CHAPTER 6: The NASA Family

The melding of all of the NASA centers, contractors, universities, and often strong personalities associated with each of them into the productive and efficient organization necessary to complete NASA's space missions became both more critical and more difficult as NASA turned its attention from Gemini to Apollo. The approach and style and, indeed, the personality of each NASA center differed sharply. The Manned Spacecraft Center was distinctive among all the rest.

Fortune magazine suggested in 1967 that the scale of NASA's operation required a whole new approach and style of management: "To master such massively complex and expensive problems, the agency has mobilized some 20,000 individual firms, more than 400,000 workers, and 200 colleges and universities in a combine of the most advanced resources of American civilization." The author referred to some of the eight NASA centers and assorted field installations as "pockets of sovereignty" which exercised an enormous degree of independence and autonomy.[1] An enduring part of the management problem throughout the Mercury and Gemini programs that became compounded under Apollo, because of its greater technical challenges, was the diversity and distinctiveness of each of the NASA centers. The diverse cultures and capabilities represented by each of the centers were at once the space program's greatest resource and its Achilles' heel.

NASA was a hybrid organization. At its heart was Langley Memorial Aeronautical Laboratory established by Congress in 1917 near Hampton, Virginia, and formally dedicated in 1920. It became the Langley Research Center. Langley created the Ames Aeronautical Laboratory at Moffett Field, California, in 1939. After the formation of NASA, Ames expanded its capabilities in research and experimentation in the life sciences and aerodynamics. Under congressional authority, Langley established the Lewis Flight Propulsion Laboratory adjoining the Cleveland Municipal Airport in 1940. As NASA's Lewis Research Center, the facility continued its work on propulsion systems. Its research on hydrogen fuel rockets contributed to the development of the upper stages of Saturn (Apollo) and Centaur rockets, and Lewis scientists and engineers made significant discoveries in solar power, reentry aerodynamics, lifting body concepts, and thermal protection systems. A High Speed Flight Station at Edwards, California, which had been formed in 1946, continued under the same name until it was renamed the Dryden Flight Research Center for Hugh L. Dryden. The Pilotless Aircraft Research Station at Wallops Island, Virginia, which provided hypersonic flight test support for Langley and was the point of origin of many MSC engineers, became NASA's Wallops Station which reported to Goddard Space Flight Center (earlier Beltsville Space Center) in Greenbelt, Maryland.[2]

Three of the NASA centers which were central to the Apollo program had non-NACA origins and very different personalities from those with a Langley lineage. These included the Marshall Space Flight Center in Huntsville, Alabama, the Kennedy Space Center at Cape Canaveral, Florida, and the Jet Propulsion Laboratory (JPL) in California. The JPL, founded in 1944 for work with the Army Air Forces, was operated under contract for NASA by the

California Institute of Technology. JPL had more real identity as a "pocket of sovereignty" because of its independent role in supporting the Army and then NASA, and its unique academic affiliation.

The JPL reported to the NASA Headquarters Office of Space Sciences. It had major responsibilities for lunar and planetary exploration and in that role provided data that helped validate engineering models used for Apollo lunar module development. Through the Ranger and Surveyor programs, which it supervised, JPL provided information on Apollo lunar flight approach patterns and landing sites.[3]

In addition to JPL and an Electronics Research Facility established in Cambridge, Massachusetts, NASA established four post-Sputnik spaceflight centers. These included MSC, Goddard Space Flight Center, Marshall Space Flight Center, and Kennedy Space Center. These four centers were similar in that they tended to operate as development or operations centers while the older NACA centers, including Langley Research Center, continued their traditional concentration on research and technology studies. Goddard Space Flight Center and MSC retained a closer filial relationship with the centers of NACA extraction because of their Langley lineage. They, and especially the MSC scientists and engineers, revered the NACA laboratory-research heritage of autonomy and independence. Marshall Space Flight Center and, to a lesser extent, Kennedy Space Center came out of the military Department of Defense culture. They were more accustomed to working under a central authority and to "systems" approaches to management.[4]

Managing NASA and achieving program objectives not only involved problems of managing a large scale and physically scattered institution that rather suddenly sprang into being, but NASA's component parts were very unlike one another. The changing relations between MSC, Headquarters, and other NASA centers and the tensions which existed within the NASA organization reflected not only the diversity and culture of NASA, but the changing complexity of programs. Spaceflight was an intricate and highly interdependent business and became more so as programs developed through the Mercury, Gemini, and Apollo phases.

Manned spaceflight, initially almost solely the responsibility of the Space Task Group, became increasingly the collective responsibility of all NASA Centers with MSC, Goddard Space Flight Center, Kennedy Space Center, and Marshall Space Flight Center having lead roles. MSC managed the development of the spacecraft, Marshall had responsibility for launch vehicles, Goddard developed the tracking and monitoring networks and emphasized scientific instrumentation and operations for manned and unmanned programs, and Kennedy conducted launches and provided ground support for both manned and unmanned missions. Although center responsibilities became reasonably clear and well-defined by the mid-1960's, spaceflight programs required very careful interfacing and cooperation by the essentially autonomous NASA centers and their equally independent contractors.[5]

Each NASA center had a distinctly different style, personality, and approach to management and operations. They were staffed by civil service employees largely trained in the NACA concept of in-house design, development and testing or, in the case of Marshall and Kennedy personnel, they were accustomed to the arsenal-procurement style of management. The newer manned spaceflight centers had to redirect their efforts into the developmental and operations spheres, as well as to accept their primary role as managers of independent contractors who did the actual construction and fabrication—in contrast to the

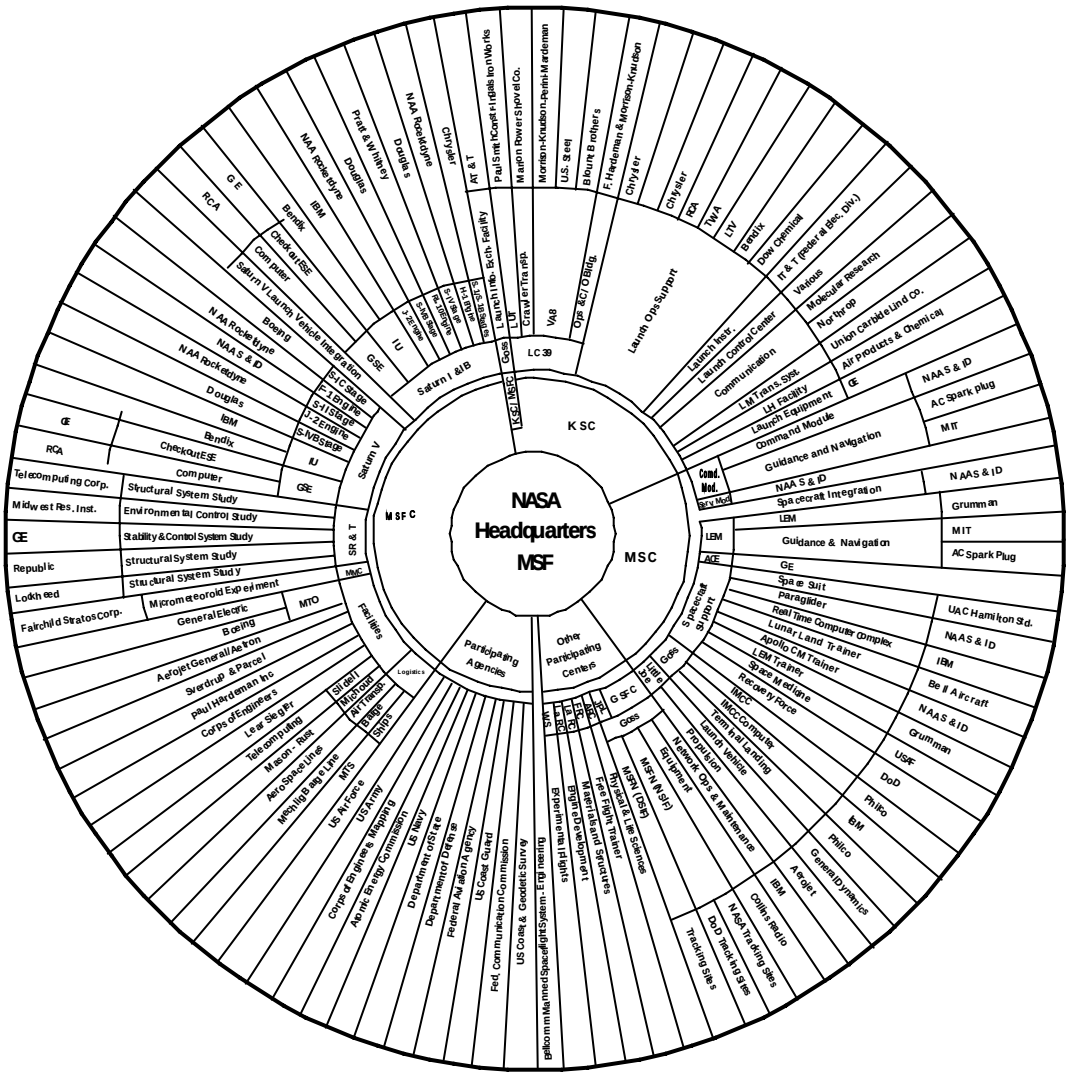
Langley in-house research and testing experience. But MSC personnel in particular sought to preserve the "hands-on" engineering associated with Langley, as well as the autonomy and independence consistent with NACA tradition. They, as did Langley engineers and scientists, tended to view themselves as part of a collegial association or federation. This perception contributed to stress between MSC, NASA Headquarters, and other NASA centers.

George Mueller, the Associate Administrator for Manned Space Flight, felt that MSC exhibited an unusually independent attitude, and indeed that the world view of each NASA center was startlingly different from that in NASA Headquarters. Headquarters constantly sought to bring the NASA centers under tighter central control. One such effort was the appointment of Edgar M. Cortright as Director of Langley Research Center in 1968. Some believed that Cortright's experience on the road to the directorship—specifically his project management work at NASA Headquarters—would bring about dramatic changes in the NACA style of "independent" management at Langley.[6] MSC, as a matter of perceived professional integrity and heritage, rather fiercely resisted Headquarters control—not because it was any less committed to the policies and programs established by NASA, but largely because MSC engineers believed that project management could not be separated from center-based technical capability.

There were, to be sure, other reasons for conflicts and stress. NASA engineers and managers, particularly those at the director and administrator levels, were people of great experience and considerable expertise, and by nature independent and competitive. Moreover, MSC attitudes of independence were bolstered in part by the perception that it emerged from the Space Task Group originally charged with the task of putting Americans in space. MSC regarded itself as the lead center in manned spaceflight activities, and looked upon other centers as suppliers and upon Headquarters as the funding agency. Thus, in the following government-industry functional matrix wheel representing the space consortium involved in the Apollo program (figure 7), one might substitute MSC at the hub in place of the NASA Headquarters Office of Manned Space Flight to properly see the program as it was seen in Houston.[7] Very likely the other centers had the same viewpoint.

NASA Headquarters established program goals and objectives, allocated resources (including budget procurement and distribution), and maintained critical interface with Congress, the executive offices, other government agencies, the scientific community and the public. NASA, as true of most large-scale businesses and multinational corporations, operated on the basis of delegation of authority and decentralized management. Administrator James Webb, in 1968, described the NASA management system as one of planned disequilibrium. For 10 years, he said, "we have been constantly seeking to prepare for and organize to meet substantive and administrative conditions which could not be foreseen. We have sought to avoid those concepts and practices which would result in so much organizational stability that maneuverability would be lost."[8]

Although there were pressures for greater central control, through its first several decades of existence a decentralized management style prevailed which seemed to best fit the need for the specific independent tasks being performed by the NASA centers. But this planned disequilibrium also meant fluid organizational dynamics and instability, themselves causes of stress. It also, perhaps, maintained an appropriate environment for the highly motivated, bright, aggressive, and competitive personalities of the NASA community.



Source: The Apollo Program Development Plan, Office of Manned Space Flight, January 15, 1965, Apollo Series, JSC History Office.

Figure 7. Apollo Program Government-Industry Functional Matrix

Although organizational structures (or the lack of them), programs, and Congress gave form to the NASA administrative system, individuals within the organization at every level made the system work. Thus, from Headquarters, Abe Silverstein and George Low interfaced with the Space Task Group and MSC during the Mercury years, and during the Gemini and Apollo programs, with George E. Mueller (who served both as Associate Administrator for

Manned Space Flight and Acting Director of the Gemini Program Office) and Samuel Phillips, whom Mueller made Apollo Program Manager with responsibility for planning schedules, budgets, and systems. Bob Gilruth, Director of MSC, with Kurt H. Debus, Director of the Kennedy Space Center, and Wernher von Braun, who directed the Marshall Space Flight Center, served on Mueller's Executive Council which met monthly. These people, with Administrator James Webb, and Deputy Administrator Robert C. Seamans, Jr., set the tone of relations between NASA Headquarters and the centers for the years between 1964 and 1968 when Gemini closed and Apollo made its debut.

Arnold S. Levine (*Managing NASA in the Apollo Era*) credits George Mueller with the administrative changes at Headquarters and within the manned spaceflight centers that resolved the management crises precipitated by Brainerd Holmes' efforts to centralize Apollo program management. Tensions between Headquarters and MSC in particular affected NASA management well into the 1970's. Mueller, however, "restructured the Apollo program so that every functional element at the Headquarters program office had a corresponding element in the center project office." This facilitated a liaison and promoted cooperation without imposing hierarchical direction and control by NASA Headquarters over the centers. For each of the major systems, Mueller made one person singly responsible for performance, costs, and schedules. That person "defended his programs before top management and Congress, set and interpreted policy with his program managers and center directors, and set the terms on which long-range planning would proceed."[9]

Mueller joined NASA in November 1963, upon the departure of Brainerd Holmes, and by the end of 1964 effectually completed the reorganization of the Manned Space Flight Office. A native of St. Louis, Missouri, Mueller received a bachelor of science degree in electrical engineering from the Missouri School of Mines and earned a master of science degree at Purdue University before joining the Bell Telephone Laboratories where he continued research on video amplifiers, television links, and microwave research. He pioneered in work on the measurement of radio energy from the sun, microwave propagation through gases, and the design of low-field magnetrons. In 1946, Mueller joined the faculty of Ohio State University as assistant professor of engineering, where he also continued graduate studies and completed his Ph.D. in physics in 1951. Prior to joining NASA, Mueller spent 5 years with Space Technology Laboratories, Inc. of Redondo Beach, California, serving as Vice President for Space Systems Management and Vice President for Research and Development.[10]

When he arrived at NASA, Mueller's experience in the laboratory and in the commercial side of the space business gave him valuable insights into the management problem. He set about, he said, trying to convince Wernher von Braun at the Marshall Space Flight Center to implement a systems engineering approach. The design and construction of booster engines, manned spacecraft, and electronic guidance systems involved distinctive tasks and products that had to be fitted after they were built. Systems engineering required a strict interface control system. What he wanted, Mueller said years later, was to meld the traditional research strengths of NACA, with the technical know-how of Marshall and the MSC STG experiences. He inserted a "program management system in parallel with the functional systems" and set up what he called a "5-box" management structure which provided for direct communications between like disciplines.[11] Thus many parallel lines of communication existed between

Headquarters and the centers, and between the centers. As Aleck Bond and Jerry Hammack put it, a division head or anyone else could (and did) pick up a telephone and call their counterpart about a problem anywhere in the NASA organization.[12] Spaceflight was a team operation. The team was far-flung and disparate, and communications between them was essential.

Mueller also provided critical liaison between NASA and Congress and between NASA and its contractors. He organized the Apollo Executives Committee, comprising corporate Chief Executive Officers (CEOs) or their representatives who were Apollo contractors. The committee met periodically to keep the contractors apprised of overall program progress, to review problems, and to better develop systems engineering approaches. We worked "quite openly" with our contractors, Mueller said. The committee provided an invaluable and more informal link with the contractors than existed at the center level where relationships were largely defined by the contract. Mueller said in 1989 he did not think it would be any longer possible to create such a body. Legal constraints in the contracting process and changing relationships between NASA and its contractors preclude the close, personal cooperation of earlier days.[13]

It was particularly imperative, Mueller said, that close relations be maintained with Congress. He personally met frequently with the House Science and Astronautics Committee, and monthly with Olin E. Teague and the Manned Space Flight Subcommittee. Teague, as mentioned earlier, took a strong and personal interest in the space program and became an invaluable congressional ally for NASA. Teague and other members of Congress relied heavily on the work of William E. Lilly, who worked under Mueller as the Manned Space Flight Program Control Officer. Bill Lilly supervised program planning, costs, and schedules, and had responsibility for the management of resources and facilities. He was, in effect, comptroller for the Apollo program and highly respected on Capitol Hill. When Lilly gave a figure, it was reliable. Although first impressions suggested that he was somewhat rough or coarse, he made highly polished presentations. Moreover, he was a strategic conduit between lower-level managers at a center and Headquarters who responded to calls for help from individuals stuck with a cost that their own institution could not readily absorb. Oran Nicks, who worked at NASA Headquarters, called Bill Lilly the "unsung Godfather" in Washington of MSC. Nicks also described Mueller as an indefatigable manager who dressed like a math professor and often carried the day in meetings by his perseverance.[14]

As the human spaceflight program shifted from the Gemini to the Apollo program, Sam Phillips became a major conduit between Washington and MSC. His counterpart in Houston was George Low, who had long experience in Washington with Abe Silverstein. The Phillips/Washington—Low/Houston connection proved exceptionally providential. Phillips and Low were enormously respected at every level. Phillips had been manager of the Air Force Minuteman program and Vice Commander of the Air Force Ballistic Missile Division before being detailed to NASA in 1963. Mueller assigned Phillips responsibility for Apollo planning, budgets, systems engineering and "other functions needed to carry out the program." Center Apollo program offices, prime contractors, and special intercenter coordination panels reported to Phillips. Phillips traveled extensively to the centers. He provided strong technical direction, was very conscientious ("dropping in on every detailee" at the Houston center for example) and, according to some MSC engineers who worked with him, "kept George Mueller (who was inclined to go off in every direction) straight."[15]

Kenneth Kleinknecht said that Phillips had a "tremendous understanding of the way to manage and direct a program from the Headquarters level," but he thought that as time passed, the Washington office became too involved in too much detail. For example, MSC's Mission Operations Director, Chris Kraft, had to specifically forbid the Headquarter's Mission Director from intervening in Mission Control Center flight operations during Gemini flights. That individual had the nominal authority but not the experience, practice, and training with the Mission Control team to direct flight operations. Headquarters' job, Kleinknecht said (probably reflecting the view of most of the centers), should be to "sell the program, get the money, and let us do it."[16] With only a few exceptions that generally reflected Headquarters' management philosophy during the Mercury and Gemini programs.

By the end of 1964, Sam Phillips, working with Mueller, the three spaceflight center directors, and other staff officers at Headquarters, developed a comprehensive "Apollo Program Development Plan," which established basic organizational guidelines for the program throughout its existence. The Mercury program, according to these guidelines, "established man's ability to perform effectively in the environment of orbital flight" and developed the foundation for manned spaceflight technology. Through Gemini, they stated, "we would gain operation proficiency and develop new techniques, including rendezvous." Apollo seeks to achieve "preeminence in space and to develop the ability to explore the Moon and return safely to Earth before the end of this decade."[17]

Apollo mission planning envisioned three flight phases including unmanned suborbital and Earth-orbital flights, manned Earth-orbital and long-duration and Earth-orbital-rendezvous flights, and manned lunar flights. The first Saturn IB flight was scheduled for 1966, with manned IB flights in 1967 and unmanned Saturn flights the same year. The next year, 1968, the Saturn V was to be used for manned Earth-orbital flights, followed in 1969 by manned lunar orbit and lunar landing flights. The plan specified that the Marshall Space Flight Center held responsibility for developing the Saturn I, Saturn IB, and Saturn V launch vehicles and engines and providing associated ground support equipment and flight operations support. MSC had responsibility for the Apollo spacecraft with ground and mission support, and Kennedy Space Center was responsible for launch and facilities.[18]

"A large segment of the United States industrial base is required to support NASA in accomplishing these responsibilities," the plan acknowledged. The government-industry functional matrix, mentioned earlier (figure 7) provides a visual representation of the magnitude of the Apollo program. The plan specified that "Whenever possible, matters of mutual concern are resolved by direct communication between participating organizations." When those agreements or concerns affected other centers, they had to be informed. Phillips created 8 standing Intercenter Coordination Panels and 15 subpanels reporting to a Panel Review Board chaired by Phillips. An Executive Secretariat composed of the chairman from the Office of Manned Space Flight and representatives of each of the three field centers set the agenda and meetings of the Panel Review Board and implemented decisions of the board. The Apollo plan also attempted to relate other unmanned space programs, such as the Ranger lunar survey, Surveyor lunar landing surveys, and Lunar Orbiter, to the completion of the Apollo missions.[19] Overall, Phillips' 1965 document offered a clear, comprehensible, and feasible action plan for the Apollo program. Phillips worked very hard to implement those plans.

So did the center directorates and program managers, such as George Low in Houston, who (after the Apollo 204 fire) was the primary interface with Phillips in the Headquarters' Apollo Program Office. Low went to Headquarters with Abe Silverstein in 1958 with a number of other Lewis engineers, including Edgar M. Cortright, William (Bill) Fleming, John Sloop, John H. Disher, DeMarquis D. Wyatt and Warren J. North. There were, in fact, so many Lewis engineers who served on the NASA Headquarters staff that it is appropriate to suggest that one of the great and most direct contributions of the Lewis Research Center to the manned spaceflight program was its pool of managing engineers who staffed the Headquarters program offices.[20] NASA engineers in Houston counted George Low, who came to their center as Deputy Center Director and later as Apollo Spacecraft Manager, among their most esteemed colleagues.

Aleck C. Bond, who managed Systems Test and Evaluation at MSC, worked hand in glove with Low. Low was a "human dynamo," he said, who got up at 5:30 in the morning and jogged, was in his office by 6:30 or 7:00, and kept three secretaries busy all the time. Jerry Hammack, Deputy Manager of Vehicles and Missions in the Gemini Project Office, who regularly put in 12-hour days at the center, remembered seeing Low's little white Ford Mustang in the parking lot when he arrived and there when he left in the evening. They, and most who worked with him, remember George Low as the man who could cut through red tape, maintain good rapport, and get things done. Self-effacing, he always had time to commend others for their work and provided inspiration to all who worked with him.[21] In November 1969, when James Webb turned over the Administrator's job to Thomas O. Paine, Low returned to Headquarters as NASA's Deputy Administrator, and became Acting Administrator upon Paine's resignation.

Low's technical skills related largely to aerodynamic laminar flow and boundary layers, but his management skills were "people" skills. He, with Phillips, helped maintain a generally cordial and cooperative mode with Washington. But MSC managers strongly resisted technical control of projects by Headquarters, and were perhaps even more jealous of their functional offices such as Public Affairs. For example, when the first Apollo orbital missions (Apollo 7 and 8) began to attract tremendous public attention, Julian Scheer (Assistant Administrator for Public Affairs at Headquarters) instructed Paul Haney, the public affairs officer at MSC, that NASA Headquarters would produce the Apollo 8 film rather than it being done in Houston as had been true on all previous flights. The MSC response was: "Your arrangement is unacceptable to this center. We intend to handle film as we have in the past, and have issued instructions to this effect. Your office is receiving a copy of the instructions."[22] George Mueller responded directly to Bob Gilruth agreeing to MSC film management and requesting that the center deliver copies of processed film to the Public Information Officer and the Office of Manned Space Flight in Washington 24 hours after processing, "with whatever release restrictions you may desire to impose."[23]

Although relations between Headquarters and MSC could sometimes be strained, they could be downright difficult between Marshall Space Flight Center and MSC. No two NASA centers were at once so interdependent in terms of their technical work and so independent in terms of their spirit as were MSC and the Marshall Space Flight Center. One built the spacecraft, the other built the engines that made it fly. The interface between MSC and Marshall became much more critical and complex as NASA's programs expanded from

Gemini to Apollo. The MSC was the lead center for Mercury and Gemini and operated under a relatively small and close-knit Headquarters organization, George Low said later. Until Apollo, MSC, Low commented, "had been clearly in charge not only of the spacecraft but also the launch vehicle and the flight operations." Marshall, in other words, first related to MSC more as a supplier than a partner. Moreover, the Redstone-Agena rocket, Kenneth Kleinknecht said, involved much simpler functional interface and required less contact and cooperation between the centers. Apollo, however, changed that because the Saturn rockets and the space vehicle were of an integrated design. Thus the changing nature of NASA space programs helps explain the changing relationship between MSC, Marshall, Headquarters, and the space community.[24]

Marshall and MSC worked on the same team and aspired to the same goals. Both accepted their roles as members of the NASA family, but as Kleinknecht explained, being "brothers" in the same family created special kinds of problems:

> . . . you start working with your brother—sometimes it's harder than working with a neighbor, and that's kind of like what I think we've been through with Marshall. Even the fact that everybody became so dedicated to this program as a national goal maybe made it a little difficult. Everybody was trying harder—worked long hours and always thinking of what we can do to make it better, regardless of whose hardware it was.[25]

It was an institutional form of sibling rivalry—basically healthy and often productive, but frequently annoying.

Although the two centers might be considered "brothers" in the NASA family, they had somewhat different parentage which contributed a bit to internecine strife. The MSC culture came through its NACA/Langley origins. The Marshall Space Flight Center evolved from the Army Ballistic Missile Agency (ABMA) which in a very real sense was uprooted and transferred from Germany's World War II Peenemünde rocket group headed by the irrepressible Wernher von Braun. In the minds of most MSC engineers, Von Braun defined the personality of Marshall and its relations to MSC. The two centers held something of the traditional "brotherly" love-hate relationship. Marshall seemed to demand both caution and a defensive position by MSC engineers on the one hand, and respect and admiration on the other.

MSC's perception of itself as NASA's "lead center" irritated Marshall engineers who prided themselves on being the real pioneers in spaceflight. Von Braun and his colleagues regarded their rocket developments for the German military as an expediency by which they could "indulge in spaceflight operations." Marshall engineers resented their initial role with the ABMA as a supplier or subcontractor to NASA. They regarded NACA and NASA as "an old stodgy short-sighted research organization that kind of got into the spaceflight game politically." There had always been "this background of resentment between ABMA and the Space Task Group, and then between Marshall and MSC," Paul Purser, Gilruth's special assistant observed.[26]

In some respects the modern space age began not with the launch of Sputnik, but rather with the launch of the German V-2 rockets by Von Braun's group at Peenemünde. I.B. Holley, Jr., then an Air Force officer stationed at Wright Field, recalled many years later having attended a meeting shortly after V-E day for a report on the status of German research and

development. "Among other things," he said, "the speaker told us about uncovering German plans for establishing stations in space from which to bomb the United States. The idea seemed so farfetched, so impossible, that a roar of laughter swept through the hall." But it was the Germans, he said, who conceptualized the reality of space; it was we who, with the critical assistance of the Von Braun group, "picked up the ball and ran with it." Holley closed his remarks with the story of a Russian cosmonaut and an American astronaut who on passing each other in space, spoke to each other only in their native languages. Finally one blurted out, "Why don't we cut out this nonsense and speak German?"[27]

The philosophical or cultural differences between the two centers were aggravated by the contrast in the style of management and operation. Von Braun, Purser said, "ran his organization at Marshall with an iron hand and nothing was ever decided there without holding a big committee meeting over which Wernher presided and made the final decision. . . . Gilruth, on the other hand, worked closely with his people and tended to delegate more authority and responsibility to individuals . . ."[28] Purser, who helped establish the initial relationship between the Space Task Group and the ABMA, believed that he and Wernher von Braun developed a mutual respect and friendship.

Purser worked hard, but without considerable effect, to improve the personal relationships between Gilruth and Von Braun. But they were two markedly different personalities. Von Braun, Purser said, had a tendency to "run off at the mouth," while Gilruth always waited until there was a break in the conversation. With Von Braun around, there was never a break in the conversation. And Von Braun inadvertently offended Gilruth on a number of occasions. For example, on one occasion, Purser recalled, Von Braun wrote Gilruth a very condescending letter noting that it was the duty of a teammate to tell a fellow teammate when one of his shoelaces was untied. He warned Bob Gilruth that one of his shoelaces was untied—that being a poor job of wiring done by one of his contractors. On another occasion, Von Braun gave Gilruth a 4-hour harangue about MSC planning to use the Agena rocket in the Gemini program without first consulting Marshall. Later, Purser protested to Jack Keuttner that Von Braun's raving coupled with Marshall's independent proposal to Headquarters for Marshall to head a program for an orbiting laboratory—without consulting MSC—did not help intercenter relationships "one damn bit." Von Braun, Purser said, was unaware of the Marshall proposal and had "lost control of his troops," and when he found out he was at fault he apologized profusely to Gilruth.[29]

Although personal relationships remained cool, the two centers did cooperate and direct intercenter contacts were maintained by the engineers of each center. And most of the MSC engineers retained a genuine respect for Wernher von Braun and Marshall personnel, mixed with a proper dose of caution. Ken Kleinknecht said that Von Braun was a supersalesman. "Wernher," he said, "could sell refrigerators to the Eskimos and even after they had them for 6 months they still wouldn't be mad at him, when they found out they didn't need them." He credited Von Braun with being better known in the space business than anyone else other than perhaps the astronauts, and with having been a significant contributor to the American manned space effort. Before Sputnik, Max Faget said, Von Braun proposed to put an American as a payload on a Redstone rocket for a 5-minute experience of weightlessness. He concurred that Von Braun's spaceflight planning preceded Sputnik and NASA.[30]

The ABMA, which became the core of Marshall, played a largely peripheral role in the Mercury program. "We had a minimum amount of intercourse with Marshall," Bob Gilruth commented. "They did produce the Redstone rocket for us in connection with the suborbital flights of Mercury." But, he added, "we had more than our share of difficulty in working out arrangements with them." Marshall, he said, wanted MSC to send its capsules to Marshall for integration with the launch systems, and Gilruth would not agree to that. He added that "we flew four Mercury spacecraft on the Redstone."[31]

Titan II rockets, used as the Gemini booster, were being developed by the Air Force and its contractors to deliver warheads. Even while vigorously continuing its own missile program, the Air Force reconfigured and man-rated the Titan II rockets for use by NASA's Gemini program. Marshall's role in the Gemini program largely related to intermittent consideration of the use of Agena or even Saturn rockets in the Gemini stack, but Marshall did play a peripheral role in Gemini, rather than having "no part" as Bob Gilruth said.[32]

The Apollo spacecraft, managed by MSC, however, required close cooperation and integration with the Saturn systems being developed by Marshall. Apollo employed multistage Saturn launch vehicles built by different contractors under Marshall supervision, interfacing with the command modules and lunar modules developed under MSC direction. Marshall had a major part in the Apollo program. Marshall accomplished a technical tour de force in the development of the Saturn rocket used to boost the Apollo spacecraft. Unlike for Mercury and Gemini programs, Headquarters provided the interface between Marshall and MSC. As Gilruth noted, during Apollo "the relationships aren't so much between centers now as they are between centers and Headquarters. We now have good relations with MSFC."[33]

What happened is, as George Low indicated, the role of MSC in the Apollo program changed considerably from its role in Mercury and Gemini. "In Apollo, MSC was to be a third and equal partner (with Kennedy and Marshall) under an overall Headquarters Program Office, whereas for Mercury and Gemini, MSC had been a lead center with a relatively weak Headquarters organization." Thus, the initial reorganization of NASA administrative systems under Brainerd Holmes and the establishment of the Office of Manned Space Flight was an attempt to provide centralized direction for the Apollo program with each "lead" center, including Marshall, MSC, and Kennedy Space Center, having its own assigned portion of the program. Holmes' problem, Low believed, was simply that he tried to manage too much of the technical detail from Headquarters. When Joe Shea, who headed the Apollo Program Office, with the technical support of BellComm (Headquarters' contractor management team), began to assume responsibility for the technical decisions in spacecraft development, design, systems engineering and mission operations, "in fact, all the things for which MSC had prime responsibility," it quickly became clear that this kind of effort from Headquarters, directed by people who did not have the experience that the people in MSC had and who were unaware of MSC's independent spirit and rather unique culture "would not and could not work."[34]

Thus, as mentioned earlier, Brainerd Holmes left the Office of Manned Space Flight in 1963, a casualty, in a sense, of the friction generated by efforts to centralize program management. At this point, George Mueller and Sam Phillips, working through such experienced program managers as George Low in Houston, reestablished a more balanced management system that reinstated the basic integrity and autonomy of each Apollo lead center while imposing greater control and surveillance by Headquarters.

Intercenter difficulties and rivalries, continued, however, particularly those between Marshall and MSC. For 2 years before 1967, Faget said, the Marshall center had tried to "get a piece of the spacecraft" and was at work on manned orbital workstations. George Mueller, he said, was giving Marshall "more and more license" in the spaceflight business.[35] In 1965 Houstonians became concerned that Marshall was attempting to usurp the programs and responsibilities of MSC and move programs and personnel to Huntsville, Alabama.

In October 1965, a *Houston Post* story mentioned that Marshall might assume control of the forthcoming Apollo Applications Programs that would extend Apollo work into areas other than the lunar flights. One year later, the *Houston Post* front-paged an article under the ominous title: "Von Braun a Persuasive Voice: Some MSC Tasks Being Moved," with the lead sentence reading, "Some of the work that should be done at the MSC is being steadily transferred, with as little publicity as possible, to the Marshall Space Flight Center in Huntsville, Alabama." With the last flight of Gemini scheduled for November 9, 1966, and the first manned Apollo flight scheduled for December 5, Jim Maloney, the journalist in the story, commented, now "MSC's responsibilities are being diluted." The Marshall Center, Maloney suggested, had run out of things to do just when the acceleration of the war in Vietnam made money for new projects more difficult to come by; so Marshall "officials" had sold NASA the idea that the basic Marshall scientific and engineering organization needed to be maintained as a group. As a result, Apollo Applications Program, that is the use of Apollo hardware and systems for other than Moon trips, was to be assigned to Marshall.[36]

Maloney argued that the completion of Saturn V, scheduled for launch in 1966, marked the end of the road for Marshall, until NASA decided that Marshall should help out with Apollo spacecraft work. And, he said, MSC officials made no fuss of this decision. "None at all. MSC will have plenty of work, MSC officials said." This was a major MSC responsibility, the *Post* reported, that was slipping away to the Marshall Space Flight Center.[37]

There followed some frenetic activity after the *Post*'s revelations of a transfer of programs to Huntsville. A NASA release, dated October 16, 1966, stated that contrary to the information contained in the *Post* article of October 10, "no work has been transferred from the MSC, Houston, Texas. In fact, 200 positions were transferred during this last year from the Marshall Space Flight Center, Huntsville, Alabama, to the MSC in Houston to provide for the buildup of personnel necessary for the Apollo launch control facilities." The article in the *Post*, according to the unsigned NASA memorandum, "does not deal in substantive fact and attempts to establish a case for movement of work from the MSC on the basis of unfounded opinion."[38]

The Houston public and Texas Congressmen remained unconvinced and concerned. Olin "Tiger" Teague wrote William P. Hobby, Jr., President and Executive Editor of the *Houston Post* and Teague's friend, on October 17, suggesting that the *Post* might be "crying wolf." On October 19, George Mueller wrote Teague, who chaired the Subcommittee on Manned Space Flight, to the effect that no MSC projects were being transferred to Marshall, but on the contrary 200 civil service personnel were transferred from Marshall to MSC during the past year. The project relating to the Apollo Telescope Mount, he said, dealt with experiments and not with spacecraft development, and MSFC would develop "Experiment modules designed primarily for astronomical experiments." The mission of MSC continued to include vehicle development, life support systems, astronaut activities, flight operations,

medical research and operations, and lunar surface scientific activities, he added. The Kennedy Space Center, he said, will continue to be responsible for launch operations and support.[39] Although it continued to be debated in Congress and within NASA, overlapping program responsibilities, like system redundancies, provided a degree of quality control and engineering alternatives. There were different ways to solve the same problem.

Hobby responded to Teague in early November that the NASA Memorandum sent by Teague tended to substantiate rather than refute the *Post*'s concerns that "responsibility for the development of spacecraft for post-Apollo uses is being shifted to Marshall." Teague took Bill Hobby to task a few days later, saying:

> Bill, every person with whom I talk and who are connected with NASA are glad and happy they moved to Houston. As an example, at Cape Kennedy, Astronaut Cernan came over to me and said, "I just want to tell you how much we enjoy Houston, Texas." On a plane from Ellington Field to Cape Kennedy, Bob Gilruth, George Low and Chris Kraft started a discussion of how pleased they were to be in Houston. I know that we can trust these people and I know that we can trust Dr. George Mueller.

And he added, "I don't believe there is any more of a chance of downgrading the Houston Center than there is of my being one of those going to the Moon."[40] The incident was not the first time that a Texas delegation or constituency rushed to defend MSC (and local interests) from a threatened diminution of programs, funding, or personnel, nor certainly would it be the last.

Although "Tiger" Teague might never make it to the Moon, with the successful completion of the Gemini flights in November 1966 and the launch of two unmanned Apollo craft earlier in the year, the Moon now seemed appreciably more accessible than it had been since the beginning of the manned space program. The first Apollo-Saturn launch was made from the Kennedy Space Center on Cape Kennedy on February 5, 1966. The "stack" began with a Saturn IB first stage, having eight H-1 engines built by Rocketdyne that produced 1.6 million pounds of thrust. The second (S-IVB) booster stage built by Douglas Aircraft featured a single Rocketdyne J-2 engine to which was attached the launch vehicle adapter, service module and command module, headed by the pylon-shaped launch escape tower constructed by North American. Bad weather forced a halt in the launch countdown, but after a 5-day delay, the countdown was resumed on February 25. Only 3 seconds before ignition, falling pressure in two helium spheres on the Saturn forced another delay until, finally, on February 26, 1966, the first successful launch of the assembled Apollo-Saturn system sent the unmanned command module on a 37-minute downrange flight. There were some minor malfunctions, but the system worked.[41] AS-201 marked a significant step forward for the manned lunar landing mission.

The launch of AS-201 was organizationally a much more complex thing than the launches of previous Mercury or Gemini missions. In 1960, when NASA's Space Task Group representatives, G. Merritt Preston and Scott Simpkinson arrived at "Hangar S" at Cape Canaveral, they were given work stations in a janitor's closet. Gilruth recalled how "shocked and disgusted Scott Simpkinson was at the time." Within 2 years, however, the group occupied the entire hangar and a newly constructed engineering building that adjoined the hangar.

Throughout the Mercury flights, MSC had its own launch directors and personnel at the Cape. Relations with the Florida center, Gilruth said, "were quite good."[42]

The launch facilities at Cape Canaveral included the Air Force Missile Test Center, the Space Task Group's launch team, and the Army's Missile Firing Laboratory, originally established in 1952 and transferred in 1956 to the command of the ABMA at Redstone Arsenal, Alabama. The laboratory operated the launch facilities used for the Redstone and Jupiter rockets. Wernher von Braun directed the technical work of the Army's agency, when General J.B. Medaris was in command. Dr. Kurt Debus, one of Von Braun's engineers who fled with him to the west after Germany's collapse, reported to Von Braun for the work at the launch facility. Debus received degrees from Darmstadt University in mechanical and electrical engineering, a dueling scar on his left cheek, a doctorate in 1939, and an appointment as assistant professor at the university the same year.[43]

AS-201 liftoff, Cape Kennedy, Florida, on February 26, 1966. This unmanned flight marked the first flight of the Saturn IB first stage and Saturn IVB second stage, and the first flight of an Apollo production command and service module. The Apollo 009 spacecraft was retrieved 5000 miles downrange in the Atlantic Ocean near Ascension Island.

When NASA acquired most of the personnel and properties of the ABMA and its Missile Firing Laboratory on Cape Canaveral, the launch facility became the Launch Operations Directorate under Marshall. Debus continued to direct the manned flight portion of Cape operations, while unmanned launches were handled by a Goddard team.

On March 7, 1962, NASA separated the launch facility from Marshall and organized it as a Launch Operations Directorate under Debus. The launch facility became a separate Launch Operations Center in July 1962. For the continuation of Mercury flights and through the Gemini program, the Launch Operations Center at Cape Canaveral remained directly responsive to MSC and interfaced with MSC through such individuals as Merritt Preston and Walter J. Kapryan, who became launch director in 1969. Preston became launch operations director for the Gemini program and his STG/ MSC group, permanently assigned

to Kennedy Space Center (as it was redesignated in 1964 after President John F. Kennedy's assassination) became the center's Operations Directorate.[44]

During all Gemini launches, MSC retained a tangible presence at Kennedy in the form of old STG personnel who had been reattached to Kennedy. Despite the overriding presence of Debus and the Army/Von Braun legacy and the earlier "janitor closet" confrontation, relations between Kennedy Space Center and MSC were generally cordial. During Mercury and Gemini flights, business tended to be conducted directly between the centers, rather than through Headquarters, but the Apollo program invoked more formal relations through the appropriate office at Headquarters. For whatever reasons, but likely because of the early infusion of MSC/STG personnel into the Cape Canaveral launch center, harmony and cooperation generally prevailed between MSC and Kennedy Space Center.

Donald K. "Deke" Slayton, Director of Flight Crew Operations, and George M. Low, MSC Deputy Director, relax during the AS-202 unmanned flight in August 1966. On April 10, 1967, George M. Low became Apollo Spacecraft Program Manager.

The year 1966, when Apollo-Saturn 201 made its maiden flight, was packed with activity at the Cape. In March after the AS-201 launch, Gemini 8 carrying Neil Armstrong and David Scott was lofted. Gemini 9 followed in June. On July 5, the launch team fired AS-203, an Apollo-Saturn launch without a payload. The flight was intended to study liquid-hydrogen fuel behavior in a weightless environment, and to determine if the third S-IVB rocket stage would retain enough fuel to boost the command module and lunar module into a lunar obit. Engineers decided that it could indeed. Within 2 weeks, Kennedy launched Gemini 10 into a 72-hour Earth-orbital mission; and a month later, on August 25, fired another unmanned Apollo-Saturn system into orbit. This, the AS-202 (originally scheduled to precede AS-203), tested engine firing sequences and the reentry performance of the capsule and heat shield. The final two Gemini craft flew respectively on September 12 and November 11.[45]

NASA now planned to launch its first manned Apollo craft (AS-204) before the end of 1966. But the intensive training of astronauts Gus Grissom, Edward White, and Roger Chaffee, under the supervision of Deke Slayton, was hampered by constant modifications to the command module, which meant that the mission simulator and training procedures constantly required revisions. Moreover, North American (which merged with Rockwell in

AS-204 astronauts Edward Higgins White II, Virgil Ivan "Gus" Grissom, and Roger Bruce Chaffee died when an oxygen-enriched fire swept the interior of the spacecraft during preflight tests at Cape Kennedy on January 27, 1967.

1967) was experiencing production problems with the command module, which was finally shipped to Kennedy Space Center in August but in a state that required considerable engineering work to make it flight-ready. The 012 service module associated with the capsule for the flight was held up for inspection when a similar unit (017) exploded at the factory. By the time these problems were resolved, the AS-204 flight was rescheduled for February 1967.[46]

A launch simulation preparatory to the actual launch was scheduled for January 27. Shortly after noon Grissom, White and Chaffee were in the module on top of the Saturn IB, some 25 or 30 engineers and technicians were in the launch tower adjoining the capsule, and another 1000 technicians, engineers and ground crew were assisting in the launch simulation. The astronauts began removing all gases except oxygen from their space suits and the cabin, as was the standard procedure for all previous Gemini and scheduled Apollo flights. Finally, the cabin pressure stood at 16.7 pounds per square inch of pure oxygen, and the long tests of equipment and procedures continued, with interruptions, long into the afternoon. At 6:30 p.m. someone in the command module cried over the radio circuit, "There is a fire in here!" Within moments the cabin was engulfed in a flash fire of pure oxygen, and the three astronauts were dead of asphyxiation.[47] It was the worst moment up to that time in the history of the manned space program.

The AS-204 fire and the death of the astronauts was a great tragedy and felt personally throughout MSC, Kennedy, Marshall and NASA. "It shouldn't have happened," George Low said later, "it could have happened in Mercury or Gemini, but it didn't." Administrator Webb appointed a Review Board chaired by Floyd L. Thompson and including Frank Borman and Max Faget of MSC and representatives of other centers, the President's Science Advisory Council, and others outside of government. NASA asked Congress to delay a full-scale congressional investigation until the Review Board submitted a report, which Congress agreed to do. The press insisted on public hearings, wanted more direct access to information, and suspected a "cover-up." The Review Board literally presided over the dismantling and review of every component in the cabin and each procedure relating to launch. Information was released to the public in what the press regarded as "small doses" but which NASA declared to be all that was really available—which could have been the case. Investigations were slow but thorough. By April a summary report concluded that conditions leading to the fire included having a sealed cabin with a pressurized oxygen atmosphere, extensive combustible materials within the cabin, vulnerable electrical wiring, plumbing containing a combustible and corrosive coolant, a hatch that could not be opened quickly for escape, and inadequate provisions on the launch site for rescue or medical assistance. The final report was compiled in 3000 pages and 14 booklets.[48]

An independent report by North American employee Thomas R. Baron, who had been fired by the company on January 5 before the fire, implied gross negligence on the part of the contractors and others, but in hearings before Olin Teague's subcommittee, none of the allegations could be supported. Baron and his family died in a car-train crash only a week after the congressional hearings. It did become clear, however, that a General Electric official had warned Joseph F. Shea, MSC's Apollo Program Manager, about the possibilities of fire in the spacecraft before launch, and MSC Medical Director Charles Berry had expressed concern about flammable materials in the pure oxygen environment of the spacecraft.[49] Many Americans, within and outside the government, wondered if the disaster might have a long-term adverse effect on spaceflight and even bring the program to an end.

Already the growing preoccupation with the war in Vietnam and rising government deficits occasioned by that war and by President Johnson's expensive Social Security, Medicare, and War on Poverty programs were contributing to purse tightening by Congress and to a rising disaffection or at least a disinterest in space by the American public. Olin Teague, for example, as a Congressman closely involved with the space program and a vigorous supporter of MSC in Houston, was extremely interested in the repercussions of the Apollo tragedy. One measure of the public pulse was given him the day after the fire by a radio talk show commentator, Lou Martin with station WTOP in Washington, D.C., who took a quick poll of his listeners as to whether the space program should be continued. Of the 59 people who got through on the telephone in his 15-minute time allotment, 70 percent advised either continuing the program at its present level or accelerating the program. Only nine callers suggested curtailing the space effort, and another nine thought it should be abandoned completely.[50]

Despite considerable public contention (and rather remarkably when compared to the aftermath of the *Challenger* accident in 1986), the tragic fire created a new resolve within the NASA establishment and concurrent support from Congress, the Executive and the public.

George Low, among many others at MSC, regarded the fire as a turning point in the entire space program. In January 1969, Low said "the reexamination of Apollo that came as an aftermath of the fire required us to build a different Apollo spacecraft," and most importantly, he added, "it created an entirely different atmosphere among ourselves, our contractors, and within MSC."[51]

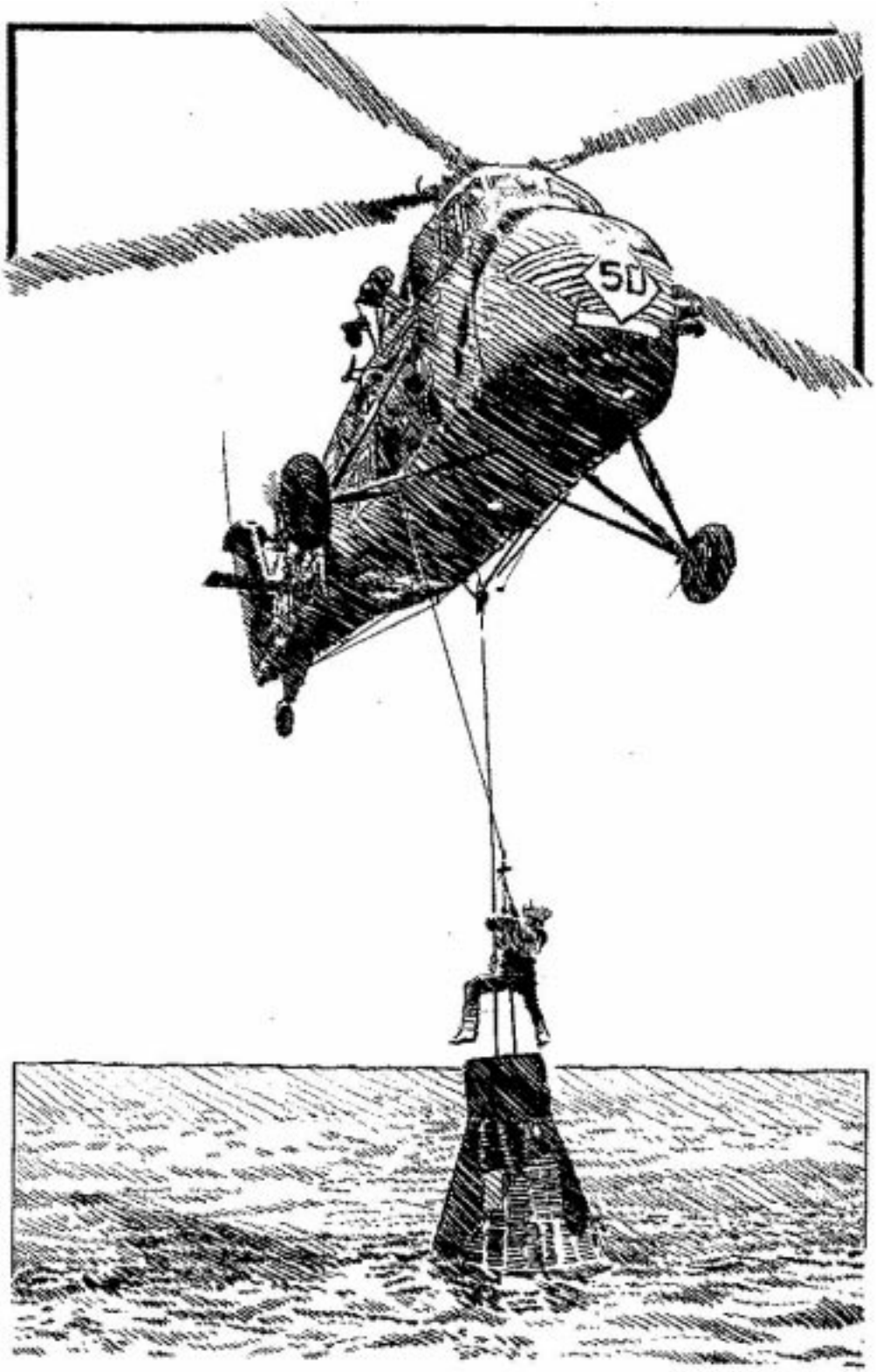
Among the immediate repercussions of the Apollo fire was the resignation of Joseph Shea, who was personally devastated by the accident, as Apollo Program Manager at MSC. George Low stepped from the Deputy Director's seat into that chair. Gilruth appointed a "tiger team," including Frank Borman, Douglas Broome, Aaron Cohen, Jerry W. Craig, Richard E. Lindeman, and Scott H. Simpkinson to visit the North American plant in Downey, California, and review production systems and techniques. North American, in turn, replaced its president of the Space and Information Systems Division with William D. Bergen, formerly of Martin Marietta. Bergen's role, with his managers Bastian Hello stationed at Kennedy Space Center and John P. Healy who was to supervise the Block II module production at Downey, was to improve quality, safety, and production review procedures, and to eliminate the problems existing or anticipated by the Review Board. Grumman Aircraft, responsible for the lunar excursion module, intensified its review and quality control processes with the assistance of Richard S. Johnston, an MSC materials expert. All levels in the spacecraft production chain conducted careful reviews of materials being used in the modules.[52]

Max Faget's Engineering and Development Directorate launched a multifaceted testing and evaluation program, headed by Aleck Bond, directed at understanding in detail the characteristics of the Apollo 204 fire and toward the development and evaluation of an array of new and improved fireproof or flame-retardant materials. Joseph Kotanchik's Structures and Mechanics Division conducted in situ fire tests employing Apollo boilerplate command modules, using first the old and then the new materials. Richard S. Johnston, chief of the Crew Systems Division, tested and helped develop nonmetallic materials such as Beta cloth, flame-retardant velcro and other materials that were upgraded and improved for fire safety.[53]

Bond and his team directed tests in MSC stress laboratories, vibration acoustic facilities, space environmental simulation laboratory, and in the thermochemical and structures laboratories on every material that might be associated with spaceflight. The work stressed duplicating the real environment in which the materials would exist in space, and the combinations in which they might be used. "The only way you can understand materials," he said, is to test them in their real environment. "The tests," he said, "contributed to redesigning the space cabin environment and its atmosphere. In the longer run, the tests contributed to a better understanding of terrestrial uses of materials, flight and fire safety, and energy efficient modular design," he said. Bond, who had earlier worked on "man-rating" materials for human use in the environment of space, found these principles applicable for both terrestrial and nonterrestrial environments.[54]

The trauma of the AS-204 fire precipitated a vital new learning experience and a renewed dedication and sense of cooperation among the NASA centers and contractors. Managerially, NASA began to move from a state of planned disequilibrium to one of greater stability. Headquarters began to exert more influence and control. The older NACA

traditions of informality, collegiality, and center independence waned under the pressures of an enforced technical collectivism. MSC retained a strong sense of independence, a product in part of its Langley legacy, and, perhaps, its Texas environment. It retained its self-image of being the lead center for manned space programs, a mantle which it assumed in its origins as the Space Task Group and earned in the Mercury and Gemini programs. As was the entire NASA organization, MSC personnel were shaken by failure and the loss of the crew of AS-204, but even more determined to succeed. By the end of 1967, the new Apollo-Saturn 501, renamed Apollo 4, stood atop the new Saturn V rocket ready for launching from the pad at Kennedy Space Center. Apollo soon would be ready to deliver its precious human cargo to the Moon.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