Chapter 4

Joseph G. Gavin, Jr. and His Contributions to American Aerospace Achievement*

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Abstract

Joseph G. Gavin, Jr. had an extraordinary aerospace engineering career in an extraordinary age for American aviation and spaceflight. His employment coincided exactly with the Cold War era of lofty defense spending and ambitious megaprojects. Following degrees from MIT in 1942 and four years as a naval officer in the US Navy's Bureau of Aeronautics, Gavin spent his entire career with the Grumman Corporation, rising from design engineer in 1946 to president and chief operating officer in 1976 before his retirement in 1985. He was directly involved in the development of naval aircraft, the core Grumman product. He headed development of several aerospace projects, including the *Orbiting Astronomical Observatory* as Grumman's chief missile and space engineer, a precursor to the *Hubble Space Telescope*. Of greatest historical significance, from 1962 to 1972, Gavin oversaw 7,500 employees as director of the Apollo Lunar Module program. NASA awarded him the Distinguished Public Service Medal for his

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role in saving the *Apollo 13* mission; and in 1974 he was elected to the National Academy of Engineering. In retirement, Gavin continued to conduct research on technology and resource policy issues, pursuing especially a fascination with alternative energy that he had developed while an executive at Grumman. He advised the US government and gave presentations to diverse audiences, with a special emphasis on communicating with students from the primary to the doctoral level. Gavin was involved extensively in charitable activities, with particular interest in education, health care, and equal opportunity. A member of the MIT Corporation, he was closely involved with the development of his alma mater throughout his adult life, and attended his last board meeting a month before his death at age ninety in 2010. Gavin's wide range of responsibilities, contacts, and experiences—combined with a penchant for travel that included attendance at virtually every International Astronautical Congress from 1980 to 2005—afforded him unusual insights into the geopolitics, military-technological frontier, and policies of his era. Aside from succinct presentations at a few major venues—such as the 2002 Congress and when receiving the Aero Club of New England's 2010 Godfrey L. Cabot Award—however, Gavin's humility and focus on the future prevented him from writing a memoir or otherwise publicizing his experiences. To finally tell this story of an engineer's extraordinary life in an extraordinary age of American aerospace activity, the author draws on interviews with Gavin and his family, as well as access to his personal records.[1]

I. Getting Launched in Life

"Those who knew Joe knew he never sought to be in the limelight, though, as head of our space program, he should have been," said Patricia McMahon, vice president of Northrop-Grumman, upon Gavin's death in 2010. "He was one of the great pioneers in the aerospace industry."[2] Since Gavin did not leave memoirs of his own, this chapter aims to shed light on his life and career to a degree previously unavailable to the public.

Joseph Gleason Gavin, Jr. was born on September 18, 1920, in Somerville, Massachusetts. His lifelong interest in aircraft and space travel began early. As a youth he drew inspiration from Buck Rogers and Charles A. Lindbergh—traveling hours as a seven-year-old to see "Lucky Lindy" land on a small Vermont airfield following his transatlantic flight in 1927. Still more important, at a 4-H camp one summer he met Dorothy Grace Dunklee of Brattleboro, Vermont. They married in 1943, a love match that lasted sixty-seven years until Gavin's death.

Gavin graduated from the Boston Latin School. At MIT, where he was captain of the varsity (heavyweight) crew, he earned a combined bachelor's-master's degree with honors in aeronautical engineering in 1942. There Gavin would form lifelong personal and professional associations. In 1995, at Gavin's induction as a life member emeritus of the MIT Corporation, Carl Mueller, fellow classmate and crew team member, would attest that "his generosity and abiding concern have strengthened this institution immeasurably," describing him as "a modest gentle man whose powerful intellect and effective leadership have literally put men on the moon and returned them safely to Earth."[3]

Following graduation in 1942, Gavin spent four years in Washington, DC. He entered the US Naval Reserve as an engineering officer with the rank of lieutenant. He was posted at the Naval Bureau of Aeronautics, then housed temporarily on the National Mall. There he was involved in the early work on aircraft jet propulsion and served as the project officer on the Navy's first jet airplane. Thanks to his recent studies at MIT, Gavin viewed aeroengines as a revolutionary technology that would make a significant difference by allowing flight speeds to increase by several hundred miles per hour. Some of the more senior naval aviation specialists were skeptical about the new technology's potential, affording Gavin unusual opportunity and responsibility for his age.[4] Gavin received a commendation for his contributions to the US Navy's jet fighter program.

II. Initial Employment at Grumman, 1946–1962

In 1946, having selected from among offers at some of the leading aircraft corporations such as Boeing and McDonnell Douglas, Gavin went to work for the Grumman Aircraft Engineering Corporation in Bethpage, Long Island, New York. This proved to be a full-career affiliation of forty-four years: Gavin started in the lower engineering ranks as a design engineer and concluded with nine years as the president and chief operating officer of Grumman Corporation, before retiring from leadership in 1985 and consulting through 1990.

In his early years in Bethpage, Gavin was deeply involved in the development of naval aircraft, Grumman's primary product. He started as a design engineer (1946–1948) on Grumman's first jet fighter, the XF9F *Panther,* before becoming engineer, Preliminary Design Group (1948–1950). He worked on several aircraft projects, including Grumman's first and second jet fighters: Grumman's first swept wing fighter, the F9F-6 *Cougar* (project engineer, 1950–1952), and supersonic F11F-1 *Tiger* (project co-engineer, 1952–1956).[5]

During 1956–1957, Gavin served as Grumman's chief experimental projects engineer. From 1957–1962 Gavin served as Grumman's chief missile and space engineer. This capped his leadership in the company's development of several aerospace programs, including the *Orbiting Astronomical Observatory* (*OAO*), a precursor to the *Hubble Space Telescope*.

Gavin's early career traced Grumman's preparation to bid on something large and unprecedented: the Apollo Program's Lunar Module. Experience in developing the *OAO*, together with the canister for the *Echo* balloon, gave the aircraft-centric company the experience to compete credibly, if unsuccessfully, to participate in the Project Mercury. Meanwhile, in developing a new aircraft optimized for antisubmarine warfare, Grumman developed systems engineering capability. "We won that competition, and that airplane was one that had a lot of my fingerprints on it," Gavin later recalled. Collectively, these Grumman achievements "provided a reasonable chance to bid on some of the space programs."[6]

III. Lunar Module Program, 1962–1972

Grumman's, and Gavin's, opportunity of a lifetime came through the Apollo program. It was during a decade as vice president and director, Lunar Module program, that Gavin faced his greatest challenges in management of technological innovation, after Grumman won the NASA competition to build the Lunar Module (LM) that would deliver NASA astronauts Neil Armstrong and Buzz Aldrin to the Moon's surface on July 20, 1969. Under Gavin's management, Tom Kelly, LM chief design engineer (1962-1969), and the Grumman team succeeded with a bold design of a craft that landed on the Moon and returned to lunar orbit six times, and saved the crew on Apollo's one aborted mission. At its peak, Gavin managed 7,500 employees (about half of whom were engineers) in several locations across the United States. Just over half of what ultimately became approximately $2.2 billion in appropriated LM program dollars went to subcontractors that Grumman managed. Working together and with NASA, they achieved a highly successful model of public-private partnership.

According to an official NASA history, "The story of Grumman's drive for a role in manned space flight has a rags-to-riches, Horatio Alger-like quality. The company had competed for every major NASA contract and, except for the unmanned Orbiting Astronomical Observatory satellite, had never finished in the money."[7] Beginning in January 1961, formalizing efforts started the previous year, Gavin led Grumman's self-funded study by its Space Group of a novel Moon-landing technique, lunar-orbit rendezvous (LOR). From November 1961 through June 1962, NASA debated whether LOR should prevail over Wernher von Braun's preferred approach of Earth-orbit rendezvous. LOR finally prevailed, triggering a bidding competition that fall that Grumman won in November before signing a contract in January 1963.[8] Unusually, proposals involved answering a set of twenty questions. "NASA hadn't really bought [our] design," Gavin later recalled, "They thought they'd bought an engineering service."[9]

There was no precedence, and certainly no blueprints, for a machine anything like the Lunar Module. The unique craft had to be completely reliable even though lunar conditions could not be duplicated on Earth for full testing. Moreover, there were conflicting information and assessments about the suitability of the Moon's surface for a landing. Worst-case scenarios included Cornell University Professor Thomas Gold's assertion that the LM would sink into "ten meters of impalpable dust…electrostatically it'll probably just cover everything up."[10] All this had to be overcome without today's modern electronics, computing, and employee databases.

The LM's design evolved in a relentless effort to counter the weight growth of the 32,000-pound vehicle and maximize reliability under uncertain conditions in a remote environment with extremes of heat and cold, radiation, and even micrometeoroids. This forced considerable rethinking by an organization whose foundational culture was grounded in the design of naval fighters by Gavin and other "graduates of the aircraft business."[11] Indeed, it took strong backing by Grumman's management to overcome opposition by a faction of "conservative aircraft traditionalists"[12] who believed that "these guys on the lunar module are nuts"[13] and that entering the space business presented excessive risks. Whereas aerodynamic considerations required aircraft to be built from the outside-in, the harsh vacuum of space required a spacecraft like the ungainly LM to be built from the inside-out. The heavy helicopter-style windshield that Gavin initially envisioned shrunk to small triangular windows pressed against the faces of standing crewmembers, their seats eliminated in recognition of the flight's short duration and one-sixth gravity environment.[14]

Oversights were usually harmful but occasionally helpful. Unexpected stretching of the LM's fuel tank membranes, proportionally thinner than eggshells, accommodated twenty seconds more fuel—the margin that Neil Armstrong had left when he landed unexpectedly far downrange to avoid a field of boulders. This push to the limits was one of the few times during an Apollo mission that Gavin was nervous to the point of holding his breath.[15]

Central to the difficulties in designing and proving the LM was that it could not be flight-tested, a conundrum that had no analogue in Grumman's aircraft business, wherein even a vehicle that crashed could be retrieved and examined.[16] Each LM had to be launched brand new without even a comprehensive test of its propulsion system: storable propellants could not be purged completely, and ground conditions differed completely from those in space. Most critical of all was takeoff from the Moon. The conditions simply could not be duplicated, precluding direct testing of the LM design as a fully integrated system. In Gavin's words, "you had a limited time, you had to punch the button, and everything had to work. The ascent engine had to ignite. The explosive bolts had to explode. The guillotine had to cut the connections, and then it had to fly up. And this is something we never saw happen until the last mission."[17]

To address these challenges, Gavin and his team developed and implemented a testing regimen whose rigor far exceeded that for aircraft at that time. "We…came up with the idea," Gavin explains, that "there should be no such thing as a random failure…if in running tests you find something that doesn't work, there has to be a reason for it, and if you're patient enough, you ought to be able to find out why it failed and do something about it." A central example of this regimen was testing for over 600 different landing conditions, including ones in which the LM skidded laterally and caught its relatively fragile legs in a crater or curb-like formation. This led to a conservative design whose landing gear Gavin believed in retrospect was twice as heavy as strictly necessary.

As program director, Gavin dealt intensively with NASA, subcontractors, and Grumman's own management. To him, "it was a balancing act where the program director tries to keep the program on the right track despite what the internal management might think, and to some degree what NASA might think, because, after all, if [the product] doesn't work, it's our fault."[18]

NASA attempted to incentivize Grumman and other Apollo contractors with a complex formula trading off fulfillment of three major objectives. For Gavin and his team, however, the equation quickly became largely fixed. (1) Mission success was nonnegotiable. (2) Schedule was important; having started a year behind the Command and Service Module, the LM was subject to continuous catch-up efforts. Here, technology was a dominant factor: "You weren't going to advance the program by meeting a schedule if the technology wasn't right." (3) Only the third area, cost, offered significant flexibility. This required considerable forbearance from NASA and its congressional funders; Grumman only began to receive significant incentive pay when actual missions began and maximized it with a perfect track record. "From 1963 to 1967, very little fee was earned," Gavin recalled. "The program was always behind the desired schedule and over cost. Once the missions began, the fee situation improved; the Lunar Module 'worked' every time."[19]

Gavin had to make some difficult decisions on the spot. One example concerns the approach that Grumman would choose regarding the nozzle of the LM's descent engine, the first wide-range-throttleable rocket engine. "NASA was not supposed to make the decision," Gavin recalled, "so I made the decision, and [NASA manager Maxime Faget] said, 'Fine,' and that was that."[20]

In a singular instance, meeting a scheduling target for NASA was so important that Gavin found a way to countenance the breaching of a test sequence procedure. A motor replacement had to occur in a confined space that could only accommodate two people. Gavin devised a procedure whereby two specially selected individuals would work therein: the best technician from the Grumman subcontractor (Hamilton Standard Division, United Aircraft Corporation) would replace the motor, supervised by Grumman's best mechanic. Such a judgment call was only possible because of the direct personal knowledge that Gavin accrued over the years of the people within his organization. He directly telephoned Nelson Vosbergh, whom he first met as "a very junior engineer at Grumman… clearly the best nuts-and-bolts mechanic I have ever seen."

Gavin's word was good enough for NASA Administrator George Low when he declared: "I've known this chap for over fifteen years, and he's the best mechanic I've ever seen do anything." Gavin elaborates: "we got him indoctrinated on what to look for, and we got the expert from Hamilton Standard and the two of them at the Cape, and they went in and they changed the motor. A routine check said everything works, and on the basis of that, we launched the mission. And [Nelson will] never forget that, and I won't ever forget it, because it was one of the few times that we really breached the procedural testing sequence that we had set up."

In yet another judgment call, Gavin had to require that a Rocketdyne injector be used in an engine that was otherwise built entirely by Bell—a crushing disappointment to the Bell team with whom he had worked quite closely.

Another important decision by Gavin concerned not technology per se but rather supporting his colleagues. In fall 1961, when he took his sixty-man team to negotiate details of the LM contract with NASA, Houston was still segregated. Hotel after hotel would not accommodate two of their top engineers, Reaction Control System Project Leader Ozzie Williams and Guidance & Navigation Project Leader George Henderson. Being regrettably familiar with such prejudice, they volunteered to find their own rooms, but Gavin insisted on keeping the team together no matter what. Under his direction, the group finally found the one hotel in the area that would accept all of them, and negotiations proceeded successfully. Following Gavin's death, an outpouring of dozens of letters and reminiscences suggested that this was just one of many times that he had stood up for people and supported them. Some anecdotes were new to Gavin's family, as he had been too modest to recount them himself.

During the aborted *Apollo 13* mission of 1970, the LM became an unexpected lifeboat and tugboat. Throughout that crisis, Gavin helped to coordinate the urgent assessment and application of the LM's capabilities for this emergency assignment from NASA's Mission Control Center in Houston. Manning his post at the forefront of Grumman's multiple layers of technical support, "the tensest episode in [his] career,"[21] Gavin estimates that he only "got two hours of sleep in that whole [four-day] mission." Upon the astronauts' successful splashdown, Gavin recounts, Mission Control "just burst into cheering…the atmosphere was…so buoyant and so relieved."[22] Watching the movie *Apollo 13* in retirement, Gavin observed that it did not depict the small American flags that people were waving in celebration. He regretted that nobody had consulted Grumman in making the film, which he believed did not properly credit the company for how it helped to save the day.[23]

For his contribution, NASA awarded Gavin its Distinguished Public Service Medal in 1971. In 1974, in one of his proudest career accomplishments, he was elected to the National Academy of Engineering "for leadership in the design and the production of the Apollo Lunar Module."[24] In accepting recognition, Gavin always credited these technical feats to the spirited teamwork throughout his company, across the nation, and around the world.

Grumman was not successful in all of its efforts. Gavin believed that his team produced a "first-class" lunar rover design and was disappointed when NASA selected Boeing abruptly when his company's prototype was still in testing. Grumman likewise lost the bidding competition for the Space Shuttle, despite submitting what Gavin believed to be a superior proposal. For Gavin and Grumman, space development thus reached its apogee during the heady LM years. Under his subsequent leadership, Grumman would focus on traditional naval aircraft while attempting commercial diversification on Earth.

IV. Lessons from Bethpage and Beyond

Gavin drew larger lessons from his team's experience in developing the LM. Some he applied to Grumman's subsequent aircraft business. All he distilled and shared with interested audiences, culminating with his delivery of a paper at the 2002 IAC World Space Congress in Houston, "The Apollo Lunar Module (LM): A Retrospective." Written in an engineer's impersonal bulletized shorthand, its four pages of diagram-rich text constitute Gavin's capstone public discussion of his career, the machine that made it, and the underlying principles that he internalized, exemplified, and conveyed in actions and statements. Here, the author draws on additional sources to elaborate on Gavin's conclusions and distill them into eight principles that he espoused professionally but never listed formally or sought credit for.

IV.1. Create Conditions for Success

Gavin emphasized the important conditions powering Project Apollo and its LM. He cited three significant decisions: (1) Eisenhower's establishment of NASA as a civilian organization, (2) John Houbolt's promotion of the LOR concept to NASA at the risk of his career, and (3) Kennedy's bold commitment on May 25, 1961, to put a man on the Moon by the end of the decade. "In hindsight," Gavin assessed, putting NASA rather than the US Air Force in charge of spaceflight "was a really wonderful decision, because it made the space effort in this country open to the public and the world, whereas the Soviets were still carrying on their efforts with the usual...secrecy, and in the long run this worked out very much to the advantage of the American effort."[25] He viewed the LOR concept as a critical breakthrough: "it was a radical change, and I think it was responsible for the success of the program. I don't think the program would have succeeded on the original path of Saturn" that von Braun had championed.[26] A product of the era that motivated its creation, the program was energized by heightened geo-technological competition on the ultimate stage and sustained by Kennedy's backing and legacy. Regarding the *Apollo 1* fire, Gavin reflected, "I'm not sure the program could have continued under today's situation, but then it could because we were in the midst of the superpower contest."[27]

IV.2. Reliability is Attainable

As explained previously, Grumman under Gavin adopted a rigorous testing regimen grounded in the principle that "There is no such thing as a random failure." To identify and eliminate sources of failure, they had to study deeply a panoply of esoteric subjects, including the properties and performance dynamics of glass and batteries.

IV.3. Innovation Requires Flexibility in Schedule and Costs

Gavin encapsulated his experience in managing technological innovation, which he believed inherently rendered timelines and spending unpredictable: "If a major project is truly innovative, you cannot possibly know its exact cost and its exact schedule at the beginning. And if in fact you do know…, chances are that the technology is obsolete."[28] Accordingly, Gavin and his team prioritized performance (including safety) first, schedule second, and cost a distant third.[29]

Delays during Apollo's early years and considerable cost growth throughout proved the price of mission success.

IV.4. Don't Complicate Things Unnecessarily

Gavin and his team found new relevance in the time-honored adage "if it ain't broke, don't fix it." He described this as "the basic rule that if something works, be very careful if you try to change it, because maybe you'll get into something you don't foresee."[30] In an episode that Gavin recounted repeatedly up through his Cabot Award shortly before his death, upgrading to a costlier, purer rust-inhibitor additive caused unexplained glycol crystals in electronic coolant fluid that no amount of exotic filtering could remove. In this case, investigation included "us[ing] almost all the bowls in the Grumman cafeteria to have samples of glycol sitting around where people could look at it." The solution: "we reverted to the cheap stuff, and all the rest of the missions were straightforward."[31]

IV.5. Remove Hierarchical Barriers

Gavin credits Grumman's informal, responsive, relatively flat organizational structure with fostering innovation and quality control. He and others regularly received reports from employees at all levels who felt empowered to pick up the phone and call anyone in the company without fear of being penalized for identifying a problem. He worked to enhance communications and morale by regularly traversing different departments after lunch when not on travel, and once overlapping with the night shift for two months. Maintaining constructive relations between Grumman's engineers and skilled manufacturing-floor staff was a top priority, and the company made sure that they were located as close together as possible physically to ensure information flow and reduce dissonance between the disparate professional cultures.

IV.6. Empower Individuals

Grumman's organizational culture encouraged employees to investigate and solve problems on their own initiative. Gavin's favorite example involved a talented young engineer who averted potential failures by proactively investigating the standard miniature toggle switches used throughout the LM, which scores of aircraft had employed for years.[32] In one-third of the cases, sectioning samples revealed loose solder pellets that could mis-set a switch in zero-gravity. While it was too late to change the switch type, Grumman devised a means of identifying and rejecting the proportion that were compromised. To Gavin, "this was a case…of how an inquisitive mind…led to the right thing. Nobody could have told the individual that this was something that should be done." Instead, "he said, 'You know, I am responsible…I'd better understand everything about everything.'"[33]

IV.7. Share Information

Constant information flow was likewise essential. Gavin greatly valued his daily stand-up meeting from 7:30–8:00 A.M. with twenty to thirty principals in Bethpage, themselves linked by telephone conference to field sites at Cape Kennedy, Houston, and White Sands.[34] This ensured shared awareness of design changes and their potential consequences ("configuration control").[35]

IV.8. Remember Your Customer

Most importantly, Gavin's aforementioned conclusions all served an overarching imperative: return spacefarers safely to Earth. He and his colleagues knew they were building the LM for real people whose lives depended on it.[36] "The team at Grumman developed a personal relationship with every one of the astronauts in the Apollo era," Gavin stressed. "We were building machines that our friends would operate, not some faceless individuals unknown to us."[37] While the astronauts' personalities varied greatly, all were top-caliber professionals and "their visits to the plant made people feel that 'We're not just building something for some mysterious customer; we're building it for these people.'…that was very useful."[38] This concern for astronauts' wellbeing encapsulated an ethos from the company's founder, World War I naval aviator Leroy Grumman. Grumman, Gavin recalled, "had one basic direction to all of us…'You bring the pilot back one way or another.'"[39] Gavin's LM program never failed in this most critical of missions.

V. Leadership at Grumman, 1972–1990

Having been a senior vice president from 1970–1972, Gavin was next president of the subsidiary Grumman Aerospace Corporation (1972–1976) and served concurrently as chairman of the board (1973–1976). In 1976, Gavin was elected president and chief operating officer of the Grumman Corporation itself (in effect the holding company for smaller specialized Grumman companies). He came to this position from a long career within Grumman that made him a true believer in the organization, then a Fortune 500 Company exceeding a billion dollars in annual sales and Long Island's largest employer by far.

Gavin viewed Grumman as an unusual enterprise that took unusually good care of its employees and granted supervisors marked autonomy in how best to manage those for whom they were responsible. As an executive, one of his ceremonial roles involved presiding over the distribution to every employee of a turkey at Thanksgiving and Christmas. He shook everyone's hand, a particularly humbling process with some manufacturing floor workers possessing extraordinary grip strength. Employees were encouraged to literally have a stake in the corporation through generous stock options.

A core tenet of Grumman's philosophy was keeping a smaller workforce and having them work overtime rather than raising a larger workforce that would face layoff risks. As part of that equation, particularly during the peak tempo of the Apollo years, employees—and especially managers—worked extraordinarily long hours. Gavin himself spent considerable time away from home, both on a daily basis and with frequent travel.

Grumman's unusual corporate ethos was questioned by various outsiders. Congressional overseers speculated about the percentage of the price tag for each Grumman aircraft that covered employee health and benefits. One of Gavin's greatest tests as a leader concerned the company's very name and future. Hoping to bail out its underfunded pension plan with Grumman's overfunded one, LTV Corporation attempted a hostile takeover. The timing was unexpectedly difficult: Grumman's Chairman of the Board John ("Jack") Bierwirth was cruising the Mississippi with his wife aboard the *Delta Queen*; in that pre-cellphone era, it took time to recall him to Bethpage. Gavin quickly assembled a team and met with lawyers late into the night for several days straight. Together with Bierwirth, other executives, and even the company's 86-year-old founder Leroy Grumman who emerged temporarily from medical retirement, Gavin rallied his employees, who owned a great percentage of Grumman stock, and persuaded them to reject LTV's offer. In the end, Grumman's leadership and its employees' loyalty carried the day. Gavin later stated that he was relieved to have retired before the company that he so loved had to merge with Northrop in 1994.[40]

Serving in top management positions brought Gavin full circle, back into the naval aircraft development that remained at the core of Grumman's business. He worked rapidly to reacquaint himself: "I was faced with catching up on what had been happening for ten years in naval aviation and for getting the F-14 into production, and that was a learning experience."[41] Gavin implemented best practices from Grumman's spacecraft development, particularly improving initial construction to reduce the need for tests. "Because of becoming president," he recounted, "I got back into worrying about aircraft. We adopted a lot of the practices learned on the LM back into the aircraft business and managed to cut down the number of tests before delivery." The key: "you build a better vehicle with discipline, and then you don't have to flight-test it so many times to work out the bugs."[42]

A major highlight at the beginning of Gavin's tenure at Grumman's helm was beginning delivery to Iran of 79 F-14s, together with related hardware, training, and after-market servicing. He personally oversaw the preparation and dispatch of 2,000 Grumman employees and their families to a facility near Imperial Iranian Air Force Base Khatami, fifteen miles north of Isfahan. This gave Gavin a unique window into some of the personalities and professional happenings of Iran's governing and technological elite of the time. Iran's ambassador to the Washington had the unenviable task of awakening in the early hours of each morning to brief the Shah by telephone concerning what was then Tehran's most important bilateral relationship.

Iran's revolution of 1979 terminated the effort just as Gavin was about to make a site visit. He frequently credited his employees' protection by local Iranians and safe exit from the country with the Persian language and cultural sensitivity program that he had required them and their families to take. Amazingly, months after their stateside return, the personal belongings they had abandoned in their haste arrived by shipping container without valuables missing. For years afterward, Gavin followed the progress of members of the Shah of Iran's government and industry with whom he had become familiar professionally; many settled in Houston and Los Angeles and applied considerable talents to making a new life in their adopted home.

Gavin served in this capstone position as president and chief operating officer for nine years. In 1985, upon reaching Grumman's mandatory retirement age and heading the design of a new leadership structure, he concluded his management responsibilities. That year, he became chairman of the Executive Committee of the Board of Directors and senior management consultant. He would serve five years in the latter capacity before retiring fully in 1990.

VI. Service and Interests into Retirement, 1990–2010

Even in retirement, Gavin remained quite active professionally and intellectually. He continued to conduct research and offer policy recommendations regarding aerospace, technology, and energy issues. His professional memberships included: the American Institute of Aeronautics and Astronautics (AIAA), which he served briefly as its president in the early 1980s; the National Academy of Engineering (NAE); the International Academy of Astronautics (IAA); the

British Interplanetary Society (BIS); and the American Association for the Advancement of Science (AAAS).

Through Grumman's involvement in the Princeton Tokomak fusion energy project, Gavin had developed a strong interest in energy policy. This led to service as chairman of the Committee on International Cooperation in Magnetic Fusion, National Research Council (NRC); and the Technical Panel on Magnetic Fusion, Energy Research Advisory Board, Department of Energy. Gavin also chaired a major NRC committee on Advanced Space-Based High-Power Technologies, served as a member of the Department of Defense's Policy Committee on Trade, and supported MIT's president in advising US policy regarding the *Freedom* space station.

In addition to advising the US government, Gavin gave presentations to diverse audiences, with a special emphasis on communicating with students from the primary to the doctoral level. In part because of his longtime dedication to such outreach, the Aerospace Education Council, Inc., had presented him with its Man of the Year award in 1968.

Beyond his support of company and country, Gavin was a man of family and community. He held many leadership positions, including chairman of the Greenlawn-Centerport School Board and chairman of the Huntington Hospital Board of Directors. He was an active supporter of and fundraiser for his schools.

Particularly noteworthy was Gavin's association with and support for MIT throughout his adult life. A member of the MIT Corporation since 1973, he served on its executive committee from 1984-1991, in addition to many visiting committees. He was also a member of the MIT Education Council. During 1986–1987, he served as the executive president of MIT's Alumni Association, having received its 1972 Presidential Citation for two-decades' service as a member of the Long Island Educational Council. He was a director of the Charles Stark Draper Laboratory, having collaborated closely with its previous incarnation, MIT Instrumentation Laboratory, developer of the LM's onboard guidance, navigation, control (GNC) computer system. Dick Battin, technical director of mission development during the MIT Apollo program, recounted how Gavin supported engineering education extensively at MIT directly, often by lecturing in Battin's seminars.[43] "He was really good with the freshmen," Battin recalled. "I didn't even have to ask" him to participate in the seminar. "He would call me up to ask to take part."[44]

Gavin was a downhill skier until age eighty-six, a tennis player, and a voracious reader of history. He spoke German and read Latin. He and his wife enjoyed travel, visiting five continents—in part by attending virtually every International Astronautical Congress from 1980 to 2005.

To the very end of his life, Gavin remained focused on pursuing new technological horizons and helping the organizations he valued look to the future. He attended his last MIT Corporation board meeting on October 1, 2010, driving the two hours each way alone. This was just twenty-nine days before his death at age ninety, surrounded by family members in his home at the Applewood Retirement Community in Amherst, Massachusetts.

VII. Vision and Legacy

Gavin enjoyed an extraordinary engineering-executive career in an extraordinary age for American achievements in air and space. His employment coincided exactly with the Cold War era's lofty defense spending and ambitious megaprojects. Like an unusually talented and fortunate surfer, Gavin caught an unprecedented wave at just the right time and rode it nearly perfectly.

Gavin's wide-ranging responsibilities, contacts, and experiences afforded him unusual insights into the military-technological frontier of his era and the people that propelled it. He broke bread with von Braun and his brother and discovered that they telephoned their father in Germany each morning. He saw firsthand how von Braun's "real charisma" was supported by the unsung diligence of his longtime deputy Eberhardt Rees. In recounting Apollo, Gavin made sure to recognize stalwart contributors such as Robert Gilruth, Director of NASA's Manned Spacecraft Center, whom he felt "should have gotten far more credit." Gavin's own combination of diligence, personal modesty, and constant desire to continue looking toward the future rather than basking in the glories of past accomplishments is reflected in a glowing memorial tribute by Neil Armstrong. He described Gavin as "a highly regarded aerospace engineer" as well as "an engineer and engineering manager in the highest tradition of the National Academy of Engineering [who] will be well remembered."[45] It reads as the heartfelt respect of one humble engineer's engineer for another.

Most fundamentally, Gavin was driven by the excitement of innovation in engineering: "There's a certain exuberance that comes from being out on the edge of technology, where things are not certain, where there is some risk, and where you make something work." He was forced to elaborate on this core philosophy when, during one of his many talks to schoolchildren, a girl asked him, "Mr. Gavin, why would anybody want a job like the one you had?" He replied: "Well, you must understand that there's a certain satisfaction in living and working at the cutting edge of new technology. And while this isn't for everybody, for those of us who are true enthusiasts, it is the place to be."[46] Asked for career guidance, Gavin advised, "Find a way to do something you love. You'll never do anything better."[47] Gavin later elaborated, "When I was at Grumman I was doing something I would have preferred to do over anything else. When you're in that situation, the hours don't mean much. You do whatever is necessary."[48]

An engineer at heart, Gavin was concerned that after the Apollo years the United States political process did not sufficiently support foresighted planning and investment concerning science and technology over a range of potential applications, from energy to space.

He was particularly interested in the potential of Japan and China to develop advanced aerospace technologies and programs. "I think the place that we're going to have to watch is the Japanese and the Chinese," he told the author in 1998.[49] Over the course of Gavin's career and his support for the International Experimental Thermonuclear Reactor, he visited Japan several times beginning in the 1970s and was impressed with its government's ability to pursue programs and invest with foresight. At the first opportunity, through the International Astronautical Congress of 1996 in Beijing, he visited China. In the process of touring space facilities in Beijing, Xi'an, and Shanghai, he was impressed by the caliber of the leading young aerospace specialists that he met. He assessed that if placed in top US programs (e.g., at MIT and Caltech) they would perform with distinction.[50]

Gavin's lifetime of devotion to the pursuit of technological innovation at the frontier of cosmic discovery is encapsulated by the quote by George Bernard Shaw that was flown to the Moon on his behalf: "You see things, and you say: 'Why?' But I dream things that never were, and I say 'Why not?'"[51]

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Front Cover Illustration:

Charles Lundquist (right) gives a presentation on orbital trajectories at the Army Ballistic Missile Agency in Huntsville, Alabama, to Hermann Oberth (left) and Wernher von Braun (center) on June 28, 1958. Credit: NASA and UAH Library.

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Foreword

As series editor for the International Academy of Astronautics (IAA) history symposia volumes, the authors of the scholarly papers that become chapters in these volumes always surprise me. I am amazed at how they present new details about familiar projects or events, and I am stunned by how they introduce previously forgotten or unappreciated aspects of rocket and space history. This latest, long-awaited volume is no exception.

As I reflected on its nineteen chapters, it occurred to me that I have lived through and, in some instances, personally experienced bits and pieces of the stories these authors so captivatingly tell. Practically every one of them, in their own way, delivers memorable space- or rocket-related history from my lifetime. Looking backward in quinquennial fashion, I found mention of the last Apollo flight to the Moon in 1972—forty-five years prior to this IAA symposium. Before that, in 1967—fifty years before the symposium—the *Apollo 1* tragedy that cost the lives of three brave American astronauts came to mind, as did the happier memory of *WRESAT*, the first Australian satellite, being launched. Five years before that—as a high school student, in 1962—I was glued to the television screen, watching John Glenn's Mercury-Atlas 6 send the first American into Earth orbit. And, five years even earlier—as a ten-year-old boy, in the autumn of 1957—I gazed upward to watch *Sputnik*'s rocket body pass swiftly across the nighttime sky. Then, when Charles Lundquist's obituary informed me that he first became acquainted with Wernher von Braun's work seventy years earlier, in 1947, it took me back to my birth.

Looking backward, as this historical volume prompted me to do, left me mindful of the rich complexity of the space-related activities that constitute the foundation upon which today's rocket scientists, satellite engineers, and other spaceflight professionals continue building. Most often, today's work is evolutionary, but that is not to say revolutionary ideas spark unforeseen twists and turns, just as they did in the past. The chapters in this volume tell tales of both these progressive avenues.

Indeed, after a thorough reading, they prompted me to sit back in my chair and contemplate the quinquennial pattern of the future. Looking forward, I see billionaires building space rockets and their corporate enterprises operating dozens, even hundreds of privately funded satellites. Will private human spaceflight occur in 2022? Will a privately financed presence be established on the Moon in 2027? Will a government-sponsored space organization manage to send humans to Mars in 2032? Where will rocketry and spaceflight take us in 2037? The history that appears in this volume leaves me extremely excited about the future and unbelievably curious about how it will unfold.

Dr. Rick W. Sturdevant
Series Editor
United States Space Force
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Preface

The Fifty-First History Symposium of the International Academy of Astronautics took place during the Sixty-Eighth International Astronautical Congress in September 2017. The picturesque city of Adelaide, capital of South Australia, was the venue for the congress, only the second time the event had been held in the Land Down Under (the first was held in Melbourne, Victoria, in 1998).

The year 2017 was special for space in Australia, marking fifty years since the launch of the country's first satellite, *WRESAT* (*Weapons Research Establishment Satellite*). This fiftieth anniversary formed a major theme of the education and outreach programs associated with the congress. Highlights included an extensive exhibition on the history of the Woomera Rocket Range, held at the State Library of South Australia, and the release of a special WRESAT anniversary stamp and first day cover by *Australia Post.*

History was also made during the congress, with the announcement at the opening ceremony that the Australian government would form the nation's first space agency, a goal long pursued by the Australian space community. The jubilation with which the Australian delegates greeted this announcement will be long remembered by everyone present.

The Fifty-First History Symposium was composed of four sessions: Memoirs and Organizational Histories; Science and Technology Reviews; a session on the History of Australian Contributions to Astronautics, in recognition of the host country; and a special session as part of the lead-up to the fiftieth anniversary of the *Apollo 11* Moon landing in 2019, under the title "Can You Believe They Put a Man on the Moon?" This special session was the first in a series that will continue until 2019, focusing on all aspects of the development and preparation for the first human landing on the Moon in 1969. Its four papers encompassed an eclectic range of topics: from the cultural impact of the Apollo program and the larger lessons to be learned from the space race to the contribution of Spain's

Fresnedillas space tracking station and the experience of watching the *Apollo 11* landing in Ireland.

This volume is divided into four parts, reflecting the four sessions of the symposium outlined above. The papers presented in 2017 covered a wide spectrum of space history topics, but—in addition to the special focus on the Apollo program—a few themes emerged. As 2017 was also the sixtieth anniversary of the launch of the world's first satellite, several papers addressed the legacy of *Sputnik 1,* while the achievements of little-known rocketeers of the 1930s and less-well known figures in the US space program were also presented. Regrettably, the lead author of a fascinating presentation on the work of Robert Farquhar, the "father of halo orbits," failed to provide a written paper. In its stead, an extended abstract is included to acknowledge Farquhar's significant work. A particularly important contribution in this volume is Frank Winter's chapter, reassessing the significance of the Viking sounding rocket and demonstrating that it must be considered the first rocket specifically designed for flight into space.

Sadly, space historian and long-time participant in the history symposia, Dr. Charles Lundquist passed away in 2017. A memorial celebrating his life and contributions to space history research is included in this volume as a mark of respect to a valued colleague.

Kerrie Dougherty
Part III Editor

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