Project Apollo: A Retrospective Analysis

Introduction

On 25 May 1961 President John F. Kennedy announced to the nation a goal of sending an American safely to the Moon before the end of the decade. This decision involved much study and review prior to making it public, and tremendous expenditure and effort to make it a reality by 1969. Only the building of the Panama Canal rivaled the Apollo program's size as the largest non- military technological endeavor ever undertaken by the United States; only the Manhattan Project was comparable in a wartime setting. The human spaceflight imperative was a direct outgrowth of it; Projects Mercury (at least in its latter stages), Gemini, and Apollo were each designed to execute it. It was finally successfully accomplished on 20 July 1969, when Apollo 11's astronaut Neil Armstrong left the Lunar Module and set foot on the surface of the Moon.

The Kennedy Perspective on Space

In 1960 John F. Kennedy, a Senator from Massachusetts between 1953 and 1960, ran for president as the Democratic candidate, with party wheelhorse Lyndon B. Johnson as his running mate. Using the slogan, "Let's get this country moving again," Kennedy charged the Republican Eisenhower Administration with doing nothing about the myriad social, economic, and international problems that festered in the 1950s. He was especially hard on Eisenhower's record in international relations, taking a Cold Warrior position on a supposed "missile gap" (which turned out not to be the case) wherein the United States lagged far behind the Soviet Union in ICBM technology. He also invoked the Cold War rhetoric opposing a communist effort to take over the world and used as his evidence the 1959 revolution in Cuba that brought leftist dictator Fidel Castro to power. The Republican candidate, Richard M. Nixon, who had been Eisenhower's Vice President tried to defend his mentor's record but when the results were in Kennedy was elected by a narrow margin of 118,550 out of more than 68 million popular votes cast.[1]

Kennedy as president had little direct interest in the U.S. space program. He was not a visionary enraptured with the romantic image of the last American frontier in space and consumed by the adventure of exploring the unknown. He *was*, on the other hand, a Cold Warrior with a keen sense of *Realpolitik* in foreign affairs, and worked hard to maintain balance of power and spheres of influence in American/Soviet relations. The Soviet Union's non-military accomplishments in space, therefore, forced Kennedy to respond and to serve notice that the U.S. was every bit as capable in the space arena as the Soviets. Of course, to prove this fact, Kennedy had to be willing to commit national resources to NASA and the civil space program. The Cold War realities of the time, therefore, served as the primary vehicle for an expansion of NASA's activities and for the definition of Project Apollo as the premier civil space effort of the nation. Even more significant, from Kennedy's perspective the Cold War necessitated the expansion of the military space program, especially the development of ICBMs and satellite reconnaissance systems.2

While Kennedy was preparing to take office, he appointed an ad hoc committee headed by Jerome B. Wiesner of the Massachusetts Institute of Technology to offer suggestions for American efforts in space. Wiesner, who later headed the President's Science Advisory Committee (PSAC) under Kennedy, concluded that the issue of "national prestige" was too great to allow the Soviet Union leadership in space efforts, and therefore the U.S. had to enter the field in a substantive way. "Space exploration and exploits," he wrote in a 12 January 1961 report to the president-elect, "have captured the imagination of the peoples of the world. During the next few years the prestige of the United States will in part be determined by the leadership we demonstrate in space activities." Wiesner also emphasized the importance of practical non-military applications of space technology--communications, mapping, and weather satellites among others--and the necessity of keeping up the effort to exploit space for national security through such technologies as ICBMs and reconnaissance satellites. He tended to deemphasize the human spaceflight initiative for very practical reasons. American launch vehicle technology, he argued, was not well developed and the potential of placing an astronaut in space before the Soviets was slim. He thought human spaceflight was a high-risk enterprise with a low-chance of success. Human spaceflight was also less likely to yield valuable scientific results than, and the U.S., Wiesner thought, should play to its strength in space science where important results had already been achieved.3

Kennedy only accepted part of what Wiesner recommended. He was committed to conducting a more vigorous space program than had been Eisenhower, but he was more interested in human spaceflight than either his predecessor or his science advisor. This was partly because of the drama surrounding Project Mercury and the seven astronauts that NASA was training.4 Wiesner had cautioned Kennedy about the hyperbole associated with human spaceflight. "Indeed, by having placed the highest national priority on the MERCURY program we have strengthened the popular belief that man in space is the most important aim for our non-military space effort," Wiesner wrote. "The manner in which this program has been publicized in our press has further crystallized such belief."5 Kennedy, nevertheless, recognized the tremendous public support arising from this program and wanted to ensure that it reflected favorably upon his administration.

But it was a risky enterprise--what if the Soviets were first to send a human into space? what if an astronaut was killed and Mercury was a failure?--and the political animal in Kennedy wanted to minimize those risks. The earliest Kennedy pronouncements relative to civil space activity directly addressed these hazards. He offered to cooperate with the Soviet Union, still the only other nation involved in launching satellites, in the exploration of space. In his inaugural address in January 1961 Kennedy spoke directly to Soviet Premier Nikita Khrushchev and asked him to cooperate in exploring "the stars."6 In his State of the Union address ten days later, he asked the Soviet Union "to join us in developing a weather prediction program, in a new communications satellite program, and in preparation for probing the distant planets of Mars and Venus, probes which may someday unlock the deepest secrets of the Universe." Kennedy also publicly called for the peaceful use of space, and the limitation of war in that new environment.7

In making these overtures Kennedy accomplished several important political ends. First, he appeared to the world as the statesman by seeking friendly cooperation rather than destructive competition with the Soviet Union, knowing full well that there was little likelihood that Khrushchev would accept his offer. Conversely, the Soviets would appear to be monopolizing space for their own personal, and presumably military, benefit. Second, he minimized the goodwill that the Soviet Union enjoyed because of its own success in space *vis-…-vis* the U.S. Finally, if the Soviet Union accepted his call for cooperation, it would tacitly be recognizing the equality of the U.S. in space activities, something that would also look very good on the world stage.8

The Soviet Challenge Renewed

Had the balance of power and prestige between the United States and the Soviet Union remained stable in the spring of 1961, it is quite possible that Kennedy would never have advanced his Moon program and the direction of American space efforts might have taken a radically different course. Kennedy seemed quite happy to allow NASA to execute Project Mercury at a deliberate pace, working toward the orbiting of an astronaut sometime in the middle of the decade, and to build on the satellite programs that were yielding excellent results both in terms of scientific knowledge and practical application. Jerome Wiesner reflected: "If Kennedy could have opted out of a big space program without hurting the country in his judgment, he would have."9

Firm evidence for Kennedy's essential unwillingness to commit to an aggressive space program came in March 1961 when the NASA Administrator, James E. Webb, submitted a request that greatly expanded his agency's fiscal year 1962 budget so as to permit a Moon landing before the end of the decade. While the Apollo lunar landing program had existed as a longterm goal of NASA during the Eisenhower administration, Webb proposed greatly expanding and accelerating it. Kennedy's budget director, David E. Bell, objected to this large increase and debated Webb on the merits of an accelerated lunar landing program. In the end the president was unwilling to obligate the nation to a much bigger and more costly space program. Instead, in good political fashion, he approved a modest increase in the NASA budget to allow for development of the big launch vehicles that would eventually be required to support a Moon landing.10

A slow and deliberate pace might have remained the standard for the U.S. civil space effort had not two important events happened that forced Kennedy to act. The Soviet Union's space effort counted coup on the United States one more time not long after the new president took office. On 12 April 1961 Soviet Cosmonaut Yuri Gagarin became the first human in space with a one- orbit mission aboard the spacecraft *Vostok 1*. The chance to place a human in space before the Soviets did so had now been lost. The great success of that feat made the gregarious Gagarin a global hero, and he was an effective spokesman for the Soviet Union until his death in 1967 from an unfortunate aircraft accident. It was only a salve on an open wound, therefore, when Alan Shepard became the first American in space during a 15-minute suborbital flight on 5 May 1961 by riding a Redstone booster in his *Freedom 7* Mercury spacecraft.11

Comparisons between the Soviet and American flights were inevitable afterwards. Gagarin had flown around the Earth; Shepard had been the cannonball shot from a gun. Gagarin's Vostok spacecraft had weighed 10,428 pounds; *Freedom 7* weighed 2,100 pounds. Gagarin had been weightless for 89 minutes; Shepard for only 5 minutes. "Even though the United States is still the strongest military power and leads in many aspects of the space race," wrote journalist Hanson Baldwin in the *New York Times* not long after Gagarin's flight, "the world--impressed by the spectacular Soviet firsts--believes we lag militarily and technologically."12 By any unit of measure the U.S. had not demonstrated technical equality with the Soviet Union, and that fact worried national leaders because of what it would mean in the larger Cold War environment. These apparent disparities in technical competence had to be addressed, and Kennedy had to find a way to reestablish the nation's credibility as a technological leader before the world.

Close in the wake of the Gagarin achievement, the Kennedy Administration suffered another devastating blow in the Cold War that contributed to the sense that action had to be taken. Between 15 and 19 April 1961 the administration supported the abortive Bay of Pigs invasion of Cuba designed to overthrow Castro. Executed by anti-Castro Cuban refugees armed and trained by the CIA, the invasion was a debacle almost from the beginning. It was predicated on an assumption that the Cuban people would rise up to welcome the invaders and when that proved to be false, the attack could not succeed. American backing of the invasion was a great embarrassment both to Kennedy personally and to his administration. It damaged U.S. relations with foreign nations enormously, and made the communist world look all the more invincible.13

While the Bay of Pigs invasion was never mentioned explicitly as a reason for stepping up U.S. efforts in space, the international situation certainly played a role as Kennedy scrambled to recover a measure of national dignity. Wiesner reflected, "I don't think anyone can measure it, but I'm sure it [the invasion] had an impact. I think the President felt some pressure to get something else in the foreground."14 T. Keith Glennan, NASA Administrator under Eisenhower, immediately linked the invasion and the Gagarin flight together as the seminal events leading to Kennedy's announcement of the Apollo decision. He confided in his diary that "In the aftermath of that [Bay of Pigs] fiasco, and because of the successful orbiting of astronauts by the Soviet Union, it is my opinion that Mr. Kennedy asked for a reevaluation of the nation's space program."15

Reevaluating NASA's Priorities

Two days after the Gagarin flight on 12 April, Kennedy discussed once again the possibility of a lunar landing program with Webb, but the NASA head's conservative estimates of a cost of more than $20 billion for the project was too steep and Kennedy delayed making a decision. A week later, at the time of the Bay of Pigs invasion, Kennedy called Johnson, who headed the National Aeronautics and Space Council, to the White House to discuss strategy for catching up with the Soviets in space. Johnson agreed to take the matter up with the Space Council and to recommend a course of action. It is likely that one of the explicit programs that Kennedy asked Johnson to consider was a lunar landing program, for the next day, 20 April 1961, he followed up with a memorandum to Johnson raising fundamental questions about the project. In particular, Kennedy asked

Do we have a chance of beating the Soviets by putting a laboratory in space, or by a trip around the moon, or by a rocket to go to the moon and back with a man? Is there any other space program that promises dramatic results in which we could win?[16]

While he waited for the results of Johnson's investigation, this memo made it clear that Kennedy had a pretty good idea of what he wanted to do in space. He confided in a press conference on 21 April that he was leaning toward committing the nation to a large- scale project to land Americans on the Moon. "If we can get to the moon before the Russians, then we should," he said, adding that he had asked his vice president to review options for the space program.[17] This was the first and last time that Kennedy said anything in public about a lunar landing program until he officially unveiled the plan. It is also clear that Kennedy approached the lunar landing effort essentially as a response to the competition between the U.S. and the U.S.S.R. For Kennedy the Moon landing program, conducted in the tense Cold War environment of the early 1960s, was a strategic decision directed toward advancing the far-flung interests of the United States in the international arena. It aimed toward recapturing the prestige that the nation had lost as a result of Soviet successes and U.S. failures. It was, as political scientist John M. Logsdon has suggested, "one of the last major political acts of the Cold War. The Moon Project was chosen to symbolize U.S. strength in the head-to-head global competition with the Soviet Union."[18]

Lyndon Johnson probably understood these circumstances very well, and for the next two weeks his Space Council diligently considered, among other possibilities, a lunar landing before the Soviets. As early as 22 April, NASA's Deputy Administrator Hugh L. Dryden had responded to a request for information from the National Aeronautics and Space Council about a Moon program by writing that there was "a chance for the U.S. to be the first to land a man on the moon and return him to earth if a determined national effort is made." He added that the earliest this feat could be accomplished was 1967, but that to do so would cost about $33 billion dollars, a figure $10 billion more than the whole projected NASA budget for the next ten years.[19] A week later Wernher von Braun, director of NASA's George C. Marshall Space Flight Center at Huntsville, Alabama, and head of the big booster program needed for the lunar effort, responded to a similar request for information from Johnson. He told the vice president that "we have a sporting chance of sending a 3-man crew *around the moon* ahead of the Soviets" and "an excellent chance of beating the Soviets to the *first landing of a crew on the moon* (including return capability, of course.)" He added that "with an all-out crash program" the U.S. could achieve a landing by 1967 or 1968.[20]

After gaining these technical opinions, Johnson began to poll political leaders for their sense of the propriety of committing the nation to an accelerated space program with Project Apollo as its centerpiece. He brought in Senators

Robert Kerr (D-OK) and Styles Bridges (R-NH) and spoke with several Representatives to ascertain if they were willing to support an accelerated space program. While only a few were hesitant, Robert Kerr worked to allay their concerns. He called on James Webb, who had worked for his business conglomerate during the 1950s, to give him a straight answer about the project's feasibility. Kerr told his congressional colleagues that Webb was enthusiastic about the program and "that if Jim Webb says we can a land a man on the moon and bring him safely home, then it can be done." This endorsement secured considerable political support for the lunar project. Johnson also met with several businessmen and representatives from the aerospace industry and other government agencies to ascertain the consensus of support for a new space initiative. Most of them also expressed support.21

Air Force General Bernard A. Schriever, commander of the Air Force Systems Command that developed new technologies, expressed the sentiment of many people by suggesting that an accelerated lunar landing effort "would put a focus on our space program." He believed it was important for the U.S. to build international prestige and that the return was more than worth the price to be paid.22 Secretary of State Dean Rusk, a member of the Space Council, was also a supporter of the initiative because of the Soviet Union's image in the world. He wrote to the Senate Space Committee a little later that "We must respond to their conditions; otherwise we risk a basic misunderstanding on the part of the uncommitted countries, the Soviet Union, and possibly our allies concerning the direction in which power is moving and where long-term advantage lies."23 It was clear early in these deliberations that Johnson was in favor of an expanded space program in general and a maximum effort to land an astronaut on the Moon. Whenever he heard reservations Johnson used his forceful personality to persuade. "Now," he asked, "would you rather have us be a second-rate nation or should we spend a little money?"24

In an interim report to the president on 28 April 1961, Johnson concluded that "The U.S. can, if it will, firm up its objectives and employ its resources with a reasonable chance of attaining world leadership in space during this decade," and recommended committing the nation to a lunar landing.25 In this exercise Johnson had built, as Kennedy had wanted, a strong justification for undertaking Project Apollo but he had also moved on to develop a greater consensus for the objective among key government and business leaders.

The NASA Position

While NASA's leaders were generally pleased with the course Johnson was recommending--they recognized and mostly agreed with the political reasons for adopting a determined lunar landing program--they wanted to shape it as much as possible to the agency's particular priorities. NASA Administrator James Webb, well known as a skilled political operator who could seize an opportunity, organized a short-term effort to accelerate and expand a long-range NASA master plan for space exploration. A fundamental part of this effort addressed a legitimate concern that the scientific and technological advancements for which NASA had been created not be eclipsed by the political necessities of international rivalries. Webb conveyed the concern of the agency's technical and scientific community to Jerome

Wiesner on 2 May 1961, noting that "the most careful consideration must be given to the scientific and technological components of the total program and how to present the picture to the world and to our own nation of a program that has real value and validity and from which solid additions to knowledge can be made, even if every one of the specific so-called 'spectacular' flights or events are done after they have been accomplished by the Russians." He asked that Wiesner help him "make sure that this component of solid, and yet imaginative, total scientific and technological value is built in."26

Partly in response to this concern, Johnson asked NASA to provide for him a set of specific recommendations on how a scientifically-viable Project Apollo, would be accomplished by the end of the decade. What emerged was a comprehensive space policy planning document that had the lunar landing as its centerpiece but that attached several ancillary funding items to enhance the program's scientific value and advance space exploration on a broad front:

1. Spacecraft and boosters for the human flight to the Moon.

2. Scientific satellite probes to survey the Moon.

3. A nuclear rocket.

4. Satellites for global communications.

5. Satellites for weather observation.

6. Scientific projects for Apollo landings.

Johnson accepted these recommendations and passed them to Kennedy who approved the overall plan.27

The last major area of concern was the timing for the Moon landing. The original NASA estimates had given a target date of 1967, but as the project became more crystallized agency leaders recommended not committing to such a strict deadline.28 James Webb, realizing the problems associated with meeting target dates based on NASA's experience in space flight, suggested that the president commit to a landing by the end of the decade, giving the agency another two years to solve any problems that might arise. The White House accepted this proposal.29

Decision

President Kennedy unveiled the commitment to execute Project Apollo on 25 May 1961 in a speech on "Urgent National Needs," billed as a second State of the Union message. He told Congress that the U.S. faced extraordinary challenges and needed to respond extraordinarily. In announcing the lunar landing commitment he said:

If we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take. . . . We go into space because whatever mankind must undertake, free men must fully share.

Then he added: "I believe this Nation should commitment itself to achieving the goal, before this decade is out, of landing a man on the moon 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; and none will be so difficult or expensive to accomplish."[30]

An Assessment of the Decision

The President had correctly gauged the mood of the nation. His commitment captured the American imagination and was met with overwhelming support. No one seemed concerned either about the difficulty or about the expense at the time. Congressional debate was perfunctory and NASA found itself literally pressing to expend the funds committed to it during the early 1960s. Like most political decisions, at least in the U.S. experience, the decision to carry out Project Apollo was an effort to deal with an unsatisfactory situation (world perception of Soviet leadership in space and technology). As such Apollo was a remedial action ministering to a variety of political and emotional needs floating in the ether of world opinion. Apollo addressed these problems very well, and was a worthwhile action if measured only in those terms. In announcing Project Apollo Kennedy put the world on notice that the U.S. would not take a back seat to its superpower rival. John Logsdon commented: "By entering the race with such a visible and dramatic commitment, the United States effectively undercut Soviet space spectaculars without doing much except announcing its intention to join the contest."[31] It was an effective symbol, just as Kennedy had intended.

It also gave the U.S. an opportunity to shine. The lunar landing was so far beyond the capabilities of either the United States or the Soviet Union in 1961 that the early lead in space activities taken by the Soviets would not predetermine the outcome. It gave the U.S. a reasonable chance of overtaking the Soviet Union in space activities and recovering a measure of lost status.

Even though Kennedy's political objectives were essentially achieved with the decision to go to the Moon, there were other aspects of the Apollo commitment that require assessment. Those who wanted to see a vigorous space program, a group led by NASA scientists and engineers, obtained their wish with Kennedy's announcement. An opening was present to this group in 1961 that had not existed at any time during the Eisenhower Administration, and they made the most of it. They inserted into the overall package supporting Apollo additional programs that they believed would greatly strengthen the scientific and technological return on the investment to go to the Moon. In addition to seeking international prestige, this group proposed an accelerated and integrated national space effort incorporating both scientific and commercial components.

In the end a unique confluence of political necessity, personal commitment and activism, scientific and technological ability, economic prosperity, and public mood made possible the 1961 decision to carry out a forward-looking lunar landing program. What perhaps should be suggested is that a complex web or system of ties between various people, institutions, and interests allowed the Apollo decision.32 It then fell to NASA and other organizations of the Federal Government to accomplish the task set out in a few short paragraphs by President Kennedy.

Gearing Up for Project Apollo

The first challenge NASA leaders faced in meeting the presidential mandate was securing funding. While Congress enthusiastically appropriated funding for Apollo immediately after the president's announcement, NASA Administrator James E. Webb was rightly concerned that the momentary sense of crisis would subside and that the political consensus present for Apollo in 1961 would abate. He tried, albeit without much success, to lock the presidency and the Congress into a long-term obligation to support the program. While they had made an intellectual commitment, NASA's leadership was concerned that they might renege on the economic part of the bargain at some future date.33

Initial NASA estimates of the costs of Project Apollo were about $20 billion through the end of the decade, a figure approaching $150 billion in 1992 dollars when accounting for inflation. Webb quickly stretched those initial estimates for Apollo as far as possible, with the intent that even if NASA did not receive its full budget requests, as it did not during the latter half of the decade, it would still be able to complete Apollo. At one point in 1963, for instance, Webb came forward with a NASA funding projection through 1970 for more than $35 billion. As it turned out Webb was able to sustain the momentum of Apollo through the decade, largely because of his rapport with key members of Congress and with Lyndon B. Johnson, who became president in November 1963.34

Project Apollo, backed by sufficient funding, was the tangible result of an early national commitment in response to a perceived threat to the United States by the Soviet Union. NASA leaders recognized that while the size of the task was enormous, it was still technologically and financially within their grasp, but they had to move forward quickly. Accordingly, the space agency's annual budget increased from $500 million in 1960 to a high point of $5.2 billion in 1965.35 The NASA funding level represented 5.3 percent of the federal budget in 1965. A comparable percentage of the $1.23 trillion Federal budget in 1992 would have equaled more than $65 billion for NASA, whereas the agency's actual budget then stood at less than $15 billion.

Out of the budgets appropriated for NASA each year approximately 50 percent went directly for human spaceflight, and the vast majority of that went directly toward Apollo. Between 1959 and 1973 NASA spent $23.6 billion on human spaceflight, exclusive of infrastructure and support, of which nearly $20 billion was for Apollo.36 In addition, Webb sought to expand the definition of Project Apollo beyond just the mission of landing humans on the Moon. As a result even those projects not officially funded under the Apollo line item could be justified as supporting the mission, such as the Ranger, Lunar Orbiter, and Surveyor satellite probes.

For seven years after Kennedy's Apollo decision, through October 1968, James Webb politicked, coaxed, cajoled, and maneuvered for NASA in Washington. A longtime Washington insider- -the former director of the Bureau of the Budget and Undersecretary of State during the Truman Administration--he was a master at bureaucratic politics, understanding that it was essentially a system of mutual give and take. For instance, while the native North Carolinian may also have genuinely believed in the Johnson Administration's Civil Rights bill that went before Congress in 1964, as a personal favor to the President he lobbied for its passage on Capitol Hill. This secured for him Johnson's gratitude, which he then use to secure the administration's backing of NASA's initiatives. In addition, Webb wielded the money appropriated for Apollo to build up a constituency for NASA that was both powerful and vocal. This type of gritty pragmatism also characterized Webb's dealings with other government officials and members of Congress throughout his tenure as administrator. When give and take did not work, as was the case on occasion with some members of Congress, Webb used the presidential directive as a hammer to get his way. Usually this proved successful. After Kennedy's assassination in 1963, moreover, he sometimes appealed for continued political support for Apollo because it represented a fitting tribute to the fallen leader. In the end, through a variety of methods Administrator Webb built a seamless web of political liaisons that brought continued support for and resources to accomplish the Apollo Moon landing on the schedule Kennedy had announced.37

Funding was not the only critical component for Project Apollo. To realize the goal of Apollo under the strict time constraints mandated by the president, personnel had to be mobilized. This took two forms. First, by 1966 the agency's civil service rolls had grown to 36,000 people from the 10,000 employed at NASA in 1960. Additionally, NASA's leaders made an early decision that they would have to rely upon outside researchers and technicians to complete Apollo, and contractor employees working on the program increased by a factor of 10, from 36,500 in 1960 to 376,700 in 1965. Private industry, research institutions, and universities, therefore, provided the majority of personnel working on Apollo.38

To incorporate the great amount of work undertaken for the project into the formal bureaucracy never seemed a particularly savvy idea, and as a result during the 1960s somewhere between 80 and 90 percent of NASA's overall budget went for contracts to purchase goods and services from others. Although the magnitude of the endeavor had been much smaller than with Apollo, this reliance on the private sector and universities for the bulk of the effort originated early in NASA's history under T. Keith Glennan, in part because of the Eisenhower Administration's mistrust of large government establishments. Although neither Glennan's successor, nor Kennedy shared that mistrust, they found that it was both good politics and the best way of getting Apollo done on the presidentially-approved schedule. It was also very nearly the only way to harness talent and institutional resources already in existence in the emerging aerospace industry and the country's leading research universities.39

In addition to these other resources, NASA moved quickly during the early 1960s to expand its physical capacity so that it could accomplish Apollo. In 1960 the space agency consisted of a small headquarters in Washington, its three inherited NACA research centers, the Jet Propulsion Laboratory, the Goddard Space Flight Center, and the Marshall Space Flight Center. With the advent of Apollo, these installations grew rapidly. In addition, NASA added three new facilities specifically to meet the demands of the lunar landing program. In 1962 it created the Manned Spacecraft Center (renamed the Lyndon B. Johnson Space Center in 1973), near Houston, Texas, to design the Apollo spacecraft and the launch platform for the lunar lander. This center also became the home of NASA's astronauts and the site of mission control. NASA then greatly expanded for Apollo the Launch Operations Center at Cape Canaveral on Florida's eastern seacoast. Renamed the John F. Kennedy Space Center on 29 November 1963, this installation's massive and expensive Launch Complex 34 was the site of all Apollo firings. Additionally, the spaceport's Vehicle Assemble Building was a huge and expensive 36-story structure where the Saturn/Apollo rockets were assembled. Finally, to support the development of the Saturn launch vehicle, in October 1961 NASA created on a deep south bayou the Mississippi Test Facility, renamed the John C. Stennis Space Center in 1988. The cost of this expansion was great, more than 2.2 billion over the decade, with 90 percent of it expended before 1966.40

The Program Management Concept

The mobilization of resources was not the only challenge facing those charged with meeting President Kennedy's goal. NASA had to meld disparate institutional cultures and approaches into an inclusive organization moving along a single unified path. Each NASA installation, university, contractor, and research facility had differing perspectives on how to go about the task of accomplishing Apollo.41 To bring a semblance of order to the program, NASA expanded the "program management" concept borrowed by T. Keith Glennan in the late 1950s from the military/industrial complex, bringing in military managers to oversee Apollo. The central figure in this process was U.S. Air Force Major General Samuel C. Phillips, the architect of the *Minuteman* ICBM program before coming to NASA in 1962. Answering directly to the Office of Manned Space Flight at NASA headquarters, which in turn reported to the NASA administrator, Phillips created an omnipotent program office with centralized authority over design, engineering, procurement, testing, construction, manufacturing, spare parts, logistics, training, and operations.42

One of the fundamental tenets of the program management concept was that three critical factors--cost, schedule, and reliability--were interrelated and had to be managed as a group. Many also recognized these factors' constancy; if program managers held cost to a specific level, then one of the other two factors, or both of them to a somewhat lesser degree, would be adversely affected. This held true for the Apollo program. The schedule, dictated by the president, was firm. Since humans were involved in the flights, and since the president had directed that the lunar landing be conducted safely, the program managers placed a heavy emphasis on reliability. Accordingly, Apollo used redundant systems extensively so that failures would be both predictable and minor in result. The significance of both of these factors forced the third factor, cost, much higher than might have been the case with a more leisurely lunar program such as had been conceptualized in the latter 1950s. As it was, this was the price paid for success under the Kennedy mandate and program managers made conscious decisions based on a knowledge of these factors.43

The program management concept was recognized as a critical component of Project Apollo's success in November 1968, when *Science* magazine, the publication of the American Association for the Advancement of Science, observed:

In terms of numbers of dollars or of men, NASA has not been our largest national undertaking, but in terms of complexity, rate of growth, and technological sophistication it has been unique. . . . It may turn out that [the space program's] most valuable spin-off of all will be human rather than technological: better knowledge of how to plan, coordinate, and monitor the multitudinous and varied activities of the organizations required to accomplish great social undertakings.44

Understanding the management of complex structures for the successful completion of a multifarious task was an important outgrowth of the Apollo effort.

This management concept under Phillips orchestrated more than 500 contractors working on both large and small aspects of Apollo. For example, the prime contracts awarded to industry for the principal components of just the Saturn V included the Boeing Company for the S-IC, first stage; North American Aviation--S-II, second stage; the Douglas Aircraft Corporation--S-IVB, third stage; the Rocketdyne Division of North American Aviation--J-2 and F-1 engines; and International Business Machines (IBM)--Saturn instruments. These prime contractors, with more than 250 subcontractors, provided millions of parts and components for use in the Saturn launch vehicle, all meeting exacting specifications for performance and reliability. The total cost expended on development of the Saturn launch vehicle was massive, amounting to $9.3 billion. So huge was the overall Apollo endeavor that NASA's procurement actions rose from roughly 44,000 in 1960 to almost 300,000 by 1965.45

Getting all of the personnel elements to work together challenged the program managers, regardless of whether or not they were civil service, industry, or university personnel. There were various communities within NASA that differed over priorities and competed for resources. The two most identifiable groups were the engineers and the scientists. As ideal types, engineers usually worked in teams to build hardware that could carry out the missions necessary to a successful Moon landing by the end of the decade. Their primary goal involved building vehicles that would function reliably within the fiscal resources allocated to Apollo. Again as ideal types, space scientists engaged in pure research and were more concerned with designing experiments that would expand scientific knowledge about the Moon. They also tended to be individualists, unaccustomed to regimentation and unwilling to concede gladly the direction of projects to outside entities. The two groups contended with each other over a great variety of issues associated with Apollo. For instance, the scientists disliked having to configure payloads so that they could meet time, money, or launch vehicle constraints. The engineers, likewise, resented changes to scientific packages added after project definition because these threw their hardware efforts out of kilter. Both had valid complaints and had to maintain an uneasy cooperation to accomplish Project Apollo.

The scientific and engineering communities within NASA, additionally, were not monolithic, and differences among them thrived. Add to these groups representatives from industry, universities, and research facilities, and competition on all levels to further their own scientific and technical areas was the result. The NASA leadership generally viewed this pluralism as a positive force within the space program, for it ensured that all sides aired their views and emphasized the honing of positions to a fine edge. Competition, most people concluded, made for a more precise and viable space exploration effort. There were winners and losers in this strife, however, and sometimes ill-will was harbored for years. Moreover, if the conflict became too great and spilled into areas where it was misunderstood, it could be devastating to the conduct of the lunar program. The head of the Apollo program worked hard to keep these factors balanced and to promote order so that NASA could accomplish the presidential directive.46

Another important management issue arose from the agency's inherited culture of in-house research. Because of the magnitude of Project Apollo, and its time schedule, most of the nitty-gritty work had to be done outside NASA by means of contracts. As a result, with a few important exceptions, NASA scientists and engineers did not build flight hardware, or even operate missions. Rather, they planned the program, prepared guidelines for execution, competed contracts, and oversaw work accomplished elsewhere. This grated on those NASA personnel oriented toward research, and prompted disagreements over how to carry out the lunar landing goal. Of course, they had reason for complaint beyond the simplistic argument of wanting to be "dirty-handed" engineers; they had to have enough in-house expertise to ensure program accomplishment. If scientists or engineers did not have a professional competence on a par with the individuals actually doing the work, how could they oversee contractors actually creating the hardware and performing the experiments necessary to meet the rigors of the mission?47

One anecdote illustrates this point. The Saturn second stage was built by North American Aviation at its plant at Seal Beach, California, shipped to NASA's Marshall Space Flight Center, Huntsville, Alabama, and there tested to ensure that it met contract specifications. Problems developed on this piece of the Saturn effort and Wernher von Braun began intensive investigations. Essentially his engineers completely disassembled and examined every part of every stage delivered by North American to ensure no defects. This was an enormously expensive and time-consuming process, grinding the stage's production schedule almost to a standstill and jeopardizing the Presidential timetable.

When this happened Webb told von Braun to desist, adding that "We've got to trust American industry." The issue came to a showdown at a meeting where the Marshall rocket team was asked to explain its extreme measures. While doing so, one of the engineers produced a rag and told Webb that "this is what we find in this stuff." The contractors, the Marshall engineers believed, required extensive oversight to ensure they produced the highest quality work. A compromise emerged that was called the 10 percent rule: 10 percent of all funding for NASA was to be spent to ensure in- house expertise and in the process check contractor reliability.48

How do we go to the Moon?

One of the critical early management decisions made by NASA was the method of going to the Moon. No controversy in Project Apollo more significantly caught up the tenor of competing constituencies in NASA than this one. There were three basic approaches that were advanced to accomplish the lunar mission:

1. *Direct Ascent* called for the construction of a huge booster that launched a spacecraft, sent it on a course directly to the Moon, landed a large vehicle, and sent some part of it back to Earth. The Nova booster project, which was to have been capable of generating up to 40 million pounds of thrust, would have been able to accomplish this feat. Even if other factors had not impaired the possibility of direct ascent, the huge cost and technological sophistication of the Nova rocket quickly ruled out the option and resulted in cancellation of the project early in the 1960s despite the conceptual simplicity of the direct ascent method. The method had few advocates when serious planning for Apollo began.

2. *Earth-Orbit Rendezvous* was the logical first alternative to the direct ascent approach. It called for the launching of various modules required for the Moon trip into an orbit above the Earth, where they would rendezvous, be assembled into a single system, refueled, and sent to the Moon. This could be accomplished using the Saturn launch vehicle already under development by NASA and capable of generating 7.5 million pounds of thrust. A logical component of this approach was also the establishment of a space station in Earth orbit to serve as the lunar mission's rendezvous, assembly, and refueling point. In part because of this prospect, a space station emerged as part of the long-term planning of NASA as a jumping-off place for the exploration of space. This method of reaching the Moon, however, was also fraught with challenges, notably finding methods of maneuvering and rendezvousing in space, assembling components in a weightless environment, and safely refueling spacecraft.

3. *Lunar-Orbit Rendezvous* proposed sending the entire lunar spacecraft up in one launch. It would head to the Moon, enter into orbit, and dispatch a small lander to the lunar surface. It was the simplest of the three methods, both in terms of development and operational costs, but it was risky. Since rendezvous was taking place in lunar, instead of Earth, orbit there was no room for error or the crew could not get home. Moreover, some of the trickiest course corrections and maneuvers had to be done after the spacecraft had been committed to a circumlunar flight. The Earth-orbit rendezvous approach kept all the options for the mission open longer than the lunar-orbit rendezvous mode.[49]

Inside NASA, advocates of the various approaches contended over the method of flying to the Moon while the all-important clock that Kennedy had started continued to tick. It was critical that a decision not be delayed, because the mode of flight in part dictated the spacecraft developed. While NASA engineers could proceed with building a launch vehicle, the Saturn, and define the basic components of the spacecraft--a habitable crew compartment, a baggage car of some type, and a jettisonable service module containing propulsion and other expendable systems--they could not proceed much beyond rudimentary conceptions without a mode decision. The NASA Rendezvous Panel at Langley Research Center, headed by John C. Houbolt, pressed hard for the lunar-orbit rendezvous as the most expeditious means of accomplishing the mission. Using sophisticated technical and economic arguments, over a period of months in 1961 and 1962 Houbolt's group advocated and persuaded the rest of NASA's leadership that lunar-orbit rendezvous was not the risky proposition that it had earlier seemed.[50]

The last to give in was Wernher von Braun and his associates at the Marshall Space Flight Center. This group favored the Earth- orbit rendezvous because the direct ascent approach was technologically unfeasible before the end of the 1960s, because it provided a logical rationale for a space station, and because it ensured an extension of the Marshall workload (something that was always important to center directors competing inside the agency for personnel and other resources). At an all-day meeting on 7 June 1962 at Marshall, NASA leaders met to hash out these differences, with the debate getting heated at times. After more than six hours of discussion von Braun finally gave in to the lunar-orbit rendezvous mode, saying that its advocates had demonstrated adequately its feasibility and that any further contention would jeopardize the president's timetable.51

With internal dissention quieted, NASA moved to announce the Moon landing mode to the public in the summer of 1962. As it prepared to do so, however, Kennedy's Science Adviser, Jerome B. Wiesner, raised objections because of the inherent risk it brought to the crew. As a result of this opposition, Webb back-pedaled and stated that the decision was tentative and that NASA would sponsor further studies. The issue reached a climax at the Marshall Space Flight Center in September 1962 when President Kennedy, Wiesner, Webb, and several other Washington figures visited von Braun. As the entourage viewed a mock- up of a Saturn V first stage booster during a photo opportunity for the media, Kennedy nonchalantly mentioned to von Braun, "I understand you and Jerry disagree about the right way to go to the moon." Von Braun acknowledged this disagreement, but when Wiesner began to explain his concern Webb, who had been quiet until this point, began to argue with him "for being on the wrong side of the issue." While the mode decision had been an uninteresting technical issue before, it then became a political concern hashed over in the press for days thereafter. The science advisor to British Prime Minister Harold Macmillan, who had accompanied Wiesner on the trip, later asked Kennedy on Air Force One how the debate would turn out. The president told him that Wiesner would lose, "Webb's got all the money, and Jerry's only got me."52 Kennedy was right, Webb lined up political support in Washington for the lunar-orbit rendezvous mode and announced it as a final decision on 7 November 1962.53 This set the stage for the operational aspects of Apollo.

Prelude to Apollo: Mercury

At the time of the announcement of Project Apollo by President Kennedy in May 1961 NASA was still consumed with the task of placing an American in orbit through Project Mercury. Stubborn problems arose, however, at seemingly every turn. The first space flight of an astronaut, made by Alan B. Shepard, had been postponed for weeks so NASA engineers could resolve numerous details and only took place on 5 May 1961, less than three weeks before the Apollo announcement. The second flight, a suborbital mission like Shepard's, launched on 21 July 1961, also had problems. The hatch blew off prematurely from the Mercury capsule, *Liberty Bell 7*, and it sank into the Atlantic Ocean before it could be recovered. In the process the astronaut, "Gus" Grissom, nearly drowned before being hoisted to safety in a helicopter. These suborbital flights, however, proved valuable for NASA technicians who found ways to solve or work around literally thousands of obstacles to successful space flight.54

As these issues were being resolved, NASA engineers began final preparations for the orbital aspects of Project Mercury. In this phase NASA planned to use a Mercury capsule capable of supporting a human in space for not just minutes, but eventually for as much as three days. As a launch vehicle for this Mercury capsule, NASA used the more powerful Atlas instead of the Redstone. But this decision was not without controversy. There were technical difficulties to be overcome in mating it to the Mercury capsule to be sure, but the biggest complication was a debate among NASA engineers over its propriety for human spaceflight.55

When first conceived in the 1950s many believed Atlas was a high-risk proposition because to reduce its weight Convair Corp. engineers under the direction of Karel J. Bossart, a pre-World War II immigrant from Belgium, designed the booster with a very thin, internally pressurized fuselage instead of massive struts and a thick metal skin. The "steel balloon," as it was sometimes called, employed engineering techniques that ran counter to a conservative engineering approach used by Wernher von Braun for the V-2 and the Redstone at Huntsville, Alabama.56 Von Braun, according to Bossart, needlessly designed his boosters like "bridges," to withstand any possible shock. For his part, von Braun thought the Atlas too flimsy to hold up during launch. He considered Bossart's approach much too dangerous for human spaceflight, remarking that the astronaut using the "contraption," as he called the Atlas booster, "should be getting a medal just for sitting on top of it before he takes off!"57 The reservations began to melt away, however, when Bossart's team pressurized one of the boosters and dared one of von Braun's engineers to knock a hole in it with a sledge hammer. The blow left the booster unharmed, but the recoil from the hammer nearly clubbed the engineer.58

Most of the differences had been resolved by the first successful orbital flight of an unoccupied Mercury-Atlas combination in September 1961. On 29 November the final test flight took place, this time with the chimpanzee Enos occupying the capsule for a two-orbit ride before being successfully recovered in an ocean landing. Not until 20 February 1962, however, could NASA get ready for an orbital flight with an astronaut. On that date John Glenn became the first American to circle the Earth, making three orbits in his *Friendship 7* Mercury spacecraft. The flight was not without problems, however; Glenn flew parts of the last two orbits manually because of an autopilot failure and left his normally jettisoned retrorocket pack attached to his capsule during reentry because of a loose heat shield.

Glenn's flight provided a healthy increase in national pride, making up for at least some of the earlier Soviet successes. The public, more than celebrating the technological success, embraced Glenn as a personification of heroism and dignity. Hundreds of requests for personal appearances by Glenn poured into NASA headquarters, and NASA learned much about the power of the astronauts to sway public opinion. The NASA leadership made Glenn available to speak at some events, but more often substituted other astronauts and declined many other invitations. Among other engagements, Glenn did address a joint session of Congress and participated in several ticker-tape parades around the country. NASA discovered in the process of this hoopla a powerful public relations tool that it has employed ever since.59

Three more successful Mercury flights took place during 1962 and 1963. Scott Carpenter made three orbits on 20 May 1962, and on 3 October 1962 Walter Schirra flew six orbits. The capstone of Project Mercury was the 15-16 May 1963 flight of Gordon Cooper, who circled the Earth 22 times in 34 hours. The program had succeeded in accomplishing its purpose: to successfully orbit a human in space, explore aspects of tracking and control, and to learn about microgravity and other biomedical issues associated with spaceflight.60

Bridging the Technological Gap: From Gemini to Apollo

Even as the Mercury program was underway and work took place developing Apollo hardware, NASA program managers perceived a huge gap in the capability for human spaceflight between that acquired with Mercury and what would be required for a Lunar landing. They closed most of the gap by experimenting and training on the ground, but some issues required experience in space. Three major areas immediately arose where this was the case. The first was the ability in space to locate, maneuver toward, and rendezvous and dock with another spacecraft. The second was closely related, the ability of astronauts to work outside a spacecraft. The third involved the collection of more sophisticated physiological data about the human response to extended spaceflight.61

To gain experience in these areas before Apollo could be readied for flight, NASA devised Project Gemini. Hatched in the fall of 1961 by engineers at Robert Gilruth's Space Task Group in cooperation with McDonnell Aircraft Corp. technicians, builders of the Mercury spacecraft, Gemini started as a larger Mercury Mark II capsule but soon became a totally different proposition. It could accommodate two astronauts for extended flights of more than two weeks. It pioneered the use of fuel cells instead of batteries to power the ship, and incorporated a series of modifications to hardware. Its designers also toyed with the possibility of using a paraglider being developed at Langley Research Center for "dry" landings instead of a "splashdown" in water and recovery by the Navy. The whole system was to be powered by the newly developed *Titan II* launch vehicle, another ballistic missile developed for the Air Force. A central reason for this program was to perfect techniques for rendezvous and docking, so NASA appropriated from the military some Agena rocket upper stages and fitted them with docking adapters.

Problems with the Gemini program abounded from the start. The *Titan II* had longitudinal oscillations, called the "pogo" effect because it resembled the behavior of a child on a pogo stick. Overcoming this problem required engineering imagination and long hours of overtime to stabilize fuel flow and maintain vehicle control. The fuel cells leaked and had to be redesigned, and the Agena reconfiguration also suffered costly delays. NASA engineers never did get the paraglider to work properly and eventually dropped it from the program in favor of a parachute system the one used for Mercury. All of these difficulties shot an estimated $350 million program to over $1 billion. The overruns were successfully justified by the space agency, however, as necessities to meet the Apollo landing commitment.62

By the end of 1963 most of the difficulties with Gemini had been resolved, albeit at great expense, and the program was ready for flight. Following two unoccupied orbital test flights, the first operational mission took place on 23 March 1965. Mercury astronaut Grissom commanded the mission, with John W. Young, a Naval aviator chosen as an astronaut in 1962, accompanying him. The next mission, flown in June 1965 stayed aloft for four days and astronaut Edward H. White II performed the first extra-vehicular activity (EVA) or spacewalk.63 Eight more missions followed through November 1966. Despite problems great and small encountered on virtually all of them, the program achieved its goals. Additionally, as a technological learning program Gemini had been a success, with 52 different experiments performed on the ten missions. The bank of data acquired from Gemini helped to bridge the gap between Mercury and what would be required to complete Apollo within the time constraints directed by the president.64

Satellite Support of Apollo

In addition to the necessity of acquiring the skills necessary to maneuver in space prior to executing the Apollo mandate, NASA had to learn much more about the Moon itself to ensure that its astronauts would survive. They needed to know the composition and geography of Moon, and the nature of the lunar surface. Was it solid enough to support a lander, was it composed of dust that would swallow up the spacecraft? Would communications systems work on the Moon? Would other factors--geology, geography, radiation, etc.--affect the astronauts? To answer these questions three distinct satellite research programs emerged to study the Moon. The first of these was Project Ranger, which had actually been started in the 1950s, in response to Soviet lunar exploration, but had been a notable failure until the mid-1960s when three probes photographed the lunar surface before crashing into it.65

The second project was the Lunar Orbiter, an effort approved in 1960 to place probes in orbit around the Moon. This project, originally not intended to support Apollo, was reconfigured in 1962 and 1963 to further the Kennedy mandate more specifically by mapping the surface. In addition to a powerful camera that could send photographs to Earth tracking stations, it carried three scientific experiments--selnodesy (the lunar equivalent of geodesy), meteoroid detection, and radiation measurement. While the returns from these instruments interested scientists in and of themselves, they were critical to Apollo. NASA launched five Lunar Orbiter satellites between 10 August 1966 and 1 August 1967, all successfully achieving their objectives. At the completion of the third mission, moreover, the Apollo planners announced that they had sufficient data to press on with an astronaut landing, and were able to use the last two missions for other activities.66

Finally, in 1961 NASA created Project Surveyor to soft-land a satellite on the Moon. A small craft with tripod landing legs, it could take post-landing photographs and perform a variety of other measurements. *Surveyor 1* landed on the Moon on 2 June 1966 and transmitted more than 10,000 high-quality photographs of the surface. Although the second mission crash landed, the next flight provided photographs, measurements of the composition and surface-bearing strength of the lunar crust, and readings on the thermal and radar reflectivity of the soil. Although *Surveyor 4* failed, by the time of the program's completion in 1968 the remaining three missions had yielded significant scientific data both for Apollo and for the broader lunar science community.67

Building Saturn

NASA inherited the effort to develop the Saturn family of boosters used to launch Apollo to the Moon in 1960 when it acquired the Army Ballistic Missile Agency under Wernher von Braun.68 By that time von Braun's engineers were hard at work on the first generation Saturn launch vehicle, a cluster of eight Redstone boosters around a Jupiter fuel tank. Fueled by a combination of liquid oxygen (LOX) and RP-1 (a version of kerosene), the *Saturn I* could generate a thrust of 205,000 pounds. This group also worked on a second stage, known in its own right as the Centaur, that used a revolutionary fuel mixture of LOX and liquid hydrogen that could generate a greater ratio of thrust to weight. The fuel choice made this second stage a difficult development effort, because the mixture was highly volatile and could not be readily handled. But the stage could produce an additional 90,000 pounds of thrust. The *Saturn I* was solely a research and development vehicle that would lead toward the accomplishment of Apollo, making ten flights between October 1961 and July 1965. The first four flights tested the first stage, but beginning with the fifth launch the second stage was active and these missions were used to place scientific payloads and Apollo test capsules into orbit.69

The next step in Saturn development came with the maturation of the *Saturn IB*, an upgraded version of earlier vehicle. With more powerful engines generating 1.6 million pounds of thrust from the first stage, the two-stage combination could place 62,000- pound payloads into Earth orbit. The first flight on 26 February 1966 tested the capability of the booster and the Apollo capsule in a suborbital flight. Two more flights followed in quick succession. Then there was a hiatus of more than a year before the 22 January 1968 launch of a *Saturn IB* with both an Apollo capsule and a lunar landing module aboard for orbital testing. The only astronaut-occupied flight of the *Saturn IB* took place between 11 and 22 October 1968 when Walter Schirra, Donn F. Eisele, and R. Walter Cunningham, made 163 orbits testing Apollo equipment.70

The largest launch vehicle of this family, the *Saturn V*, represented the culmination of those earlier booster development and test programs. Standing 363 feet tall, with three stages, this was the vehicle that could take astronauts to the Moon and return them safely to Earth. The first stage generated 7.5 million pounds of thrust from five massive engines developed for the system. These engines, known as the F-1, were some of the most significant engineering accomplishments of the program, requiring the development of new alloys and different construction techniques to withstand the extreme heat and shock of firing. The thunderous sound of the first static test of this stage, taking place at Huntsville, Alabama, on 16 April 1965, brought home to many that the Kennedy goal was within technological grasp. For others, it signaled the magic of technological effort; one engineer even characterized rocket engine technology as a "black art" without rational principles. The second stage presented enormous challenges to NASA engineers and very nearly caused the lunar landing goal to be missed. Consisting of five engines burning LOX and liquid hydrogen, this stage could deliver 1 million pounds of thrust. It was always behind schedule, and required constant attention and additional funding to ensure completion by the deadline for a lunar landing. Both the first and third stages of this Saturn vehicle development program moved forward relatively smoothly. (The third stage was an enlarged and improved version of the IB, and had few developmental complications.)71

Despite all of this, the biggest problem with *Saturn V* lay not with the hardware, but with the clash of philosophies toward development and test. The von Braun "Rocket Team" had made important technological contributions and enjoyed popular acclaim as a result of conservative engineering practices that took minutely incremental approaches toward test and verification. They tested each component of each system individually and then assembled them for a long series of ground tests. Then they would launch each stage individually before assembling the whole system for a long series of flight tests. While this practice ensured thoroughness, it was both costly and time-consuming, and NASA had neither commodity to expend. George E. Mueller, the head of NASA's Office of Manned Space Flight, disagreed with this approach. Drawing on his experience with the Air Force and aerospace industry, and shadowed by the twin bugaboos of schedule and cost, Mueller advocated what he called the "all-up" concept in which the entire Apollo-Saturn system was tested together in flight without the laborious preliminaries.72

A calculated gamble, the first *Saturn V* test launch took place on 9 November 1967 with the entire Apollo-Saturn combination. A second test followed on 4 April 1968, and even though it was only partially successful because the second stage shut off prematurely and the third stage--needed to start the Apollo payload into lunar trajectory--failed, Mueller declared that the test program had been completed and that the next launch would have astronauts aboard. The gamble paid off. In 17 test and 15 piloted launches, the Saturn booster family scored a 100 percent launch reliability rate.73

The Apollo Spacecraft

Almost with the announcement of the lunar landing commitment in 1961 NASA technicians began a crash program to develop a reasonable configuration for the trip to lunar orbit and back. What they came up with was a three-person command module capable of sustaining human life for two weeks or more in either Earth orbit or in a lunar trajectory; a service module holding oxygen, fuel, maneuvering rockets, fuel cells, and other expendable and life support equipment that could be jettisoned upon reentry to Earth; a retrorocket package attached to the service module for slowing to prepare for reentry; and finally a launch escape system that was discarded upon achieving orbit. The tear-drop shaped command module had two hatches, one on the side for entry and exit of the crew at the beginning and end of the flight and one in the nose with a docking collar for use in moving to and from the lunar landing vehicle.74

Work on the Apollo spacecraft stretched from 28 November 1961, when the prime contract for its development was let to North American Aviation, to 22 October 1968 when the last test flight took place. In between there were various efforts to design, build, and test the spacecraft both on the ground and in suborbital and orbital flights. For instance, on 13 May 1964 NASA tested a boilerplate model of the Apollo capsule atop a stubby *Little Joe II* military booster, and another Apollo capsule actually achieved orbit on 18 September 1964 when it was launched atop a *Saturn I*. By the end of 1966 NASA leaders declared the Apollo command module ready for human occupancy. The final flight checkout of the spacecraft prior to the lunar flight took place on 11-22 October 1968 with three astronauts.75

As these development activities were taking place, tragedy struck the Apollo program. On 27 January 1967, Apollo-Saturn (AS) 204, scheduled to be the first spaceflight with astronauts aboard the capsule, was on the launch pad at Kennedy Space Center, Florida, moving through simulation tests. The three astronauts to fly on this mission--"Gus" Grissom, Edward White, and Roger B. Chaffee--were aboard running through a mock launch sequence. At 6:31 p.m., after several hours of work, a fire broke out in the spacecraft and the pure oxygen atmosphere intended for the flight helped it burn with intensity. In a flash, flames engulfed the capsule and the astronauts died of asphyxiation. It took the ground crew five minutes to open the hatch. When they did so they found three bodies. Although three other astronauts had been killed before this time--all in plane crashes--these were the first deaths directly attributable to the U.S. space program.76

Shock gripped NASA and the nation during the days that followed. James Webb, NASA Administrator, told the media at the time, "We've always known that something like this was going to happen soon or later. . . . who would have thought that the first tragedy would be on the ground?"77 As the nation mourned, Webb went to President Lyndon Johnson and asked that NASA be allowed to handle the accident investigation and direct the recovery from the accident. He promised to be truthful in assessing blame and pledged to assign it to himself and NASA management as appropriate. The day after the fire NASA appointed an eight member investigation board, chaired by longtime NASA official and director of the Langley Research Center, Floyd L. Thompson. It set out to discover the details of the tragedy: what happened, why it happened, could it happen again, what was at fault, and how could NASA recover? The members of the board learned that the fire had been caused by a short circuit in the electrical system that ignited combustible materials in the spacecraft fed by the oxygen atmosphere. They also found that it could have been prevented and called for several modifications to the spacecraft, including a move to a less oxygen-rich environment. Changes to the capsule followed quickly, and within a little more than a year it was ready for flight.78

Webb reported these findings to various Congressional committees and took a personal grilling at every meeting. His answers were sometimes evasive and always defensive. The *New York Times*, which was usually critical of Webb, had a field day with this situation and said that NASA stood for "Never a Straight Answer." While the ordeal was personally taxing, whether by happenstance or design Webb deflected much of the backlash over the fire from both NASA as an agency and from the Johnson administration. While he was personally tarred with the disaster, the space agency's image and popular support was largely undamaged. Webb himself never recovered from the stigma of the fire, and when he left NASA in October 1968, even as Apollo was nearing a successful completion, few mourned his departure.79

The AS 204 fire also troubled Webb ideologically during the months that followed. He had been a high priest of technocracy ever since coming to NASA in 1961, arguing for the authority of experts, well-organized and led, and with sufficient resources to resolve the "many great economic, social, and political problems" that pressed the nation. He wrote in his book, *Space Age Management*, as late as 1969 that "Our Society has reached a point where its progress and even its survival increasingly depend upon our ability to organize the complex and to do the unusual."80 He believed he had achieved that model organization for complex accomplishments at NASA. Yet that model structure of exemplary management had failed to anticipate and resolve the shortcomings in the Apollo capsule design and had not taken what seemed in retrospect to be normal precautions to ensure the safety of the crew. The system had broken down. As a result Webb became less trustful of other officials at NASA and gathered more and more decisionmaking authority to himself. This wore on him during the rest of his time as NASA Administrator, and in reality the failure of the technological model for solving problems was an important forecaster of a trend that would be increasingly present in American culture thereafter as technology was blamed for a good many of society's ills. That problem would be particularly present as NASA tried to win political approval of later NASA projects.81

The Lunar Module

If the Saturn launch vehicle and the Apollo spacecraft were difficult technological challenges, the third part of the hardware for the Moon landing, the Lunar Module (LM), represented the most serious problem. Begun a year later than it should have been, the LM was consistently behind schedule and over budget. Much of the problem turned on the demands of devising two separate spacecraft components--one for descent to the Moon and one for ascent back to the command module--that only maneuvered outside an atmosphere. Both engines had to work perfectly or the very real possibility existed that the astronauts would not return home. Guidance, maneuverability, and spacecraft control also caused no end of headaches. The landing structure likewise presented problems; it had to be light and sturdy and shock resistent. An ungainly vehicle emerged which two astronauts could fly while standing. In November 1962 Grumman Aerospace Corp. signed a contract with NASA to produce the LM, and work on it began in earnest. With difficulty the LM was orbited on a *Saturn V* test launch in January 1968 and judged ready for operation.82

Trips to the Moon

After a piloted orbital mission to test the Apollo equipment on October 1968, on 21 December 1968 *Apollo 8* took off atop a *Saturn V* booster from the Kennedy Space Center with three astronauts aboard--Frank Borman, James A. Lovell, Jr., and William A. Anders--for a historic mission to orbit the Moon.83 At first it was planned as a mission to test Apollo hardware in the relatively safe confines of low Earth orbit, but senior engineer George M. Low of the Manned Spacecraft Center at Houston, Texas, and Samuel C. Phillips, Apollo Program Manager at NASA headquarters, pressed for approval to make it a circumlunar flight. The advantages of this could be important, both in technical and scientific knowledge gained as well as in a public demonstration of what the U.S. could achieve.84 So far Apollo had been all promise; now the delivery was about to begin. In the summer of 1968 Low broached the idea to Phillips, who then carried it to the administrator, and in November the agency reconfigured the mission for a lunar trip. After *Apollo 8* made one and a half Earth orbits its third stage began a burn to put the spacecraft on a lunar trajectory. As it traveled outward the crew focused a portable television camera on Earth and for the first time humanity saw its home from afar, a tiny, lovely, and fragile "blue marble" hanging in the blackness of space. When it arrived at the Moon on Christmas Eve this image of Earth was even more strongly reinforced when the crew sent images of the planet back while reading the first part of the Bible--"God created the heavens and the Earth, and the Earth was without form and void"--before sending Christmas greetings to humanity. The next day they fired the boosters for a return flight and "spashed down" in the Pacific Ocean on 27 December. It was an enormously significant accomplishment coming at a time when American society was in crisis over Vietnam, race relations, urban problems, and a host of other difficulties. And if only for a few moments the nation united as one to focus on this epochal event. Two more Apollo missions occurred before the climax of the program, but they did little more than confirm that the time had come for a lunar landing.[85]

Then came the big event. *Apollo 11* lifted off on 16 July 1969, and after confirming that the hardware was working well began the three day trip to the Moon. At 4:18 p.m. EST on 20 July 1969 the LM--with astronauts Neil A. Armstrong and Edwin E. Aldrin- -landed on the lunar surface while Michael Collins orbited overhead in the Apollo command module. After checkout, Armstrong set foot on the surface, telling millions who saw and heard him on Earth that it was "one small step for man--one giant leap for mankind." (Neil Armstrong later added "a" when referring to "one small step for *a* man" to clarify the first sentence delivered from the Moon's surface.) Aldrin soon followed him out, and the two plodded around the landing site in the 1/6 lunar gravity, planted an American flag but omitted claiming the land for the U.S. as had been routinely done during European exploration of the Americas, collected soil and rock samples, and set up scientific experiments. The next day they launched back to the Apollo capsule orbiting overhead and began the return trip to Earth, splashing down in the Pacific on 24 July.[86]

These flights rekindled the excitement felt in the early 1960s with John Glenn and the Mercury astronauts. *Apollo 11*, in particular, met with an ecstatic reaction around the globe, as everyone shared in the success of the mission. Ticker tape parades, speaking engagements, public relations events, and a world tour by the astronauts served to create good will both in the U.S. and abroad.

Five more landing missions followed at approximately six month intervals through December 1972, each of them increasing the time spent on the Moon. Three of the latter Apollo missions used a lunar rover vehicle to travel in the vicinity of the landing site, but none of them equaled the excitement of *Apollo 11*. The scientific experiments placed on the Moon and the lunar soil samples returned through Project Apollo have provided grist for scientists' investigations of the Solar System ever since. The scientific return was significant, but the Apollo program did not answer conclusively the age-old questions of lunar origins and evolution.[87]

In spite of the success of the other missions, only *Apollo 13*, launched on 11 April 1970, came close to matching earlier popular interest. But that was only because, 56 hours into the flight, an oxygen tank in the Apollo service module ruptured and damaged several of the power, electrical, and life support systems. People throughout the world watched and waited and hoped as NASA personnel on the ground and the crew, well in their way to the Moon and with no way of returning until they went around it, worked together to find a way safely home. While NASA engineers quickly determined that air, water, and electricity did not exist in the Apollo capsule sufficient to sustain the three astronauts until they could return to Earth, they found that the LM--a self- contained spacecraft unaffected by the accident--could be used as a "lifeboat" to provide austere life support for the return trip. It was a close-run thing, but the crew returned safely on 17 April 1970. The near disaster served several important purposes for the civil space program--especially prompting reconsideration of the propriety of the whole effort while also solidifying in the popular mind NASA's technological genius.88

A Meaning for Apollo

Project Apollo in general, and the flight of *Apollo 11* in particular, should be viewed as a watershed in the nation's history. It was an endeavor that demonstrated both the technological and economic virtuosity of the United States and established technologically preeminence over rival nations--the primary goal of the program when first envisioned by the Kennedy administration in 1961. It had been an enormous undertaking, costing $25.4 billion (about $95 billion in 1990 dollars), with only the building of the Panama Canal rivaling the Apollo program's size as the largest non-military technological endeavor ever undertaken by the United States and only the Manhattan Project to build the atomic bomb in World War II being comparable in a wartime setting.

There are several important legacies (or conclusions) about Project Apollo that need to be remembered. First, and probably most important, the Apollo program was successful in accomplishing the political goals for which it had been created. Kennedy had been dealing with a Cold War crisis in 1961 brought on by several separate factors--the Soviet orbiting of Yuri Gagarin and the disastrous Bay of Pigs invasion only two of them--that Apollo was designed to combat. At the time of the *Apollo 11* landing Mission Control in Houston flashed the words of President Kennedy announcing the Apollo commitment on its big screen. Those phrases were followed with these: "TASK ACCOMPLISHED, July 1969." No greater understatement could probably have been made. Any assessment of Apollo that does not recognize the accomplishment of landing an American on the Moon and safely returning before the end of the 1960s is incomplete and innaccurate, for that was the primary goal of the undertaking.89

Second, Project Apollo was a triumph of management in meeting enormously difficult systems engineering, technological, and organizational integration requirements. James E. Webb, the NASA Administrator at the height of the program between 1961 and 1968, always contended that Apollo was much more a management exercise than anything else, and that the technological challenge, while sophisticated and impressive, was largely within grasp at the time of the 1961 decision.90 More difficult was ensuring that those technological skills were properly managed and used.

Webb's contention was confirmed in spades by the success of Apollo. NASA leaders had to acquire and organize unprecedented resources to accomplish the task at hand. From both a political and technological perspective, management was critical. For seven years after Kennedy's Apollo decision, through October 1968, James Webb maneuvered for NASA in Washington to obtain sufficient resources to meet Apollo requirements. More to the point, NASA personnel employed the "program management" concept that centralized authority and emphasized systems engineering. The systems management of the program was critical to Apollo's success.91 Understanding the management of complex structures for the successful completion of a multifarious task was a critical outgrowth of the Apollo effort.

Third, Project Apollo forced the people of the world to view the planet Earth in a new way. *Apollo 8* was critical to this fundamental change, as it treated the world to the first pictures of the Earth from afar. Writer Archibald MacLeish summed up the feelings of many people when he wrote at the time of Apollo, that "To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together, brothers on that bright loveliness in the eternal cold--brothers who know now that they are truly brothers."92 The modern environmental movement was galvanized in part by this new perception of the planet and the need to protect it and the life that it supports.93

Finally, the Apollo program, while an enormous achievement, left a divided legacy for NASA and the aerospace community. The perceived "golden age" of Apollo created for the agency an expectation that the direction of any major space goal from the president would always bring NASA a broad consensus of support and provide it with the resources and license to dispense them as it saw fit. Something most NASA officials did not understand at the time of the Moon landing in 1969, however, was that Apollo had not been conducted under normal political circumstances and that the exceptional circumstances surrounding Apollo would not be repeated.94

The Apollo decision was, therefore, an anomaly in the national decision-making process. The dilemma of the "golden age" of Apollo has been difficult to overcome, but moving beyond the Apollo program to embrace future opportunities has been an important goal of the agency's leadership in the recent past. Exploration of the Solar System and the universe remains as enticing a goal and as important an objective for humanity as it ever has been. Project Apollo was an important early step in that ongoing process of exploration.

Notes

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15. T. Keith Glennan, *The Birth of NASA: The Diary of T. Keith Glennan*, edited by J.D. Hunley (Washington, DC: NASA SP-4105, 1993), pp. 314-15. This is essentially the same position as set forth in Logsdon, *Decision to Go to the Moon*, pp. 111-12, although McDougall, *. . . Heavens and the Earth*, p. 8, also includes a "growing technocratic mentality" as a reason for the decision.

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Summaries of Apollo Missions and Basic Statistics

Source documents in the appendix

For further information please email: hq-histinfo@nasa.gov

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