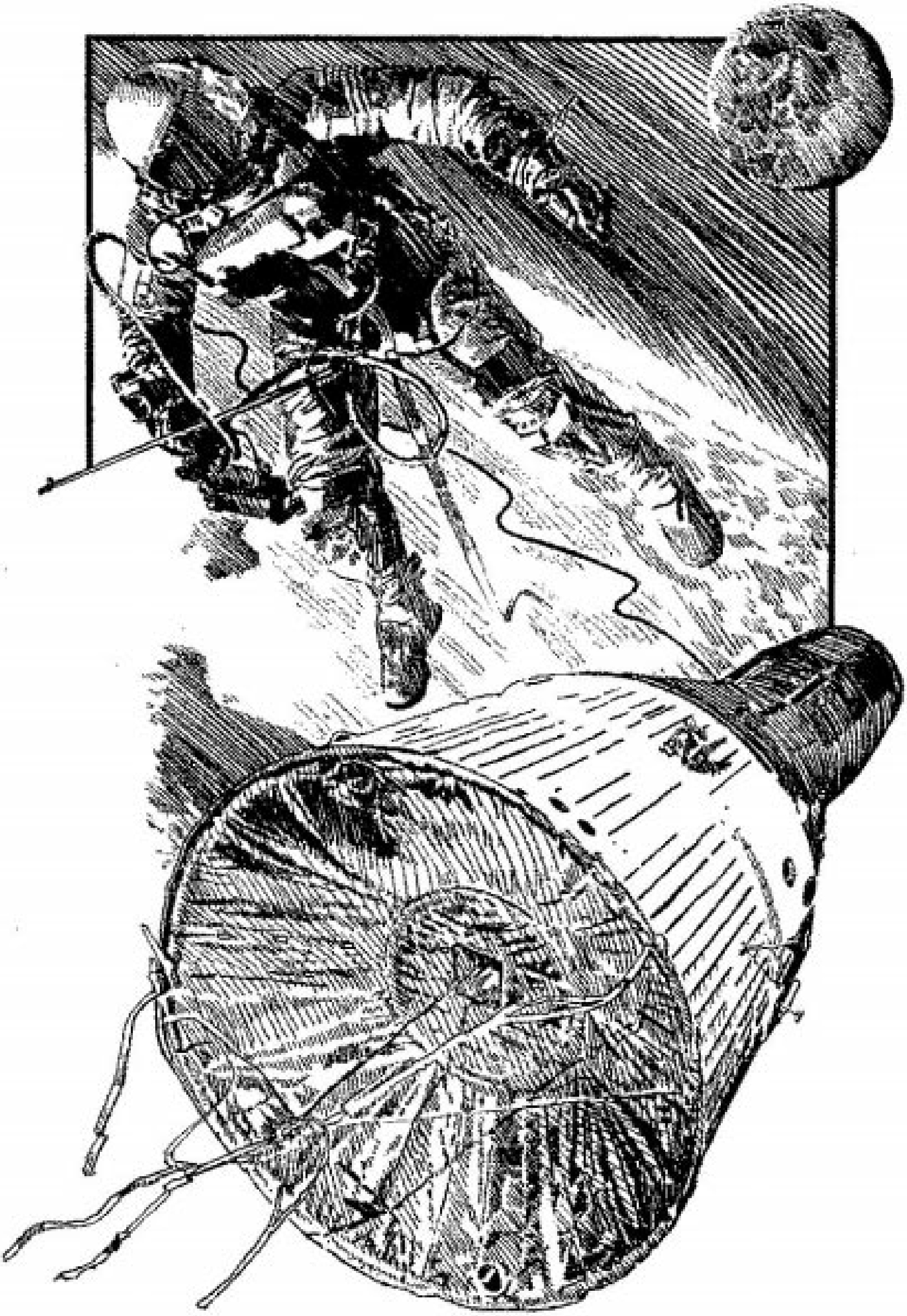


CHAPTER 5: Gemini: On Managing Spaceflight

"The first phase of the Nation's second manned space program began like a storybook success" on Saturday, April 8, 1964, when an unmanned, partly instrumented Gemini capsule entered orbit from its launch site at Cape Canaveral.[1] The 12 Gemini flights completed by mid-1966 brought America from the edge of space to outer space, from the pioneering days of Mercury to the lunar landings of Apollo, and into new management techniques including processes like systems and subsystems management, configuration control, and incentive contracting. A major building block in the operations components of spaceflight, Gemini provided an invaluable learning experience in flight control, rendezvous, docking, endurance, extravehicular activity, controlled reentry, and worldwide communications. But the acceleration of Gemini and Apollo programs strained the human resources of the Houston center and created stress and management crises. Although critical in the manned space effort, Gemini was much more and much less than a "storybook" success.

The April 1964 launch of the first unmanned Gemini spacecraft on the shoulders of an Air Force Titan II rocket was followed in May with the launch of the first Apollo vehicle aboard a Saturn I. Both coincided nicely with the final relocation of Manned Spacecraft Center personnel to their new permanent site at Clear Lake. Director Bob Gilruth declared an "open house" for the weekend of June 6 and 7, and took great "personal and professional satisfaction" in welcoming the public to the NASA MSC.[2]

It was an open house that has been extended throughout the days of the Johnson Space Center, helping establish the important precedent that the center and NASA flight missions are for participation in and viewing and use by the public. Almost 80,000 visitors attended the grand opening. They viewed a film about the Nation's space program in the auditorium (later named for Congressman Olin E. Teague) and toured exhibits in the lobby and on the grounds. Exhibits included hardware from Mercury flights, scale models of Mercury, Gemini and Apollo systems, pressure suits, survival gear, and photographs. Outside displays included full-scale mockups of the Gemini and Apollo modules, a Mercury spacecraft, a boilerplate test module and escape tower, and a Redstone launch vehicle.[3]

The open house contradicted the more traditional practice of government agencies and especially the World War II tradition which stated, that the public's "need to know" was rather limited, as well as the older NACA (and academic) attitude that the workplace should be protected from external influences. NACA had generally limited its news releases and public relations activities to an annual report to Congress and a week-long open house at the NACA facilities. Although he held a very understanding view of public relations, John A. "Shorty" Powers, who first served as the public affairs officer for the STG, hailed from the Air Force where news releases were confined largely to rather concise handouts, and he tended to follow this custom. With the very limited staff at his disposal he could do little more. But the Mercury launches gave NASA and the manned spacecraft program a visibility that could not be avoided—despite the preferences of some to do just that. A major shift in public relations came just prior to Alan Shepard's flight in May 1961 when, at an informal gathering over martinis at the Hay-Adams Hotel in Washington, D.C., Roy Neil, with the National Broadcasting Company, discussed the NASA news problem in the company of Walter Williams and Paul Haney from headquarters and Shorty Powers with the STG at Langley. Powers and Haney both supported more public access to information, and Williams finally suggested that the STG put an information officer at the console in the control center to disperse instant and accurate information to the press. Haney and Powers looked at each other and said, "Gee—I wish I had thought of that!"[4] And it was done.

Paul Haney replaced Shorty Powers in September 1963 as director of public affairs at the MSC in Houston. Powers had spent most of his personal time in travel, leaving much of the administrative detail to others and predominantly to Paul Purser, Gilruth's special assistant. Independent branches of the MSC could and did issue their own news releases and information. Moreover, the Houston center and its public information staff seemed inclined to function independently of NASA Headquarters. Administrator James Webb sent Haney to Houston to head the Public Affairs Office, and Powers returned to Washington on special assignment for a year before taking his retirement from the Air Force.[5]

Haney centralized and reorganized the Public Affairs Office of the MSC bringing in John Peterson as his key administrative officer and Roy Alford for public relations. Alford had previous experience as an assistant city manager in Texas and as a military governor of five different states in Japan. Haney and his staff immediately began to encourage an "open door" policy toward the public. He recognized that the managing engineers at the center were people "who rarely ever had to talk to reporters about anything." And he strongly believed that "we in government and particularly in NASA, by accident or design, constantly erect information barriers around our work."[6]

Haney thus encouraged the MSC's open house as a philosophical statement. James C. Elms, who replaced Walter Williams as deputy director of the MSC in November 1963, approved the plan and Robert Gilruth concurred. Haney and his staff organized a VIP welcoming ceremony for the Friday preceding the open house weekend, and recruited some 20 Gulf Coast Chambers of Commerce as hosts for a gigantic, Texas-style cocktail party at a neighboring inn in the evening. About 25,000 guests attended.[7] That and the open house weekend were great successes and clearly helped bind the goodwill of the Houston community (then the sixth largest city in the country) to the MSC.

Although Haney believed that "MSC from the outset has taken a much more understanding view of the public information role than have any of the other centers of NASA," different views of public information continued to create problems within the center and in the center's relations to other centers and with Headquarters. Bob Gilruth discovered that the public's intense interest not only necessitated an open door, but also offered an excellent opportunity for explaining the NASA and MSC mission to the public and Congress. Gilruth explained in the special edition of the *Roundup* prepared for the occasion that in the offices and laboratories of the center "a concerted effort is made by management personnel, engineers, scientists, and many support personnel to assure that the national goal of the United States achieving preeminence in all aspects of space research and exploration is attained." MSC engineers, he said, "conceive the design and specify the systems to be used in these very complex spacecraft; American industry provides the detail design and fabrication."[8] The hand of the private sector, in fact, loomed larger in the Gemini program than it had in the Mercury program.

Work on the Gemini program began as an outgrowth of Mercury. As early as 1959, NASA began considering post-Mercury flights, and McDonnell Aircraft Corporation, which manufactured the Mercury spacecraft, independently began redesigning for an "improved" Mercury. James A. Chamberlin, Chief of the MSC Engineering Division, collaborated closely with McDonnell engineers and with Max Faget's Flight Systems Division in the redesign of Mercury. Faget recalls that NASA Headquarters, having just endorsed the Apollo lunar program, was reluctant to initiate another new venture. Bob Gilruth, Faget said, convinced Abe Silverstein that Gemini was an absolute necessity and Headquarters soon endorsed the program.[9]

NASA awarded a design study contract to McDonnell in April 1961, while center engineers studied design modifications and new flight requirements. The profile for the new craft included that it support a two-person crew for extended flights of up to 14 days and that it have the capability for rendezvous, docking maneuvers, and a land landing. The landing problem led to competitive design studies for a paraglider system by Goodyear Aircraft Corporation, North American Aviation, and Ryan Aeronautical Company. First styled the "Mercury Mark II," plans developed to launch the vehicle aboard a new Titan II rocket being manufactured by the Martin Company of Baltimore, Maryland, for the Air Force. The Air Force would serve as NASA's supplier.[10]

Redesignated "Gemini" in January 1962 by an ad hoc committee at NASA Headquarters, the name was suggested by Alex P. Nagy who identified the two-man space crew with the "twins," one of the 12 constellations of the zodiac. Historian Barton Hacker and James Grimwood believed that Gemini was "a remarkably apt name," because in astrology, "Its spheres of influence include adaptability and mobility—two features the spacecraft designers had explicitly pursued—and, through its link with the third house of the zodiac, all means of communication and transportation as well."[11]

Contracts for the spacecraft, propulsion systems, and landing devices were awarded in November and December of 1961 following approval of the project at Headquarters by NASA Associate Administrator Robert C. Seamans. McDonnell Aircraft, also the prime manufacturer for the Mercury vehicle, received a contract for the manufacture of 12 spacecraft, while North American Aviation received a contract for the development of a paraglider (land) landing system, and the Air Force, acting on behalf of NASA's request, ordered 15 Titan II rockets from the Martin Company.[12] The MSC, which officially came into being almost concurrently with the Gemini program, had responsibility for management of the spacecraft and paraglider systems, while the Air Force managed the propulsion work.

Gilruth created a Gemini Project Office on January 15, 1962, and appointed James Chamberlin project manager (see figure 4, 72). Chamberlin, born in Kamloops, Canada, in 1915, graduated from the University of Toronto in 1936 and received a master's degree from the Imperial College of Science and Technology in London, England, in 1939. After a brief stint with Martin Baker, Ltd., he moved to Montreal, Canada, to work for Federal Aircraft, Ltd. on design modifications of Canada's version of the British Avro-Anson aircraft. During the war he worked on projects for Clark Ruse Aircraft in Nova Scotia, Noorduyn Aviation at Montreal, and the Royal Canadian Air Force. He joined AVRO Aircraft, Ltd. in 1946, where he became Chief of Design and was primarily responsible for the aerodynamic design of a jet fighter and a jet transport and for the overall design of the AVRO advanced interceptor, the CF-105 Arrow.[13]

When Canada canceled the AVRO-Arrow fighter program, Chamberlin was instrumental in moving the contingent of AVRO engineers to the STG. He became Chief of the Engineering Division in 1959 and, in that capacity, was responsible for managing the development and production of the Mercury spacecraft by McDonnell Aircraft. He contributed heavily to the resolution of Mercury designs and to the engineering interface between the capsule and the Atlas launch vehicle. Chamberlin began work on the improved Mercury capsule that became Gemini in February 1961, and in cooperation with other center and McDonnell engineers was the “creative genius” of the Gemini spacecraft.[14]

Chamberlin’s work on the Mercury systems in collaboration with McDonnell Aircraft made the Gemini alliance of McDonnell and Chamberlin’s Gemini Project Office a natural, comfortable and very productive arrangement. The initial letter contract between NASA and McDonnell, dated December 15, 1961, provided that the company would immediately begin a research and development program which would result in the development to completion of a two-man spacecraft, with a launch vehicle adapter and a target vehicle docking adapter. The company was to manufacture 12 spacecraft, 15 launch vehicle adapters, and 11 target vehicle docking adapters with the “test articles and ancillary hardware,” and provide field services, training and liaison with “NASA, other government agencies, NASA associate contractors, and subcontractors.” In terms of the agreement, NASA would provide astronaut pressure suits, the spacecraft paraglider, survival equipment, launch vehicles and facilities, and the target vehicle “in orbit.” The first spacecraft, with the launch adapter, was to be delivered in 15 months.[15]

The brief technical guidelines supporting the agreement stated that the vehicle should be able to orbit the Earth for 14 days, make “land” landings, rendezvous and dock with a target vehicle in orbit, have pilot-guided reentry capabilities, require simplified countdown techniques and procedures, and test “man’s performance capabilities in a space environment during extended missions.” The original letter contract would fund McDonnell development at cost-plus-a-fixed-fee with a ceiling of $25 million, to be followed by the final cost-plus-fixed-fee contract at a later date.[16]

The Gemini program soon became beset by a “pattern of rising costs.” Cost estimates rose quickly from the original estimate of $350 million made for Mark II in August 1961, to $529 million in October, to $744 million in May 1962, to a final cost of $1.283 billion. By comparison, Mercury program costs totaled $392.6 million while Apollo would cost $29.5 billion.[17] Within a few years, the MSC began an innovative contracting program for cost containment. At the moment, however, given the objectives, the time frame, and the generally robust health of the national economy, money was no object.

There were, in fact, Gemini problems that money could not solve. Jim Chamberlin, considered by many a genius at detailed design work, assumed almost sole authority for the development of the Gemini spacecraft and worked closely with McDonnell in its production. “There was not,” according to Paul Purser, “a single change made in the basic design of the Gemini spacecraft or its systems once they were established by Jim. The basic design and systems that he established were workable ones and it turned out to be a highly successful program.”[18]

Chamberlin, however, did not seek outside advice, internalized the work of the Gemini Project Office, and tended to ignore the functional divisions of the MSC. Max Faget observed that Chamberlin tended to isolate himself and his project office from other divisions. Rodney G. Rose, working in the Gemini Project Office with Chamberlin, acknowledged that Chamberlin tended to “play his cards close to the vest,” but recalled that Faget and the Engineering Division, with its hands full of Apollo, had little time for Gemini. Similarly, Chris Kraft, from the perspective of the Flight Operations Division, thought that the relative independence and isolation of the Gemini Project Office was a “comfortable” arrangement because everyone had other things to do. Nevertheless, as Bob Chilton (then acting head of the Guidance and Control Division) observed, some of Apollo’s problems derived from the fact that organizationally Gemini had been too independent of both the Mercury and Apollo programs. Gemini failed to benefit fully from the Mercury engineering and flight experiences and, subsequently, Apollo failed to learn fully from the Gemini experiences.[19]

Joe Loftus concurred that the embryonic engineering directorate at MSC “did not have as extensive a participation in Gemini as they had in Mercury and were to have in Apollo.” Many of the MSC engineers quickly came to the conclusion that the Gemini Project Office was too exclusive, and that overreliance on the contractor preempted the role of the center engineer. It was in part, Loftus believed, an extension of the old NACA versus Air Force syndrome where one group of NACA-style engineers was accustomed to in-house, hands-on development and the other group saw its role as purely consulting or advisory to the contracting engineers. It was a problem, Loftus admitted, which was both “knotty” and “classical” and it created severe stress within the center.[20]

The “Gemini management crisis” came to a head in the spring of 1963, but it was by then only one facet of a broad-based organizational and personnel imbroglio. To be sure, the crisis was attributable not only to Chamberlin’s predilection for personal control over the Gemini program, but also to the reality that MSC human resources were stretched very thin and already heavily committed to the Apollo program, which had seniority and was considered more urgent. Operations people, as well, were still busily involved with Mercury. Henry Pohl (then chief of the Auxiliary Propulsion and Pyrotechnics Branch in the Engineering and Development Directorate) believed that the management crisis was in part more presumed than real, simply because Jim Chamberlin was not a “good communicator.”[21] The organization at every level was young, growing, and inexperienced. But Chamberlin knew what he was doing and so did McDonnell Aircraft; and by temperament and circumstance, Chamberlin and Gemini did not interface with other elements of the center.

Gilruth resolved the dilemma in March by assigning Chamberlin as the Senior Engineering Advisor to the Director and placing Charles W. Mathews at the head of the Gemini office. Mathews, from Duluth, Minnesota, joined NACA in 1943, and headed the STG Operations Division and then the Spacecraft Technology Division during the Mercury years. He brought Kenneth E. Kleinknecht to the Gemini office from Mercury and helped fuse Mercury experiences, and especially its flight experiences, into the Gemini program. Chris Kraft, who worked under him, described Mathews as "an intimate part of the flight operation management team and a key individual in the development of technical policy." Many believed, as did Paul Purser, that Mathews was not only a "smart engineer" but also a good manager. He was "more willing to realize that there are several, in most cases, right ways to do something," Purser observed.[22] In the early fall, Gilruth completed a general reorganization of the MSC and there were related changes in management at NASA Headquarters.

The Gemini program actually made tremendous strides during the administration of Chamberlin, despite the real focus of MSC engineering resources on Apollo and the preoccupation of operations with Mercury. In October, McDonnell delivered the first of 12 Gemini spacecraft to Cape Canaveral, Florida, for preflight checkout procedures. Astronauts were recruited and trained and flight missions planned while life both in the center and without tended to go on largely oblivious to the Gemini program. In March, the same month that Mathews came to the Gemini office, NASA signed a contract with Grumman Aircraft Corporation ($397.9 million) for the development of the Lunar Excursion Module (LEM) for the Apollo spacecraft and Secretary of Defense McNamara visited Houston for a briefing on the Gemini program.[23]

A fourth successful firing of the Apollo Saturn rocket came in April; and in May 1963, Vice President Lyndon B. Johnson told the American Institute of Aeronautics meeting in Dallas that the United States "must forge ahead in space or become a second-rate nation." Astronaut L. Gordon Cooper flew Mercury (MA-9) in May, and following his 22 orbits, he told both houses of Congress and the packed galleries that the public's response to the flight "Shows that Americans want to express their feelings and their confidence that we . . . can conduct peaceful research programs; that we can conduct them openly, and under the surveillance of every man, woman and child in the world."[24] The MSC's and NASA's "public" had become worldwide and NASA intended to maintain an open door to that very large audience.

Cooper's flight ended project Mercury and helped salve the wounded pride inflicted by Sputnik and subsequent Russian space achievements. It also brought the sharp attention of the Operations Division of the MSC to the Gemini program. With a capsule already on location at Cape Canaveral, astronauts in intensive training, and Mercury behind them, Dennis Fielder remembered the sharp shift in attention when Chris Kraft looked at the Gemini spacecraft and said, "we're going to have to fly this."[25]

Flying Gemini would be considerably different from flying Mercury. Gemini was maneuverable. Mercury was not. Mercury was mostly a matter of trajectory and tracking. Gemini provided flight control options. Astronauts became pilots rather than passengers. Gemini operations built upon the Mercury experiences, but it became a substantially different program. The mission control and communications network which existed at the close of the Gemini flights was considerably more sophisticated than that which existed at the time of the last Mercury flight. Operations and mission control really "cut their teeth" on Gemini, designing and building the control center, creating a worldwide communications network, and flying Gemini, while looking ahead to Apollo.[26]

When Mercury flights began there was no around-the-world communications network; long distance voice connections were even more rare. Flight control for Mercury and Gemini required real-time voice contact with the spacecraft; and since the spacecraft would be accessible by a direct radio contact for only about 7 minutes, continuous contact required numerous stations and significant real-time communications between those stations. The rapid and instantaneous handling of data, which became increasingly critical as missions became orbital under Mercury and then maneuverable with Gemini, required computer and program sophistication which simply did not exist at the start of the space program. Worldwide networking required the cooperation of foreign countries with the United States and the cooperation and interfacing of American communications companies with each other. Both were relatively rare phenomena. The most serious hemispheric communications network then being developed by the Department of Defense would have been the North American Air Defense Command or DEW Line radar defense systems. Because most of this work was classified, little of that experience seems to have reached NASA. Human spaceflight "drove" a reformation and near revolution in the civilian sector of communications and computer technology.[27]

John D. Hodge, who headed flight control operations under Kraft, suggests the enormity of the communications problems surrounding the creation of the Mercury control center at Cape Canaveral, from which the Air Force launched its missiles, including the Redstone, and maintained downrange telemetry monitoring stations through the West Indies to the coast of South America. "There always seemed to be some kind of controversy," Hodge recalled, "as to who had the communications responsibility at the Cape site." The Department of Defense controlled cabling inside the fences, Radio Corporation of America (RCA) carried the cable to the fence, and NASA interposed with Western Electric, BellComm and the Bell Telephone system. "Some very strange interface problems occurred," Hodge said. Joining the cables of different commercial carriers violated legislation establishing carrier tariffs and franchises. AT&T's George Vogel, for example, said over and over that AT&T would not knowingly interconnect its services with another carrier. Subsequently, AT&T laid cables to the Cape control center while "oblivious" to the fact that NASA was going to tie everything together.[28] Thus, AT&T could compromise in fact, if not in principle.

Simply resolving disputes with the Air Force over space allocations and who should own and who should control which buildings and what equipment required some considerable diplomacy and expertise. The flight command center at Cape Canaveral operated for a time under a complex arrangement. RCA, as an Air Force contractor under special assignment to NASA, operated the command center on behalf of the Air Force, while the management authority rested in the Tracking and Ground Instrumentation Unit of the STG (located at Langley) which was administered by the Goddard Space Flight Center. Despite the apparent confusion "that was probably one of the best things that ever happened to us," Chris Kraft said, "because the people we got were all experienced and highly competent."[29]

G. Merritt Preston headed Cape Operations under the general direction of Charles W. "Chuck" Mathews who remained at Langley and supervised for a time all of the activities related to flight control, crew systems, and medical operations. In late 1962, Gilruth appointed Walter Williams Assistant Director for Operations to supervise a Preflight Division under Preston, a Flight Operations Division headed by Chris Kraft, and a Flight Crew Operations Division under W.J. North. Chuck Mathews became chief of the Spacecraft and Technology Branch under Faget's new Engineering and Development Division.[30] The organizational changes tended to be more paper than real, because the real work of the various managing engineers did not change significantly.

Chris Kraft and Tecwyn Roberts worked on the design of the Mercury control center, and Fred Mathews with Kraft and Gene Kranz concentrated on flight operations. Porter Brown was the key liaison and support person between Cape Canaveral and STG (or MSC). John Hodge and Dennis Fielder created and refined the communications network between stations. When a network contract went to Western Electric with another to IBM as an associate contractor for work on the computer integration systems, Fielder became the interface between the MSC and the contractor. Howard Kyle focused on the design of the communications systems. Bill Boyer worked on network and station contracts and permissions, and Barry Graves "and his merry men" designed and developed the instrumentation and electronic systems and managed the IBM and Philco contracts. Graves eventually got "crossways" with IBM, Philco and Chris Kraft, contributing to another substantive administrative reorganization in 1963. The problem had to do with the fact that at the close of the Mercury flights, Graves accepted a Sloan Fellowship, and when he returned to MSC in 1963, he was appointed Assistant Director for Information and Control Systems with Paul Vavra in the Ground Systems Project Office reporting to him. The major responsibility of the project office was to build the new Gemini Mission Control Center, but that design work had largely been completed and the contracts awarded. For the most part, however, everyone, including Kraft and Graves, cooperated and worked together and did what needed doing.[31] The work was intensive and exhausting—but also exhilarating. Most recognized that they were doing things no engineers had done before.

The human spaceflight program and those flight control operations which first centered at Cape Canaveral before the Mission Control Center was built at Houston became a critical catalyst in changing the world of communications. The world really did not communicate much before the advent of human spaceflight, certainly not in terms of real-time and voice communications. Mercury, Gemini and Apollo programs inspired cable and voice interfacing, stimulated the development and placement of communications satellites, and helped link the world together as never before. Philco, which had networking experience with the Discoverer satellite program, received the NASA contract to manage and develop the manned spacecraft network.[32] Networking, even assuming the existence of the technical expertise, became a problem of considerable diplomacy and statesmanship. In fact, the State Department was very much involved.

Department of State diplomats negotiated a "government-to-government" agreement with Australia to develop a number of communications and flight control stations, including stations at Muchea, north of Perth, and one in the Woomera Mountain Range. These were under the technical management of Australians and "except for a few company reps and an occasional NASA advisor" the Australians "ran the show." Spain had to be convinced that the Americans were not building a missile site on Spanish soil before agreeing to locate a NASA communications station there. Although Mexico approved a site at Guaymas, Communist and anti-American groups constantly threatened the security of the station. Nigeria approved a site after NASA representatives visited the country, and NASA brought Nigerians to America for briefings and informational tours. Although Zanzibar admitted a mobile relay station, political unrest finally forced NASA to remove the facility to Tennarive, Madagascar. The Bermuda station, already in service by the Air Force, was a primary flight control station.[33]

Two ships, the *Coastal Sentry Quebec* located near Okinawa and the *Rose Knot Victor* off the west coast of South America filled slots that could not be monitored by land-based stations. Life aboard those ships and in the remote stations could be very tedious. Before John Glenn flew in February 1962, Alan Shepard had been sent to the control room of the *Quebec* off Okinawa. Innumerable launch delays created a terrible morale problem and restlessness aboard the ship, which had been allowed to drift hundreds of miles from Okinawa toward a convenient liberty port in Japan, while awaiting the launch. Finally, Shepard called Chris Kraft, explained the problem, and asked for permission to give the sailors liberty in Japan. But Kraft hustled them back to their duty station with the word that indeed the launch was now imminent.[34] Spaceflight had many dimensions.

As Mercury began orbital missions with John Glenn's flight, equipment and procedures needed to be constantly updated. When Gemini came on line, the system established for Mercury had to be completely retooled. The Mercury control center at Cape Canaveral used "off-the-shelf" electronics gear, but more was needed. It became obvious that existing equipment and techniques were inadequate. In 1961, Chris Kraft, Dennis Fielder, Tec Roberts and John Hodge began a serious study of needs and options for an improved control center and directed a study contract awarded to Philco's Western Development Laboratory. While this study developed, IBM received a contract on competitive bids to design and build a complex digital command system which could control the Gemini spacecraft, its target vehicle Agena, and the Apollo craft. This would become part of the Mission Control Center. After Philco and NASA completed the basic control center study, contractors were given the opportunity to bid on construction of the control center. Philco received the award, and in 1963 began work on the new Mission Control Center, which, it had been decided, would be located at the MSC in Houston, rather than at the Kennedy Space Center where Mercury controls were located, or at the Goddard Space Flight Center, where the Mercury flight computer systems were located.[35] Location of the spacecraft control center proved to be a somewhat thorny problem.

Were flight operations to be part of the design center, that is, MSC in Houston or part of the operations center at Kennedy Space Center where Mercury controls were housed? Goddard Space Flight Center had the attraction of being conveniently located near the National Capital and NASA Headquarters. When the Kennedy Space Flight Center was organized, G. Merritt Preston and some of his preflight operations personnel became a part of the new center and strengthened the idea that the control center should remain with the launch operations crews in Florida. Travel also was a factor. Would travel requirements be greater or less if the control center were located in Maryland, Texas or Florida? Could communications be enhanced by locating at the launch area? By the latter stages of Mercury, some of the remote flight control stations, as at Bermuda, were being shut down. It had become more and more apparent that through networking a control center could be effectively established at any number of points in the network. But both John Hodge and Chris Kraft initially suggested that the Florida location might be most reasonable. Further discussions with Walter Williams, Bob Gilruth, and the Gemini and Apollo Program Offices, among others, resulted in the decision to locate in Houston.[36] It was, all agreed, a happy and fortuitous decision which strengthened the relationship between the engineering design and flight operations programs. Mission control and operations soon became a major component of MSC responsibilities.

Had this responsibility been assigned to Goddard Space Flight Center or to Kennedy Space Center, the MSC would likely have been more design/development oriented in the NACA/Langley tradition. As it was, construction on the new advanced control center began in late 1962, and when Gemini 2 flew in January 1965, Mission Control Center in Houston monitored the flights. Houston's mission control directed the Gemini 4 flight in June and all subsequent Gemini and Apollo flights.[37] Although the Mission Control Center at first lacked the flight simulation systems, they soon were added and became important in flight planning, training, and real-time operations. Houston's Mission Control Center did represent the state-of-the-art in modern communications.

Chris Kraft, incidentally, credited IBM and the Philco contractor teams for the design and fabrication of the Mission Control Center. IBM's technical manager, Jim Hamlin, who had worked on the Mercury control center, "was the man responsible for the development of the 7094 system which we used to support Gemini. I can't praise him too highly," Kraft said. And Philco's manager, Walter LaBerge, and the Philco team who worked closely with IBM did an outstanding job, Kraft said. But as an aside, Kraft also mentioned that despite the excellence of the Gemini control system, it, and especially the 7094 computer capability, was inadequate to meet the developing needs of planned Apollo flights. For that, yet a new generation of real-time computers would be needed.[38] Gemini, then, provided a transition in the technology of communications and control from Mercury to Apollo.

Gemini also provided a management transition from the more simple structures used in Mercury to the more elaborate systems-management structures created for Apollo. Bob Gilruth gave James C. Elms, who joined MSC on February 1, 1963, primary responsibility for developing the reorganization that would strengthen the Gemini and Apollo management systems and alleviate some of the confusion that derived in part from the more informal, collegial style of management associated with Mercury. That system could not cope with the multifaceted management responsibilities of Gemini and Apollo. Elms came to MSC (somewhat reluctantly) from his position as Director of Space and Electronics at the Aeronutronic Division of Ford Motor Company. He had previous management experience with North American Aviation and Martin Company. He said his reluctance to join MSC was because "I had a growing family and many expenses and my industrial salary was twice that of the salary I was offered in the government." But Brainerd Holmes (who would soon leave NASA Headquarters and return to industry) was a persistent recruiter and Elms accepted the job.[39]

Elms viewed the MSC organizational problem in very broad terms. "I felt that it would be possible to handle the Gemini program in somewhat the same manner as the Mercury program, but that it would be extremely wise to start taking large steps in the direction required for Apollo using the interim step known as Gemini," Elms explained in an interview some years later. "The methods used to manage the Mercury program could not possibly have been applied to the Apollo Program," he said.[40]

The problems encountered with Charles Frick's industrial-style, Headquarters-oriented control of the Apollo Program Office and Jim Chamberlin's independence in the Gemini office were symptomatic of more than a conflict with the collegial tradition of management at MSC. They reflected very real difficulties in delineating between developmental functions and operations. Thus, disputes between Barry Graves, who was developing spacecraft information and control systems, and Chris Kraft, in flight operations, involved more than personalities. Differences between the Engineering and Development Directorate under Max Faget, and the Operations Directorate under Walter Williams involved in part "deciding where development stopped and operations began." When he arrived at MSC, Elms said, he assumed one of Walter William's hats as Deputy Director for Programs and Development. Williams became Deputy Director for Missions and Operations. Some of the assistant directors, such as Barry Graves, held two different titles and reported to two different bosses. Graves reported to both Williams and Elms. "The situation was a little confusing from the theoretical organization chart point of view," Elms explained.[41]

Although there was a need to clarify roles and functions, the management problem was not truly a matter of "either organization or of personality . . . but of the philosophy of managing a difficult program involving requirements for ultra reliability, schedule, safety, and yet operational flexibility and perfection of equipment without exorbitant costs," Elms said.[42]

Quality control needed to be maintained at the manufacturer's site, not at the delivery point as had been true with Mercury spacecraft where each capsule had been virtually disassembled and reassembled prior to flight. The Gemini program stressed inspection and checkout at the factory. And it was natural and appropriate, Elms believed, that the engineering development divisions would want to maintain control over a product from its design to its completion, while the users in operations would want to participate in the development and manufacturing cycle to help assure the quality of the product. "It seemed to those involved at the time to be a very difficult and almost insoluble organizational problem," he observed.[43]

Viewed in this broader perspective, the appointments and organizational changes at MSC that occurred during the fall of 1963 and the spring of 1964 represented a broad-based and rational attempt to resolve some very difficult management issues. Gilruth's reorganization became effective November 1 and elevated Jim Elms to Deputy Director. Four functional assistant directors reported to Elms: the Engineering and Development Directorate headed by Max Faget, the Flight Crew Operations Directorate under Donald K. Slayton, a Flight Operations Directorate with Chris Kraft the assistant director, and the Administration Directorate under Wesley L. Hjornevik. The Flight Crew and Flight Operations Directorates were newly created, and facilitated the input from operations into spacecraft planning and development. Two program offices, the Apollo office under Joseph F. Shea and the Gemini office under Charles Mathews, also reported to the Deputy Director, as did the Manager of Florida Operations, G. Merritt Preston.[44]

The reorganization involved substantive changes within the various directorates, and especially within the Engineering and Development Directorate which combined with it the Information and Control Systems Offices which had been headed by Barry Graves. The basic elements of the reorganization had to do with creating small, management-oriented program offices with access to all levels of engineering and operations. Instead of program managers having their own engineering staff and in effect creating a minicenter, they would rely on the engineering expertise of the functional (or line) divisions. With this arrangement, a Gemini or Apollo program office could not isolate itself from the center management as had happened in the past, and the managing engineers at the center could provide the interface or flow of experience and expertise which seemed to be lacking to some extent between the Gemini and Apollo programs.[45] As a practical matter, the reorganization required fewer people in fewer meetings, created less confusion, and more clearly, but certainly not perfectly, defined responsibilities and lines of authority.

With these organizational changes in place, James Elms elected to return to private industry on February 1, 1964. "Our center, our agency, and our Nation owe him a debt for his accomplishment. I cannot adequately express to him my own deep and personal appreciation," Gilruth said. Much to the satisfaction of MSC personnel, George M. Low returned to the fold from the Manned Space Flight office in Washington, D.C., as the replacement for Elms.[46]

These organizational and personnel changes occurred while the pace of activity for both Gemini and Apollo programs increased. Upon completion of the successful unmanned suborbital flight of a launch vehicle and Gemini spacecraft in April, MSC announced that Virgil I. (Gus) Grissom and John W. Young would be the prime crew for the first manned Gemini flight, tentatively scheduled for November or December. The backup crew would be Walter M. Schirra, Jr., and Thomas P. Stafford. One more test suborbital flight of the Gemini-Titan system (GT-2) was scheduled December 9 (prior to the manned flight), but it was delayed until January 19 because of a cracked servo valve flange. That fully successful flight on the 19th preceded the launch on March 23 of Grissom and Young, America's first two-man team in a three-orbit mission which successfully tested the maneuverability of the craft. The "Molly Brown," as the astronauts named their craft, landed near Turks Island in the British West Indies.[47] Five more manned Gemini flights were launched and returned safely within the year, and each pushed the frontiers of spaceflight into new dimensions.

The reorganizations of 1963 and 1964 continued to unfold in terms of management efficiencies and cost savings. The growing involvement of American military forces in southeast Asia, the approval by Congress of President Johnson's War on Poverty and other social welfare programs, the rising costs of "cold war" hardware, not to mention the billions being spent on NASA, began to turn America's post-war world of budget surpluses and constant economic growth into slowdowns and deficits. As a result, President Johnson declared a campaign for economy in government and, concurrently, Gilruth announced a cost-reduction program for the space center which was expected to result in saving $2 million in operating costs for fiscal year 1964.[48] The center also anticipated greater savings, as well as

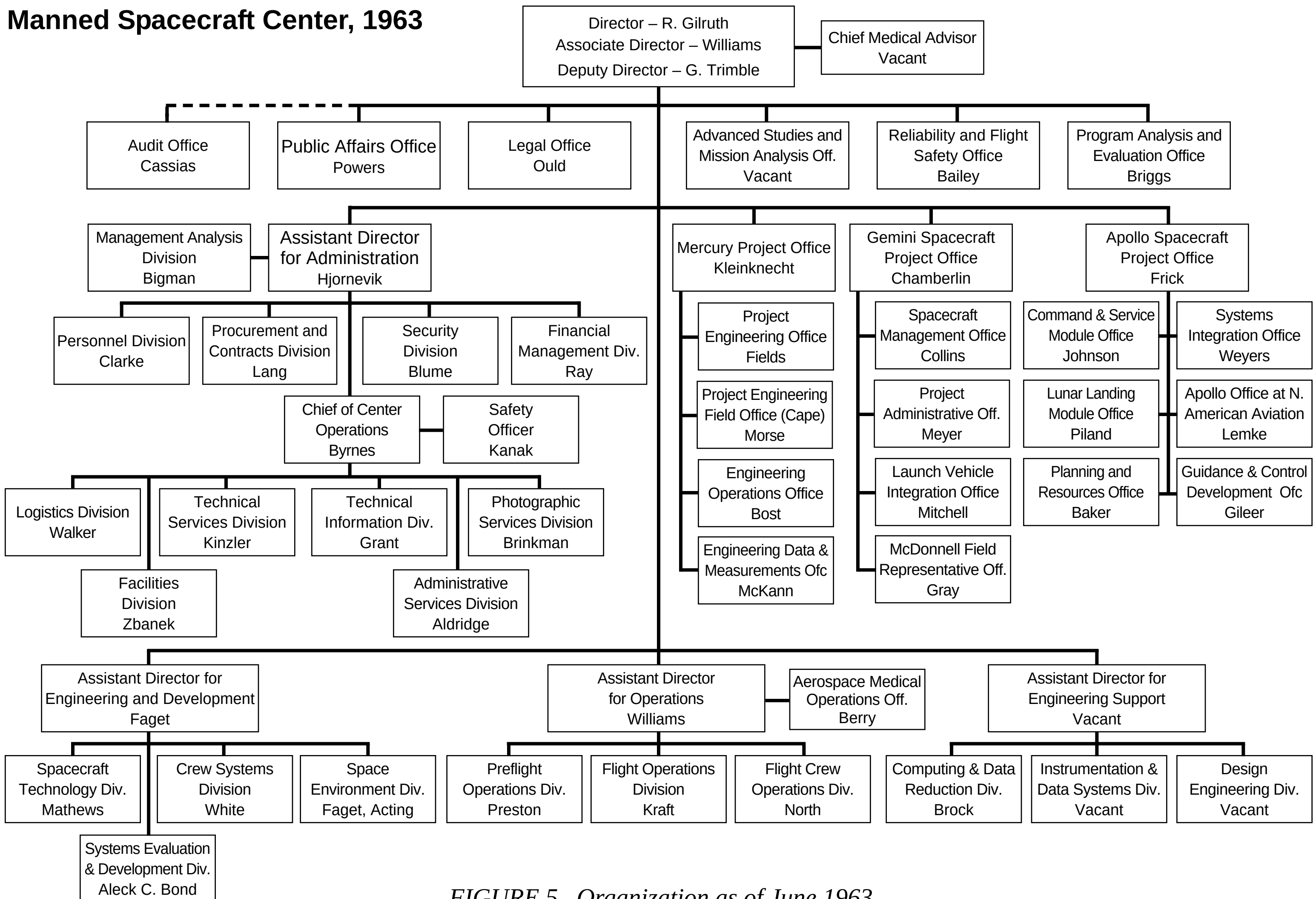


FIGURE 5. Organization as of June 1963

Manned Spacecraft Center, 1964

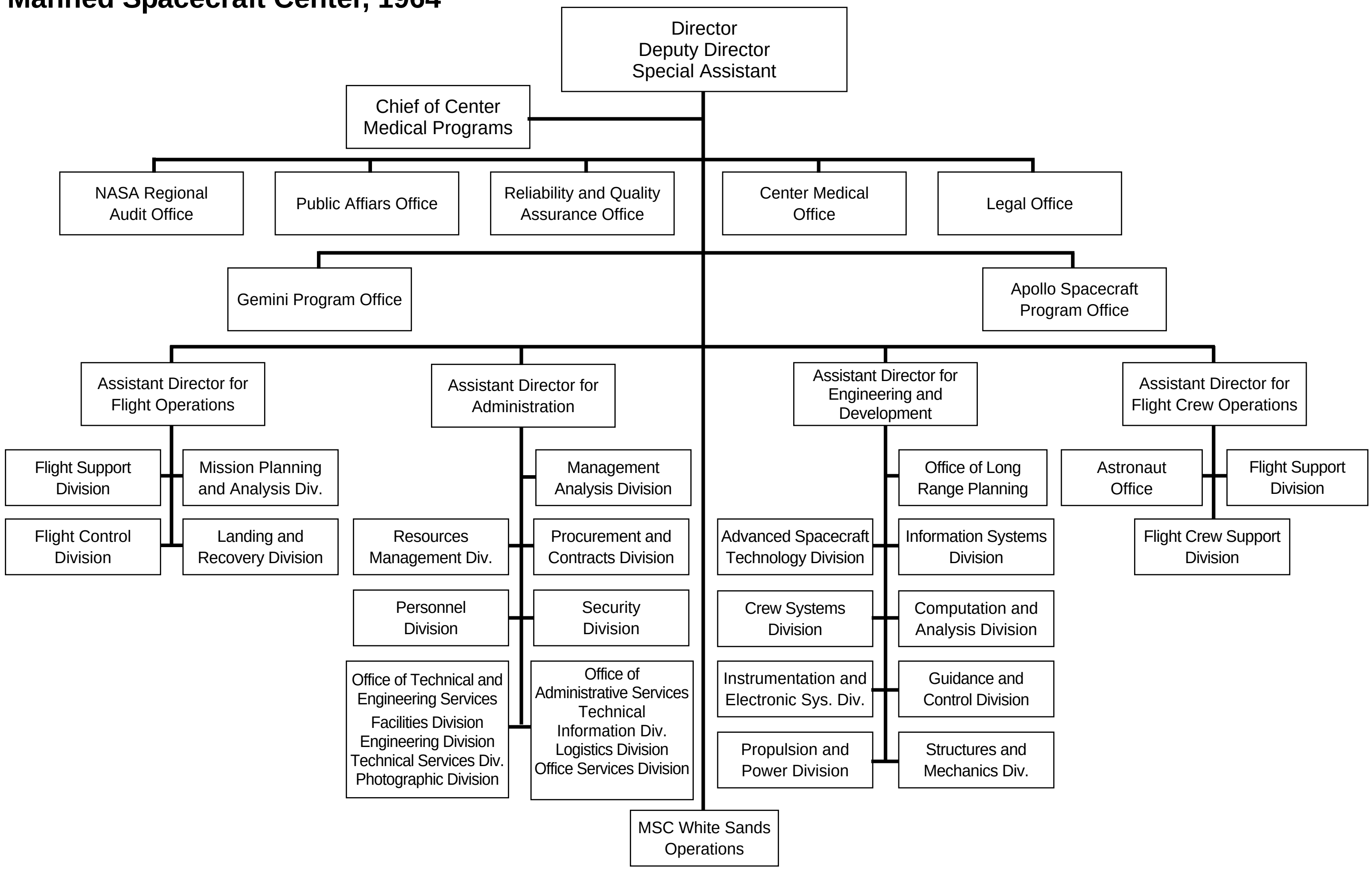


FIGURE 6. Organization as of December 1964

technically improved products, through more effective contracting procedures and better controls over design change procedures.

Cost-plus-incentive-fee contracts, the establishment of configuration management panels and boards, and the formalization of subsystem management structures promised to improve the cost efficiency and the engineering effectiveness of the center. MSC and NASA contracts had been awarded usually on the basis of cost plus a fixed fee (CPFF) to ensure the delivery of the product and a profit to the contractor. But, "the fatal flaw of the CPFF contract," Wesley Hjornevik pointed out at a meeting of the Harvard Business School Club of Houston, "is that profit is a function of estimated cost; and being established at the outset of a program it is not affected by how well or how poorly the contractor actually performed the work." Despite competitive bidding, contractors tended to overprice because the fixed-fee or profit was usually a percentage of the cost package. Once the contract was awarded, the only real incentive to simplify design, improve deliveries, or control costs would be the hope of future contracts. "This is not enough," Hjornevik said, and he explained that NASA was designing an incentive fee contract.[49]

Later that year NASA converted the McDonnell Aircraft Company's cost-plus-fixed-fee contract for the delivery of the remaining Gemini spacecraft to a cost-plus-incentive-fee basis. The change was effected after extensive study by both MSC and McDonnell study groups. Kenneth Kleinknecht headed a "Gemini Incentive Task Group" to study and renegotiate the spacecraft contracts. The initial phase involved the establishment of basic incentive criteria and the preparation of the Request for Proposal (RFP) to the contractor. McDonnell conducted its own study and costing analysis and, after negotiations, agreed to convert its $712 million contract to the new formula. The contract provided profit incentives for outstanding performance, cost controls, and timely delivery, and profit reductions for failure to do so. No performance incentive fee would be paid a contractor "on any mission involving the loss of life of a crewman." A weighted evaluation system based on performance, costs, and schedules determined performance levels. Such contracts, it was hoped, would provide an emphasis on reliability, ensure successful mission performance, control costs, and encourage timely delivery.[50]

The McDonnell incentive contract included a provision for regularizing and improving procedures for contract changes and for minimizing the costs of such changes. In developmental-type contracts, which characterized most NASA contracts, changes were part of the business. Changes could be suggested at any level by the contractor, by managing engineers in design and development work, and at the operations level. All of these elements were interfaced through the subsystem managers and by both formal and informal testing and evaluation committees.[51] But the system for approving changes had not been regularized and changes usually added significantly to production costs.

As a result, while the McDonnell incentive contract study proceeded, NASA began to devise a better system for implementing contract changes. This became known as configuration management, which created a flow of contract change information and decision making from the subsystem manager to top-level management where a final decision was approved. As the system developed, a Request for Engineering Change Proposal (RECP) had to first be approved by the individual responsible for that specific subsystem. It

Gemini 3, launched March 23, 1965, carried the first two-man crew (Virgil Grissom and John Young) on a 4-hour and 53-minute orbital mission. The astronauts completed the first piloted spacecraft maneuvers.

then went to the project officer for approval where a Configuration Control Panel (for example, a command space module panel or lunar module panel) reviewed and approved the changes. The panels ordinarily met on a regular weekly basis. From there the change went to the Configuration Control Board at the program level (e.g., for Apollo or Gemini) where representatives from each of the directorates reviewed the changes. At each level, evaluators maintained a register of changes in a system, schedules for reviews, agendas, and pertinent review information, and distributed changes proposed and approved to affected organizations.[52] First implemented in the McDonnell/Gemini contract, the configuration control system became an integral part of the Apollo management structure.

There was a natural reluctance on the part of the government and contractors to accept configuration management because it restricted somewhat their own management independence, but overall it forced discipline into design and development. Interestingly, configuration management derived from the "minimum essential" philosophy of the industrial revolution, which in layman's terms argued "if it ain't broke don't fix it." Or, in industrial language, "if it works as well rough as it does ground and polished—leave it alone." NASA's configuration management philosophy was to build for a high degree of reliability and create redundant systems when in doubt.[53] The success of the Gemini missions reflected in part the development of more mature and disciplined management systems within the MSC in particular and throughout NASA.

Each Gemini flight seemed to produce some quantum "leap" in the mastery of space. Now that the new Mission Control Center was on line, Gemini 4 became the first flight controlled from Houston and the longest duration mission to that date. The Cape Kennedy control center provided backup services for the initial launch and trajectory, and Goddard's computer center provided support for the entire 4-day mission. Three mission controllers, Chris Kraft, John Hodge, and Eugene F. Kranz, directed the flight from Mission Control. Paul Haney sat in the control room and described the flight for the press. Haney had hoped to obtain television cameras aboard Gemini flights but concerns about using additional electronic equipment in the cabins and what might be considered the frivolous nature of such expenditures overrode Haney's appeal. During the mission, an attempt by Command Pilot James A. McDivitt to rendezvous with the orbiting booster rocket failed because of excess fuel consumption during the maneuvers, but Edward H. White made history with NASA's first spacewalk—20 minutes in EVA tethered to the reentry module. "This is fun," he said, and returning to the capsule was "the saddest moment of my life." In that one flight, McDivitt and White logged more time in space than all previous United States astronauts combined.[54] Not long after that flight an African Episcopal Bishop Josiah Mtekateka of Malawi was visiting the Houston area and attended the Friendswood Episcopal Church. He asked the pastor, William Sterling, "Is it true what the drums are saying, that a man has walked in space?"[55]

Two months later, on August 21, 1966, Gordon Cooper and Charles Conrad sped into orbit aboard Gemini 5 and spent twice as long in space as the Gemini 4 astronauts. They completed 17 assigned scientific experiments and a rendezvous with a "phantom" vehicle. The Gemini 6 flight was canceled on October 25, when the Agena-D target vehicle's engine failed after separation from the booster rocket. A very bold decision followed, which Chris Kraft said was initiated by McDonnell Douglas, to launch Gemini 6 (GT-6A) while Gemini 7 was in orbit in order to accomplish the much desired rendezvous. Thus, the critical Gemini 7/6 mission began on December 4 with Frank Borman and James A. Lovell, Jr. at the controls of Gemini 7. They were joined, almost literally, by Wally Schirra and Tom Stafford, who launched aboard GT-6A on December 15 and 6 hours later came to within one foot of Borman and Lovell's module.[56]

Attention shifted for a moment from Gemini to the first suborbital launch of a Saturn IB rocket carrying an unmanned Apollo module (February 26, 1966). The previous month, based largely on the Gemini-McDonnell experience, Grumman Corporation's contract for a lunar landing module and North American's contract for the Apollo spacecraft were renegotiated as cost-plus-incentive-fee contracts. Then Gemini 8, with David R. Scott and Neil Armstrong aboard, completed a successful rendezvous and docking with an Agena target vehicle, but broke off after 30 minutes when the combined craft began to yaw and roll wildly. The astronauts made an early but safe return. The following 3-day mission of Tom Stafford and Eugene A. Cernan in Gemini 9 was beset with problems: rendezvous with the target vehicle failed because a protecting shroud over the adapter had not fallen off, and there were visibility problems during Cernan's EVA. But the mission successfully tested rendezvous maneuvers, including

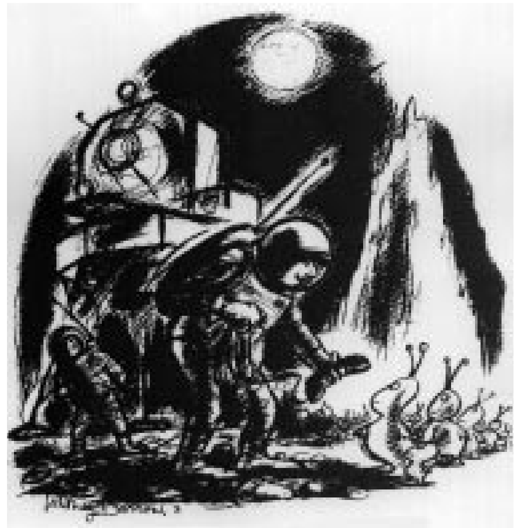
The interior of Gemini 6 has a striking similarity to the Apollo spacecraft still under development. Gemini 6, launched on December 15, 1965, completed a piloted rendezvous with Gemini 7 launched December 4. Gemini provided important technical and training missions in preparation for the Apollo lunar missions.

A critical interlude between Mercury and Apollo, Gemini proved the necessary capabilities for lunar flight including rendezvous and extravehicular activity (EVA)—more popularly called a "spacewalk." The photograph shows astronaut Edward H. White floating in the microgravity of space secured to the spacecraft by a 25-foot umbilical cord and a 25-foot tether line. He moved about using a hand-held maneuvering unit.

Gemini 10, launched July 18, 1966, carried astronauts John Young (left) and Michael Collins on a 70-hour plus mission that included rendezvous, docking, and EVA activities.

a simulated rendezvous with a lunar module.[57]

Each of the last three Gemini flights, including Gemini 10 on July 18 carrying John Young and Michael Collins, Gemini 11 on September 12 with Charles Conrad and Richard F. Gordon, and Gemini 12 on November 11 flying James A. Lovell and Edwin E. Aldrin, completed sophisticated rendezvous and docking maneuvers and EVA activities. Michael Collins on Gemini 10, for example, retrieved an experimental package from a target vehicle that had been in orbit since March. Gordon, aboard GT-11, tethered the module and target vehicles together; and on the last Gemini flight, Aldrin and Lovell completed three separate activities outside the reentry module.[58] Gemini had become an invaluable Apollo lunar landing learning experience.



"President Johnson wants to say 'Howdy.'"

Drawing by Whitney Darrow, Jr.; ©1966 *The New Yorker Magazine, Inc.*

What had been learned as a result of the Gemini program? Many of the answers to that question were not immediately apparent to those who planned and flew the Gemini missions. Dr. Charles Berry, who was the MSC flight physician for the Mercury, Gemini and Apollo programs, concluded many years later that Gemini diminished or repudiated some of the old "straw men" arguments which claimed, in spite of the Mercury missions, that long-term spaceflight would adversely affect humans physiologically and psychologically. The predicted effects of long-term weightlessness included hypertension, hypotension, reduced plasma volume, reduced blood volume, and variously that a person would urinate all the time or not be able to urinate at all, or sleep all the time or not be able to sleep at all. And there were many more bogeymen Dr. Berry said at a 1989 conference celebrating the 20th anniversary of the 1969 Apollo lunar landing. Gemini proved that during spaceflight vital functions remained normal, stress was tolerable, there was no psychomotor impairment, and cardiovascular deconditioning could occur. Gemini flights confirmed that humans could survive relatively long periods in space, but they did not wholly resolve issues for long-duration flight.[59]

Glynn Lunney, who served as flight director on Gemini and Apollo missions, some two decades later called Gemini a "stroke of genius. The operations team came out of Gemini. Flight crews and ground crews trained on Gemini and came on [Apollo] like gangbusters," he said. On the same occasion celebrating the 20th anniversary of the Apollo lunar landing, Cliff Charlesworth pointed out that Gemini flights had hardware problems, while Apollo had few. Stephen Bales said the Gemini 10 rendezvous was a particularly "historic experience" that prepared the way for Apollo, and Gerry Griffin referred to Gemini as "a whole series of little things—it was to shake out the system."[60]

Gemini recorded a series of "firsts" including the first pilot-controlled maneuvering in space, the first rendezvous, the first docking with another vehicle, the first extended flight of more than a week in duration and extended stays by astronauts outside the spacecraft, and the first controlled reentry and precision landings (albeit not on land as originally planned).[61]

But perhaps the deeper meaning of Gemini had to do with the enhancement of worldwide communications and the management reorganizations and reorientations accomplished at MSC and tested on the Gemini program. The manned spacecraft effort matured greatly during Gemini, and hardly had the program closed than Apollo did, as Glynn Lunney noted, "came on like gangbusters." But the path to the Moon would yet be strewn with many unforeseen obstacles.