Moon, back to the future, and this time, back to stay. And then a journey into tomorrow, a journey to another planet, a manned mission to Mars.[29]

As Congress and the American people began to digest this proposed long-range continuing commitment in space, NASA selected a special study group, headed by JSC's Aaron Cohen, to frame the essential elements and guidelines affecting decisions about a lunar-Mars initiative. And the pace and excitement within NASA seemed to quicken.

Atlantis (STS-34) moved into the Vehicle Assembly Building at Kennedy Space Center in August, within days of the return of STS-28. Voyager 2, an unmanned planetary probe, began sending images of the planet Neptune 2.8 billion miles through space to Earth. *Atlantis* lifted off from Kennedy Space Center on October 18 "after being threatened by a court challenge, delayed five days by a suspect main engine controller, and one day by unfavorable weather." The crew, including commander Don Williams, pilot Mike McCulley, and mission specialists Ellen Baker, Franklin Chang-Díaz and Shannon Lucid, deployed the Galileo spacecraft for a 5-year journey to the planet Jupiter and a 1995-1997 orbital tour of the great planet.[30]

That week in the Gilruth Center at JSC, Dr. Robert L. Forward, a physicist, science consultant and author, speculated with JSC personnel about the feasibility of interstellar travel. In November, Congress approved a $12.4 billion NASA budget, providing an 11.9-percent increase over the previous year. JSC's space station work would increase markedly, and a construction program was scheduled that would add a new central computing facility, an auxiliary chiller for air-conditioning, additions to the atmospheric reentry materials and structures evaluation facility, a space station "high-bay" assembly building, a space station control center, and an improved simulator/training facility. The Hubble Space Telescope, scheduled for flight in March 1990, began instrumentation tests at Kennedy Space Center.[31]

Atlantis (STS-32), however, seemed poised interminably at the launch pad for favorable weather and a good launch, as the decade of the eighties drew to a close. The launch of *Atlantis*, said Aaron Cohen, "if we do our jobs well . . . will be the first successful Space Shuttle mission of a busy, challenging year. We also find ourselves working toward the well-defined, long-range goals of establishing a permanent base on the Moon, and then sending humans on to Mars and beyond. Separate, these efforts are extremely important. Together, they are the realization of dreams."[32]

The launch went well. Another decade in space began. *Atlantis* sped into space on January 8, 1990, and returned with a prize, the LDEF, a bus-sized satellite stranded in space for almost 6 years, which carried rich documentation for long-duration spaceflight and habitation. In the returning cargo were thousands of tomato seeds sent as part of the Space Exposed Experiment Developed for Students (SEEDS). After the seeds were returned and preliminary tests were completed, NASA sent seeds to schools and individuals throughout the United States and the world in response to 130,000 requests. Would space-exposed seeds germinate, grow, and bear fruit? Technical foreman Dan Alexander planted seeds outside building 326 at JSC. There was an 85-percent germination rate for the space seeds, and a 62-percent germination for a test batch of earthbound seeds![33]

The new year also began with the promulgation of the study of the President's Space Exploration Initiative. The study, a product of a comprehensive NASA effort and directed by Aaron Cohen, involved program associate administrators at Headquarters, center directors, technical study groups, and a report assembly team. Directed to Administrator Truly for the National Space Council, the report sought to provide criteria and framework for a determination of the necessary money, personnel, and materials that might be required for a "new and continuing course to the Moon and Mars and beyond." The Space Exploration Initiative Cohen defined as encompassing both robotic and human missions—but overall a "distinctly human adventure" in the broadest sense, in that human and robotic missions into space would extend into the solar system the "skills, imagination, and support of many thousands of people who will never leave Earth."[34]

The study addressed again the question raised when the United States began its space program. "Why fly into space?" And it addressed a more contemporary question, but one which echoed from NASA's own past—"after the Shuttle, what next?" It was not unlike the question posed as the decade of the 1960's ended, and America had indeed met the challenge of putting a man on the Moon "within this decade." Then it had been—"after Apollo, what next?" Like the answers given earlier, the answers given in 1989 and 1990 to those questions would never be wholly satisfactory.

> The imperative to explore is embedded in our history, our traditions, and our national character . . . Now, in the late 20th Century and the early 21st, men and women are setting their sights on the Moon and Mars, as the exploration imperative propels us toward new discoveries.
>
> To enrich the human spirit, to contribute to national pride and international prestige, to inspire America's youth, to unlock the secrets of the universe, and to strengthen our Nation's technological foundation: human exploration of the Moon and Mars will fulfill all these aspirations and more.[35]

Almost concurrently with the preparation and release of the report on the new American space initiatives, the world as it had been known began to unravel and change markedly. The demise of the cold war, the withdrawal of Russian troops from East Germany and Soviet satellite countries, and the seemingly incredible reunification of Germany and breakup of the Soviet Union cast the old questions about space, and their answers, in a totally new context. Could the American space program survive peace? Could international cooperation replace international competition? Would Congress and the American people commit their resources to new space initiatives now that the justification for space and even high technology had seemingly changed?

Although the existing Shuttle, space station initiatives, telecommunications, navigation and information management systems provided the basic infrastructure for a lunar-Mars initiative, the Shuttle and expendable launch vehicles would need to be enhanced. Cargo flights for extraterrestrial human exploration required a lift capacity of 60 metric tons for the Moon and 140 metric tons for Mars, compared to the 17.3 metric ton capability of the Shuttle. More work was needed in the life sciences, including medical care, life support systems, and studies of human behavior in an extraterrestrial environment. Space Station *Freedom* would be intrinsic to the development of extraterrestrial capabilities, and the Shuttle, in turn, vital to the construction of the space station.[36] But much more would be required in basic research and development.

NACA/NASA, with its 75 years of research, development and operational experience, provided the core capability for the new space initiative. The new programs would, however, require a "significant augmentation of civil service positions," and a "solid balance between in-house and contracted works." New exploration initiatives offered the potential and opportunity for international cooperation. They also created a favorable environment for scientific and technological research and development, and necessitated on the part of NASA a further nurturing of science and engineering in American educational institutions.[37]

Cohen's study group examined technical variables and scheduling, or the evolutionary processes of a Moon-Mars exploration program. The committee conducted a technology assessment that linked existing and projected capabilities with costs and schedules. Although existing technology could take people back to the Moon, long-term and regenerative life support systems were yet to be developed. For example, an Earth-Mars return flight was estimated at 14 months; and with surface operations, the trip would require self-sustained flight of at least 600 days. By comparison, the Shuttle was built for a nominal 7-day mission. New propulsion systems were advised, possibly expanding on nuclear thermal rocket technology developed in the NERVA rocket program between 1955 and

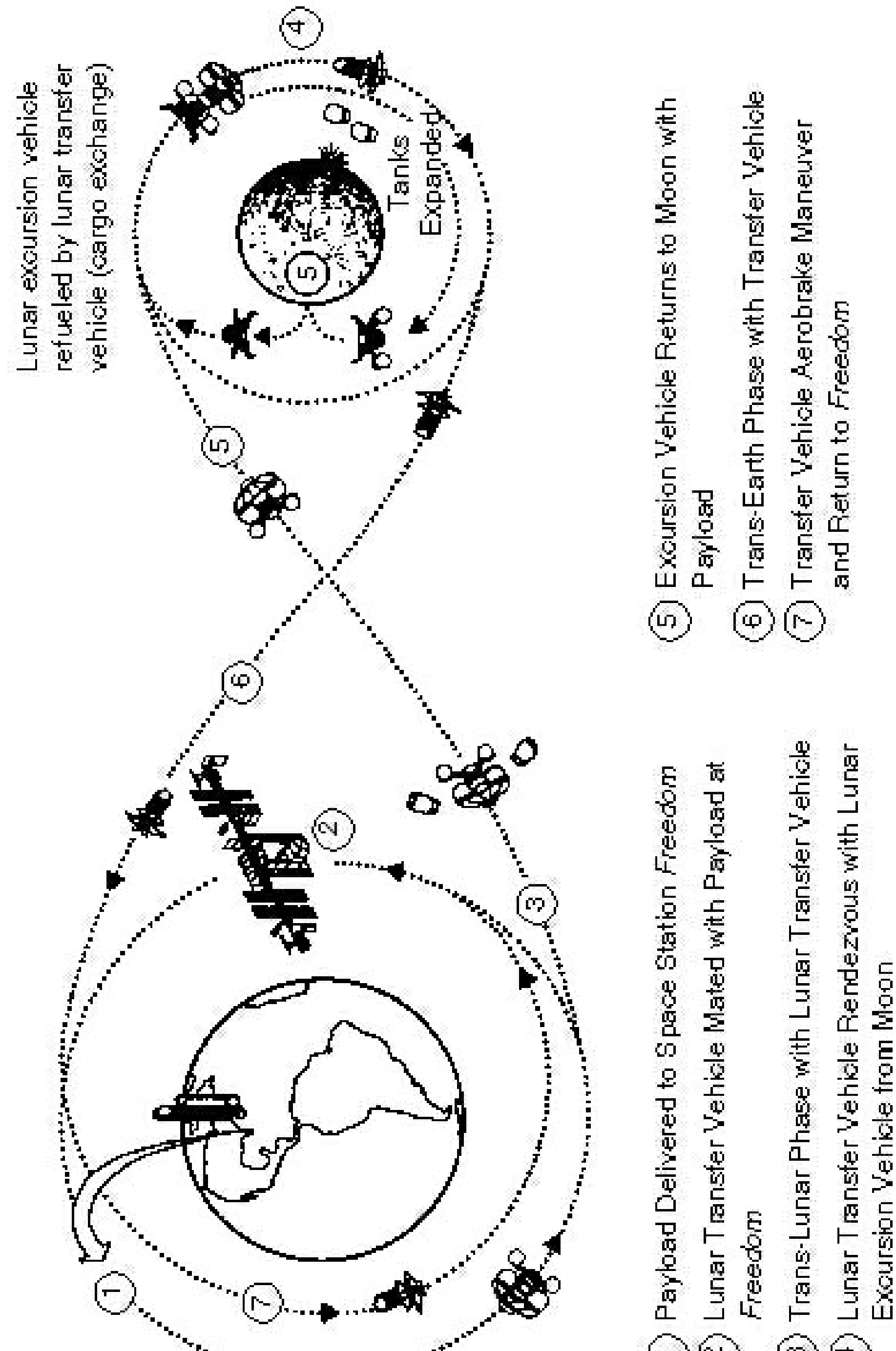


FIGURE 23. Lunar Mission Profile

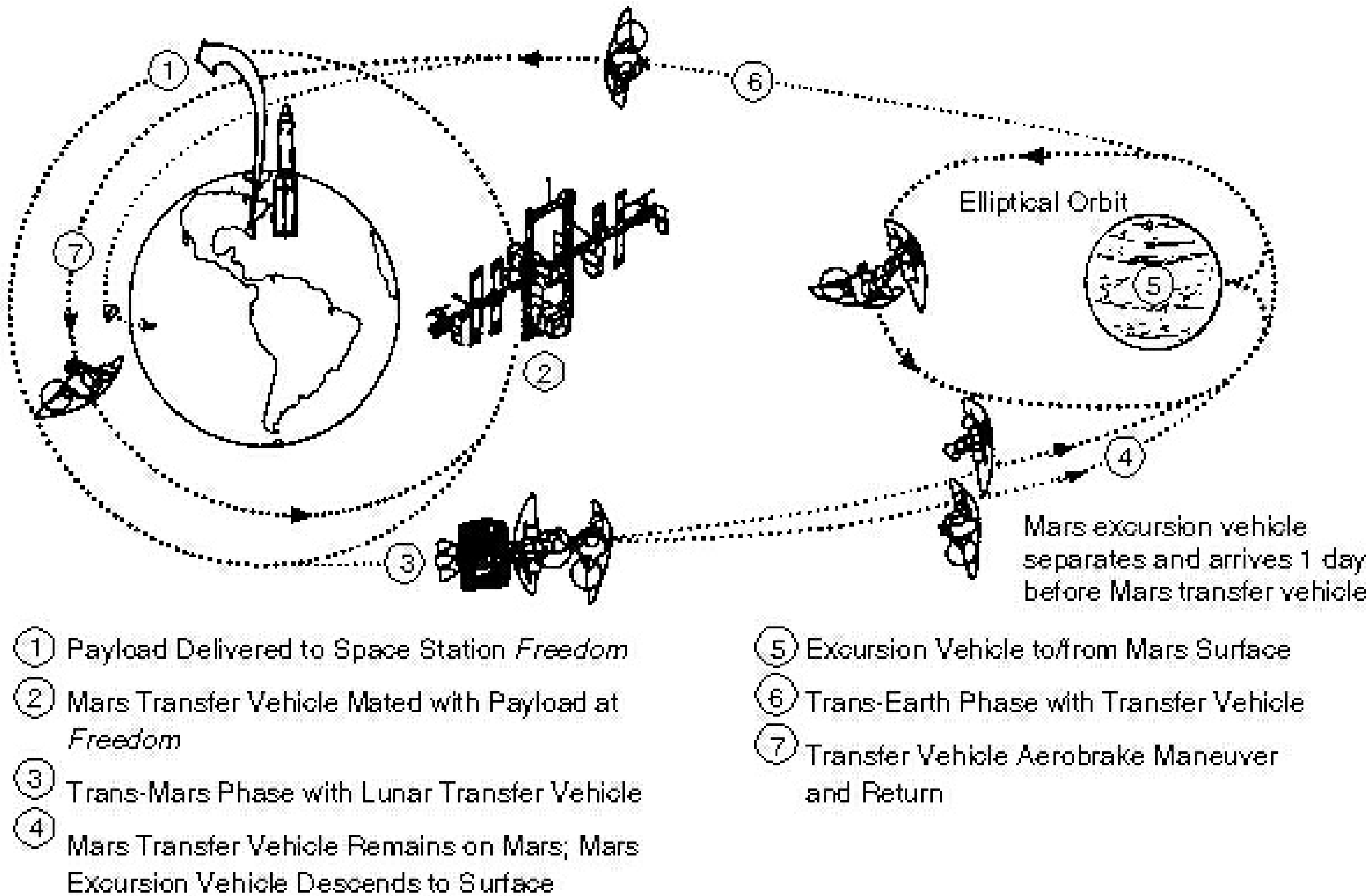


FIGURE 24. Mars Mission Profile

1973, or derived from ongoing work on electric propulsion thruster systems. Basic research and new technologies would be required to develop some of the essential service and maintenance systems.[38]

Thus, extended habitation on the Moon or a trip to and from Mars involved substantially more than launching another Apollo-type space vehicle. Apollo and the Shuttle represented relatively primitive machines and technology compared to the requirements for the Space Exploration Initiative. As was true with the decision to put a man on the Moon in the decade of the sixties, the engineering and the scientific community generally regarded the impediments, the difficulties, and the unknown as a challenge rather than a deterrent. No wonder, as Aaron Cohen noted, the 90-day study itself had generated a new enthusiasm, dedication, and excitement within the Agency.[39] But the proposed programs required a sustained, long-range, and continuing commitment. Whereas the Apollo, Shuttle, and even the space station were programs that could nominally be attained within a decade, a lunar base and a Mars expedition required many decades and more total resources than space programs had yet absorbed.

Despite what seemed to be real progress, uncertainties and doubts abounded. In the spring of 1990, NASA awarded the Operations Support Contract, including mission operations support, facility operations, and flight crew training for the space station and other programs to Rockwell Space Operations Company of Houston. Most of the contract management tasks for the 10-year $814 million contract were assigned to JSC Mission Operations Directorate. Rockwell subcontractors included Barrios Technology, Inc., Bendix Field Engineering Corporation, Omniplan Corporation, Science Applications International, Systems Management American Corporation, and UniSys-Air Defense and Space Systems Division. New jobs generated under the contract in the Houston-Clear Lake area were expected to rise from 200 in 1990 to 1450 by 1996. In anticipation that there would soon be other space vehicles added to the launch fleet, the Shuttle lost its old identity as the National Space Transportation System (NSTS) and became simply the Space Shuttle.[40]

In April, the Shuttle *Discovery* (STS-31) was mated to its tanks and rockets for a scheduled April launch. *Discovery* would carry the long awaited and much heralded Hubble Space Telescope into orbit. With the Hubble telescope, "a new era of astronomy and a new awareness of how humans fit in the cosmos will begin." After a number of "glitches," *Discovery* lifted from its pad on April 25 and placed the Hubble telescope in orbit. During the *Discovery* launch, *Columbia* (STS-35), carrying the ASTRO-1 ultraviolet astronomy telescope and a Broad Band X-ray Telescope, moved slowly aboard its crawler transporter to the adjoining launch pad for a May 16 launch. But problems with valves and freon coolant loops and hydrogen leaks forced repeated delays, until *Columbia* was rolled back to the Vehicle Assembly Building for more thorough checks. Meanwhile, the world waited expectantly for a new and brighter view of the cosmos while astronomers and technicians began targeting and focusing the Hubble telescope.[41]

By mid-summer the *Columbia* had not yet flown, and the source of its hydrogen leaks could not be located. Worse, the Hubble telescope simply could not focus the way it was supposed to focus—its primary mirror was flawed. Doubts and uncertainty grew greater. Congress stripped $300 million from the lunar-Mars initiative. But President Bush remained a supporter and asked Congress to raise NASA funding for 1991 to a record $15.2 billion, an increase of almost 25 percent over that of 1990. In an effort to help further resolve questions about America's future in space, in July, Vice President Dan Quayle, as head of the National Space Council, created a committee headed by Norman B. Augustine, Chief Executive Officer of Martin Marietta Corporation, to investigate and recommend to the Vice President, through the administrator, programs and approaches by which NASA might implement the U.S. space program in the years ahead.[42]

The Advisory Committee on the Future of the U.S. Space Program, as it came to be called, included scientists, engineers, former astronauts, business leaders and former Congressmen. Augustine's committee began its work in August, at a time when a number of external events began to intrude significantly on NASA's operations, and, indeed, on the world. In August, Iraqi armies directed by Saddam Hussein invaded and occupied neighboring Kuwait. President Bush and the United Nations responded by sending American and international forces to Saudi Arabia. The activation of reserve units immediately began to affect JSC employees. Of less traumatic but threatening proportions, Congress' failure to ratify a new fiscal year budget on time threatened to invoke the Gramm-Rudman-Hollings deficit reduction program which would require a 31.9 percent budget cut by NASA and nondefense government agencies, and more immediately result in the furlough of civil service employees until Congress did approve a budget bill.[43]

If this was not enough, NASA continued to be plagued with technical problems. Administrator Richard Truly tried to reassure NASA employees, who felt somewhat abused and confused by the problems, rising hostility in the press, the threat of foreign war, and budgetary and job uncertainties. It seemed to be something of an understatement when he explained to NASA employees in a radio broadcast from his office that "some things haven't gone right this summer." While engineers struggled to locate *Columbia's* hydrogen leak, *Discovery* (STS-41), with four previously scheduled launches already scrubbed because of such things as bent electrical connector pins and freon pressure losses, was readied for an October 5 lift-off. It made it—one day late—but on a near-perfect flight the flight crew launched the Ulysses probe bound for the planet Jupiter, conducted a variety of experiments, and returned to Earth.[44]

Crews now readied both *Atlantis* (STS-38) and *Columbia* (STS-35) on their launch pads at Kennedy Space Center for pre-Christmas launches. Payload and weather problems forced a week's delay of the *Atlantis* DoD mission, but the mid-November launch was routine. Finally, on December 2, after three previous failed launch attempts, *Columbia* carried her crew of seven into orbit and completed the long-delayed science missions. A special investigating team had discovered a crimped or damaged seal in two different engines, and tightened connections and checked all seals.[45] Since *Challenger,* the prelaunch checkout of each Shuttle, if it had not been so before, was meticulous, thorough, exhausting, time-consuming, and costly—but effective. There had been problems, but as Truly stated, those were problems uncovered by NASA.

Unfortunately, unlike the Shuttle's case, the problems with the Hubble telescope had not been uncovered prior to its launch. It turned out that the manufacturer of the Hubble mirror had tested the mirrors using an instrument which was itself defective; and NASA contract managers, who were concentrating on confining costs, forewent additional tests that could have revealed the flaws.[46] NASA began to actively consider a repair mission, perhaps as early as 1993. Meanwhile, the flawed Hubble did produce important new images and data of the universe. But the NASA image was blemished, as was the Hubble mirror.

On December 17, 1990, not long after *Columbia*'s return, Norman Augustine delivered the report of the Advisory Committee on the Future of the U.S. Space Program to Administrator Truly. There had obviously been many reports during NASA's 30 years of operation, such as *The Next Ten Years in Space, 1959-1969*, completed in 1959 by the staff of the Select Committee on Astronautics and Space Exploration, and more recently the Rogers report on the *Challenger* accident, the Ride report on *Leadership* in the post-*Challenger* era, and Cohen's report on a lunar-Mars initiative; but there was a growing perception within NASA and at JSC that the Augustine report might indeed be the charter for NASA's tomorrow. The report offered a very brief, candid, pragmatic, down-to-earth analysis of what the United States and NASA had done and might yet do in space.[47]

NASA's current problems needed to be set in the context of space history. The *Challenger* failure, hydrogen leaks aboard the *Columbia* and other Shuttles, cost overruns, and the Hubble aberration problem derived from errors or situations developing 5, 10, or more years ago. Spaceflight is not and has never been risk free. Of 37 satellite launches attempted before 1960, less than one-third were successful. Ten of the first eleven unmanned probes to the Moon failed. Three astronauts died in the AS-204 fire. A tank explosion on Apollo 13 damaged the spacecraft and jeopardized the mission. During the few months surrounding the *Challenger* accident, a Delta rocket, an Atlas-Centaur, two Titans, a French Ariane-2, and a Soviet Proton were lost.[48] Trouble-free, risk-free Apollo or Shuttle flights never existed.

There has been a distinct lack of consensus about what the goals of the American space program are and how they should be accomplished. Most people seemed to support a space program, but no two people agreed on what that program should be. Some urged robotic missions only as an efficient, low-cost approach; others argued that human involvement is the essence of exploration; still others advised commercialization of the space effort; and others stressed the pure scientific, research goals of spaceflight—"only to be challenged in turn to prove the tangible value of studies in astronomy." The committee agreed that NASA was trying to do too much—that it was overcommitted, perhaps in response to the very disparate pressures upon it. Changing project budgets demoralized both those doing the work and those paying the bills. Civil service personnel policies were incompatible with the need to maintain within NASA a "leading-edge, aggressive, confident, and able workforce of technical specialists and technically trained managers." The tendency for projects to grow in "scope, complexity, and cost," had to be countered. Space projects are very unforgiving of any neglect or human failures. Finally, the program was overly dependent on the Space Shuttle.[49] Even as that analysis was being drawn, conditions within the space industry and NASA were changing rapidly as alternative space programs developed and diminishing emphasis on defense industries turned engineer talents increasingly to civilian space interests.

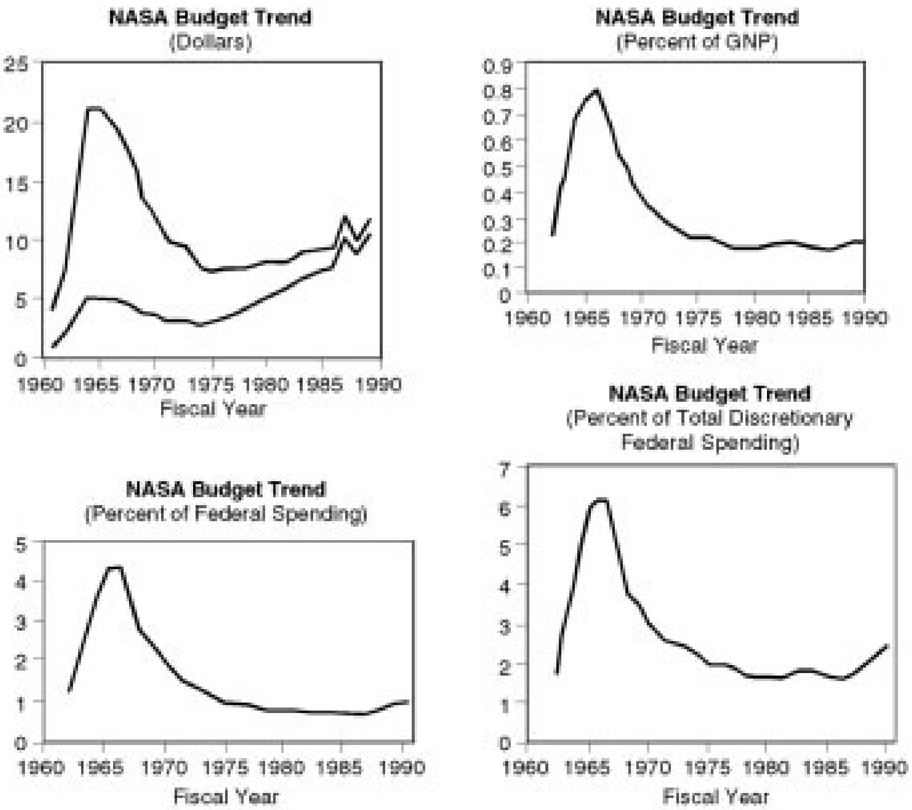
Given these parameters, the NASA Advisory Committee concluded that the Nation's space effort must continue to be directed by NASA, because it contained "by far the greatest body of space expertise in any single organization in the world." And what should be the U.S. space program? "What *should* we afford?" During the Apollo program, NASA spending accounted for 0.8 percent of gross national product (GNP), 4.5 percent of total federal spending and 6 percent of discretionary spending. From 1975 through 1990, NASA spending, equaled about .25 percent of GNP, 1 percent of federal expenditures, and 2.5 percent of discretionary spending.[50]

With the caveat that NASA cannot do everything, the report stated that the Agency should give funding priority to the space science program as the "fulcrum of the entire civil space effort." Its mission-oriented programs should support two major undertakings—a Mission to Planet Earth and a Mission from Planet Earth. The former would focus on climate and environmental issues that affect the quality of life on Earth, the latter would be focused on the exploration of space. It was the latter that had represented the most costly part of the civil space program.[51] As previously mentioned, between 1975 and 1990, approximately 85 percent of JSC resources were allocated to the Shuttle.

During the past decade, the Shuttle and manned spaceflight had been central to the controversy surrounding a space program. The advisory committee rejected unanimously the option that a space program should dispense with human flight. But what should be the objectives or projects of a manned space program? Not the cargo flights of a Shuttle to and from near-Earth space to deliver satellites or cargoes that might better be carried by unmanned vehicles! The advisory committee concurred with President Bush's lunar-Mars initiative, but counseled a "significant new approach in the planning of human space exploration." Rather than schedules, such as a landing on the Moon in this decade, a program with the long-term objective of the human exploration of Mars should be tailored to the availability of funding. Moreover, such an initiative should be a shared program of a consortium of nations. Space Station *Freedom* cannot be justified as a (nonbiological) science laboratory or as an essential transportation mode. Rather its validity derives from the contributions it can make as a life sciences laboratory and as a microgravity experiment station. This being the case, the space station can be "simplified, reduced in cost, and constructed on a more evolutionary modular basis." (Subsequently, in fiscal year 1991 Congress cut the Space Station *Freedom* budget by $500 million, directed that the planned facility be scaled back in scope, and advised NASA to cut approximately $6 billion from proposed station spending through 1997.)[52]

The Augustine Report recognized the technology base and the existing space transportation system as the two fundamental building blocks for extending the human presence in space. "NASA simply must take those steps needed to enhance the Shuttle's reliability, minimize wear and tear, and enhance launch schedule predictability." Cost reductions are "desirable," but "secondary to the preceding objectives." Costs could also be contained and efficiencies gained by providing a predictable and stable funding—which is wholly outside the province of NASA and dependent upon the support of the administration and Congress. The committee suggested diverting the funds proposed for an additional Shuttle orbiter to the construction of a new unmanned heavy lift launch vehicle, support by NASA to help nurture a commercial space industry, and a continuing national effort to enhance the Nation's mathematics and science programs.[53]

But space activity is inherently difficult and complex, the committee admonished: "As we labor under such challenges, we should insist upon excellence" and "strive for perfection." But we should be prepared for the occasional failure. The Nation "has no



Source: Congressional Budget Office.

FIGURE 25. NASA Budget Trends, 1960 to1990.

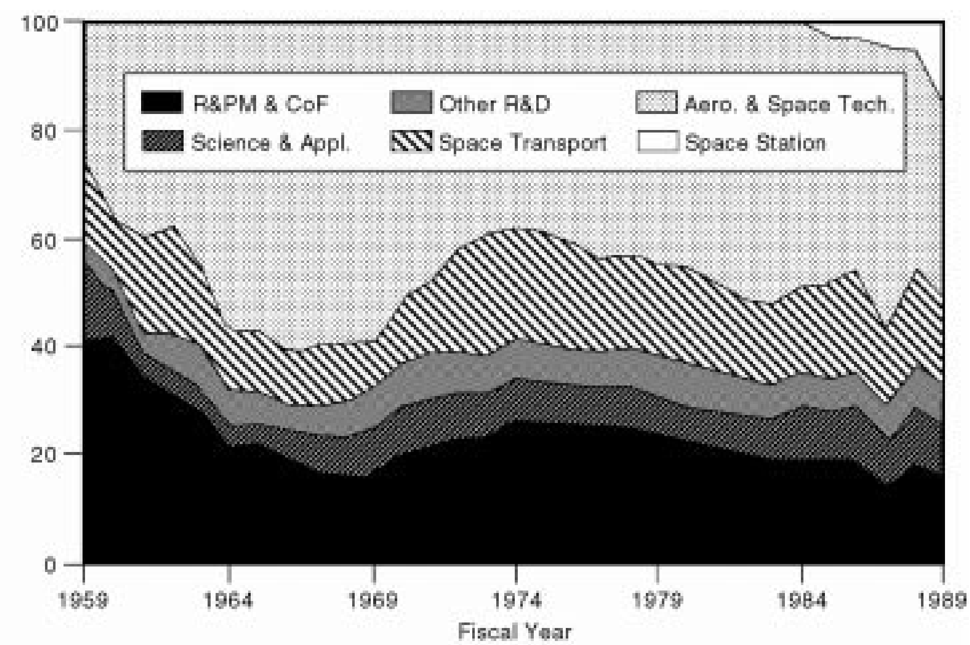
business in space if it places too great a premium on not making errors, and on "ridiculing those who strive but occasionally fail." The Augustine Committee made 15 fairly specific recommendations regarding goals, programs, costs, and management.[54]

It urged the establishment of an Executive Committee to the National Space Council including the Administrator of NASA, major civil service reforms (or specific exemptions affecting NASA employees), a review of the mission of each of the NASA centers so as to consolidate and refocus their efforts with a minimum of overlap, a reorganization of the Headquarters administrative structure, and the retention of an independent cost analysis group. The report recommended against multicenter projects, but recommended that when they could not be avoided, an "independent project office reporting to Headquarters be established near the center having the principal share of the work for that project"—and that this office have a systems engineering staff and full budget authority. This seemed to be an endorsement of the lead center management system which had been virtually abandoned for the Space Station *Freedom* program.[55]

Moreover, the report said "NASA should concentrate its hands-on expertise in those areas unique to its mission." Contract monitoring is best accomplished by systems managers with pertinent experience. NASA program offices, in effect, take the place of traditional prime contractors in defense and other government contracts, and contract work stresses performance rather than specifications—and can involve considerably more government people.[56]

Many JSC personnel believed that effective program management had more to do with attitude than organization. It involved primarily the tradition of advisory/participatory management inherited through the old NACA style and its intellectual predecessor, the National Academy of Sciences, which like NACA and then NASA had been conceived as a response to a real or imagined technological and economic threat. In the case of the National Academy of Sciences, founded in 1863, the threat was the Industrial Revolution in Europe. In NACA's case, it was competition in aviation technology; and in NASA's, a perceived national crisis engendered by Sputnik. NACA/NASA programs required the cooperation and participation of industry, academia and government, and because they also involved research and development rather than the fabrication of known structures, they further necessitated a cooperative, participatory management style.[57]

But there were other ramifications to space ventures that went beyond the role of a government agency producing a product—be it a shuttle or a space station. Exploration involves more than a product or development, but rather relates to the discovery of new frontiers and the use by society of the resources derived from that frontier. In this sense, the



Source: Congressional Budget Office.

FIGURE 26. NASA Budget, 1959 to 1989

American frontier in space *did* reflect those earlier experiences by which the United States Government actively supported expansion into new frontiers. The Lewis and Clark Expedition (1803-1806), U.S. Coastal and Geodetic Surveys (1807, 1808, 1832), the U.S. Exploring Expedition (1838-1842), transcontinental railroad construction (c. 1863-1890), the Panama Canal and even the Federal Highways Act of 1915, the Interstate Highways Act of 1952, and the establishment of the Atomic Energy Commission fit the model of federal-private-scientific cooperation, and required the commitment of a considerable proportion of the federal budget.[58] Unlike the government's commitment to space, however, these earlier projects were considerably more finite in scope, purpose, resources used, and product derived. Space seemed to have no boundaries.

Epilogue

Earthrise! A phenomenon never before observed by humankind suggests the profound technical and philosophical impact of the U.S. manned spaceflight program upon people of the Earth.

Although the book ends, the story continues. The repercussions of America's ventures in space will ripple through time and space to affect life on Earth, perhaps for all time. The ripples will be somewhat greater or lesser depending upon future funding, continuing programs and achievements, but should NASA or JSC come to the end of their time, what has been done in the past will have a continuing effect on humankind. During the past three decades, spaceflight, thought about space under the leadership of JSC, and new technology engendered by space have contributed to epochal changes in human history.

Although there were preliminaries—and the luminaries such as Robert H. Goddard, Konstantin E. Tsiolkovsky, and Hermann J. Oberth—America's ventures in space really began as a response to the challenge or threat (real or imagined) caused by the Soviet's successful launch of Sputnik I. The Space Task Group headed by Robert R. Gilruth was formed soon afterward from Langley Aeronautical Laboratory's Pilotless Aircraft Research Division.

Upon the approval of the National Aeronautics and Space Act by Congress in 1958, the older National Advisory Committee for Aeronautics (NACA) and its research centers were redirected as the research arm for NASA, while the STG became the nucleus of a new multicenter manned spaceflight program. The Space Task Group was enriched with the addition of Canadian and British engineers from Canada's recently closed AVRO Aircraft, Ltd., a subsidiary of Britain's A.V. Roe Company. Subsequently, a large contingent of German rocket scientists, headed by Wernher von Braun and working with the Army Ballistic Missile Agency, joined the NASA organization. Air Force, Navy and civilian engineers soon swelled the ranks of NASA's civil service personnel.

STG personnel with the AVRO engineers became the core of the Manned Spacecraft Center in Houston, Texas. Von Braun's group comprised the essential ingredient of the Marshall Space Flight Center organized in Huntsville, Alabama, while elements from both Marshall and MSC, with Air Force and other military personnel, were the basic ingredients of what became the Kennedy Space Center. Goddard Space Flight Center, Stennis Space Center, MSC, Marshall Space Flight Center and Kennedy Space Center, with other laboratories and test operations, constituted the manned space and operations arm of NASA.

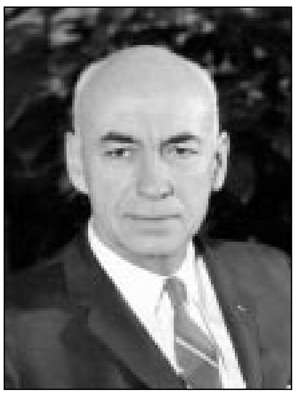
MSC, renamed the Lyndon B. Johnson Space Center in 1973 for one of Texas' leading statesmen and an architect of the national space program, became the lead center in developing the design, flight systems, and crew training for the Mercury, Gemini, Apollo and Shuttle programs. Apollo-Soyuz missions were distinctive, both in the use of diverse space hardware and in facilitating cooperation between two nations enmeshed in cold war. Johnson Space Center provided astronauts, life support systems, and flight operations for Skylab missions. In the 1990's, JSC supports Space Shuttle flight missions, Space Station *Freedom*, and the development of a lunar base that is integral to a manned mission to Mars.

During its three decades of existence, JSC developed a distinct culture and management style within the national aerospace community. That style heavily reflects the imprint of Dr. Robert R. Gilruth, the head of the original STG and first Director of MSC. It involved primarily the tradition of advisory/participatory management inherited from NACA. It was sharpened by a strong and continuing emphasis on hands-on engineering and technical accuracy, by the development of an effective and sophisticated structure of systems engineering, and by a deep sense of personal commitment to the program and to participants in the program.

NASA and space programs have directly affected the private sector of the national economy, while JSC has impacted heavily on the Houston and Texas economy. Space is largely a private business conducted by private contractors managed by NASA engineers. Pioneering the space frontier is inextricably tied to the expansion of those new, intensely earthbound frontiers in technology, organization, and management being pioneered by NASA and JSC in collaboration with American business and educational systems.

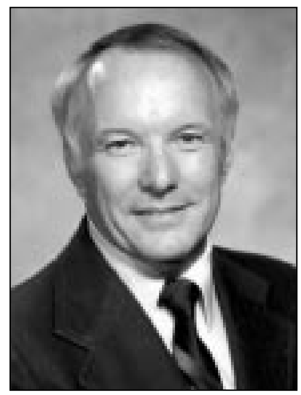
MSC/JSC Directors

MSC/JSC Directors



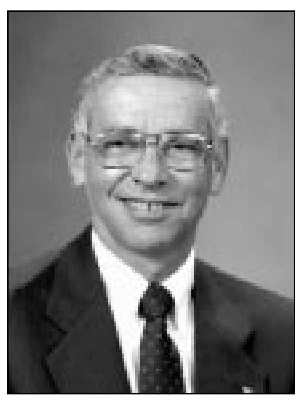
Dr. Robert R. Gilruth
1962 to 1972

Dr. Christopher C. Kraft, Jr.
1972 to 1982



Gerald Griffin
1982 to 1986

Jesse W. Moore
1986



Dr. Aaron Cohen
1986 to Present