IAC-17-E4.1.6x41602

JOSEPH G. GAVIN JR. AND HIS CONTRIBUTIONS TO AMERICAN AEROSPACE ACHIEVEMENT

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Joseph G. Gavin Jr. had an extraordinary aerospace engineering career in an extraordinary age for American aerospace achievements. His employment coincided exactly with the Cold War era of lofty defense spending and aerospace programs. Following degrees from MIT in 1941 and 1942 and four years as a naval officer in the U.S. 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, a core Grumman product. He headed development multiple aerospace programs, 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 1962-72, Gavin oversaw 7,500 employees as director of the Apollo Lunar Module program. NASA awarded him the Distinguished Public Service Medal for his 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, continuing an interest on alternative energy that he had pursued while an executive at Grumman. He advised the U.S. 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 core contributions concerning technology, medicine, and education. A life 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 90 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 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 wife, 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 paper aims to shed light on his life and career to a degree previously unavailable to the public.

Gavin 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 Rodgers and Charles A. Lindbergh—once traveling hours to see "Lucky Lindy" land on a small field in Vermont. Still more importantly, at a 4-H camp one summer he met Dorothy Grace Dunklee of Brattleboro, Vermont. They married in 1943, a love match that lasted 67 years until Gavin's death.

Gavin graduated from the Boston Latin School. He then earned a B.S. in aeronautical engineering in 1941 from MIT, where he was captain of the varsity (heavyweight) crew; and a M.S. 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 U.S. 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 U.S. Navy's jet fighter program.

II. INITIAL EMPLOYMENT AT GRUMMAN, 1946-62

In 1946, having selected from among offers at some of the leading aerospace 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 39 years: Gavin started in the lower engineering ranks as a design engineer and ended his career with nine years as the President and Chief Operating Officer of Grumman Corporation, retiring in 1985.

In his early years at Grumman, Gavin was deeply involved in the development of naval aircraft, a core Grumman product. He started as a Design Engineer (1946-48) on Grumman's first jet fighter, the XF9F "Panther," before becoming Engineer, Preliminary Design Group (1948-50). 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, 1950-52), and supersonic F11F-Tiger (Co-Project Engineer, 1952-56).[5]

During 1956-57, Gavin served as Grumman's Chief Experimental Projects Engineer. From 1957-62 Gavin served as Grumman's Chief Missile and Space Engineer. This capped his leadership in Grumman's development of multiple 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 Mercury program. Meanwhile, in developing a new aircraft optimized for anti-submarine 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, 1962-72

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, when Grumman won the NASA competition to build the lunar lander the Grumman lunar module 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, the LM Chief Design Engineer, and the Grumman team succeeded with a bold design of a craft that landed on the Moon and returned to lunar orbit six times. At its peak, Gavin managed 7,500 employees (just over half engineers) in several locations across the United States. Just over half of what ultimately became $1.5 billion in LM program dollars went to subcontractors that Grumman managed.

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] In 1961, 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 the assertion by Cornell University Professor Thomas Gold 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 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 threatened 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, whereby 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 of which could simply not be duplicated from Earth, precluding direct testing. 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 400 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 non-negotiable. (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, represented a significant trade space. 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 administrator 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 in which two specially selected individuals would work therein: the best technician from the Grumman subcontractor (Hamilton Standard Division, United Aircraft Corporation) would replace the motor, monitored 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 telephoned directly 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 team to negotiate details of the LM contract, Houston was still segregated. Hotel after hotel would not accommodate two of their lead engineers, who were black. Being regrettably familiar with such prejudice, they volunteered to find their own rooms, but Gavin insisted on keeping the team together no matter what. He 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. During that crisis, Gavin was at NASA's Houston Mission Control Center helping to coordinate the urgent assessment of the LM's capabilities for this emergency assignment. Remaining at 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 a discussion with the *Grumman Plane News* in 1979 Gavin remembered that it was the spirited teamwork at Grumman and across the nation that pulled off the amazing technological feat.

Grumman was not successful in all of its efforts. Gavin believed that his team produced a "first-class" 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.

IV. LESSONS FROM BETHPAGE AND BEYOND

Gavin drew multiple lessons from his team's experience in developing the Lunar Module. 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, TX: "The Apollo Lunar Module (LM): A Retrospective."

IV.I 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) Grumman engineer 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 U.S. 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 Russian 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. II 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.III True Innovation Renders Cost and Schedule Unpredictable

Gavin encapsulated his experience in managing technological innovation, which he believed inherently rendered schedule and cost 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 the exact cost and the exact schedule, chances are that the technology is obsolete."[28] Accordingly, Gavin and his team prioritized performance and safety first, schedule second, and cost a distant third.[29]

IV.IV 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.V 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 of all types 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 walking around different departments after lunch when not on travel and once taking the night shift for a six-week period. Maintaining constructive relations between Grumman's engineers and the skilled tradesmen on its manufacturing floor 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.VI Empower Individuals

This organizational culture empowered individuals to investigate and solve problems of their own initiative. Gavin's favorite example involved a talented young engineer who averted potential failures by investigating of his own accord 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.VII Share Information

Constant information flow was likewise essential. Gavin emphasizes the value of the daily stand-up meeting from 7:30-8:00 a.m. held with 20-30 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.VIII Remember Your Customer

Finally, Gavin and his team knew that 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, they were clearly competent 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 encapsulated an ethos dating to the philosophy of the company's founder, Leroy Grumman, a naval aviator trainee in World War I. Grumman, Gavin recalled, "had one basic direction to all of us… 'You bring the pilot back one way or another.'"[39] Gavin and the LM Program never failed in this most critical of missions.

V. LEADERSHIP AT GRUMMAN, 1972-1990

Having been Senior Vice President from 1970-72, Gavin served as Grumman's President (1972-76) and Chairman of the Board (1973-76). In 1976 Gavin was elected President and Chief Operating Officer of the Grumman Corporation. He came to this position as a company man and a true believer. He viewed Grumman as an unusual company 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 a ham at Christmas. He shook everyone's hand, a particularly humbling process in the case of some workers from the manufacturing floor who possessed extraordinary grip strength. Employees were encouraged to literally have a stake in the company through generous stock options.

A central 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. With understatement characteristic of his era, Gavin told a NASA interviewer, "We did work a lot of overtime… I don't think we had any deaths directly attributed to it."

Grumman's unusual corporate ethos was questioned by multiple 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. Sensing an acquisition opportunity, LTE Chance Vought attempted a hostile takeover. The timing was unexpected difficult: Grumman's Chairman of the Board, Clint Towl, 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. He rallied his employees, who owned a great percentage of Grumman stock, and persuaded them not to entertain LTE's offer. In the end, Gavin's leadership and his employees' loyalty carried the day. He 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 with the aircraft side: "I was faced with catching up 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] In making this transition, Gavin was able to bring with him 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 inking a major F-14 contact with Iran: one billion dollars in sales, and one billion in after-market servicing. He personally oversaw the preparation and dispatch of 500 Grumman employees and their families to a facility in Isfahan. As part of this process, Gavin would obtain 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 give the Shah a daily briefing 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 engage in 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 return to the United States, the personal belongings that 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.

He served in this capstone position for nine years, until retiring from management responsibilities in 1985. 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. His professional memberships included: the American Institute of Aeronautics and Astronautics (AIAA), which he served briefly as its president in the early 1970s; the National Academy of Engineering (NAE); the International Academy of Astronautics (IAA); the International Astronautical Federation (IAF); 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 issues. This led to service as Chairman of the Department of Energy's Fusion Energy Advisory Committee and Energy Research Advisory Committee. This included the position of Chairman, International Coop Magnetic Fusion Committee, National Research Council (1983-84). Gavin's interest in energy policy, including solar and wind sources, continued in retirement, and was the subject of many public presentations.

Gavin continued to serve on committees and conduct research on technology and resource policy issues, continuing an interest on alternative energy that he had pursued while an executive at Grumman. He advised the U.S. government and 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 professional responsibilities, 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 his lifelong association with and support for MIT, whose corporation he was a life member of and whose executive committee he served on from 1984-91, in addition to many visiting committees. He was also a member of the MIT Education Council and the Executive President of MIT's Alumni Association in 1986-87. He was a director of the Charles Stark Draper Laboratory, which in its previous incarnation as the MIT Instrumentation Laboratory had borne responsibility for the Apollo Guidance and Navigation System. Dick Battin, formerly director of mission development for the MIT Apollo program, stated that Gavin supported engineering education extensively at MIT, 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 86, a tennis player, and a voracious reader of history. He spoke German and read Latin. He and his wife enjoyed travel, visiting five continents—coverage built in part on 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 90 surrounded by family members in his home at the Applewood Retirement Community in Amherst, Massachusetts.

VII. VISION AND LEGACY

Gavin had an extraordinary aerospace engineering career in an extraordinary age for American aerospace achievements. His employment coincided exactly with the Cold War era of lofty defense spending and aerospace programs. Gavin's wide range of responsibilities, contacts, and experiences afforded him unusual insights into the geopolitics, military-technological frontier, and policies of his era.

Along the way, Gavin had a range of extraordinary personal experiences. 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 credit stalwart contributors such as NASA administrator Bob Gilruth, 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 probably helped Neil Armstrong to write a glowing memorial tribute on his behalf that described him 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 support sufficiently 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, 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 U.S. 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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[1] The author is Gavin's eldest grandson and interacted with him intensively for three decades. The author fully acknowledges the potential influences of such a deep personal connection, welcomes suggestions for improvement via www.andrewerickson.com/contact, and hopes that others in a position to be more objective will conduct their own studies of Gavin and his career. This paper draws on data compiled and curated by multiple family members; as well as Douglas Martin, "Joseph Gavin, Who Helped Put First Man on Moon, Dies at 90," *New York Times*, November 4, 2010, http://www.nytimes.com/2010/11/04/business/04gavin.html?src=busl; "Joseph Gavin '41, SM '42: Grumman Head Worked to Save Apollo 13," *MIT News*, https://alum.mit.edu/news/AlumniProfiles/Archive/gavin; "Joseph Gavin Jr.," *Brattleboro Reformer*, December 8, 2010, http://www.legacy.com/obituaries/brattleboro/obituary.aspx?pid=147002803; "Apollo: Reflections and Lessons," *MIT Tech TV*, June 11, 2009, http://techtv.mit.edu/videos/16591-apollo-reflections-and-lessons; "Joseph Gavin, Jr.," Wikipedia page; "Joseph Gleason Gavin, Jr.," *Who's Who in America*, 1988-1999, 45th Edition; "Joseph Gleason Gavin, Jr.," *American Men and Women of Science*, 1992, 16th Edition; "Background Section," *Apollo Spacecraft: Lunar Module News Reference* (Bethpage, NY: Grumman Aircraft Engineering Corporation, Public Affairs, Space, 1968), B-2; Joe Gavin, transcript of interview by HBO Productions, June 26, 1996.

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[3] David L. Chandler, "Aerospace engineer Joseph Gavin '41, SM '42 dies at 90: Former president of Grumman Aircraft led Lunar Module development for NASA, aided in the rescue of Apollo 13," MIT News Office, November 5, 2010, http://news.mit.edu/2010/obit-gavin.

[4] Author's multiple discussions with Gavin over multiple years.

[5] Neil A. Armstrong, "Joseph G. Gavin, JR. 1920-2010."

[6] Joseph G. Gavin, Jr., interviewed by Rebecca Wright, NASA Johnson Space Center Oral History Project Oral History Transcript, Amherst, MA, January 10, 2003 [Hereafter: NASA Interview, 2003].

[7] "NASA-Grumman Negotiations," https://www.hq.nasa.gov/pao/History/SP-4205/ch4-7.html.

[8] Joseph G. Gavin, Jr., "The Apollo Lunar Module (LM): A Retrospective," IAC-02-IAA.2.3.08, paper presented at 53rd International Astronautical Congress, Houston, TX, October 10-19, 2002 [Hereafter: IAC, 2002], 5.

[9] NASA Interview, 2003.

[10] NASA Interview, 2003.

[11] NASA Interview, 2003.

[12] IAC, 2002, 2.

[13] NASA Interview, 2003.

[14] NASA Interview, 2003.

[15] Author's discussion with Gavin over the years and review of his public statements and annotated flight plans, especially for Apollo 11. See also Douglas Martin, "Joseph Gavin, Who Helped Put First Man on Moon, Dies at 90," *New York Times*, November 4, 2010, http://www.nytimes.com/2010/11/04/business/04gavin.html?src=busl.

[16] Author's interview with Gavin, Amherst, MA, December 11, 1998.

[17] NASA Interview, 2003.

[18] NASA Interview, 2003.

[19] IAC, 2002, 3.

[20] NASA Interview, 2003.

[21] Martin Childs, "Joseph Gavin: Aerospace engineer who played an integral part in the first moon landing," The Independent, January 1, 2011, https://www.independent.co.uk/news/obituaries/joseph-gavin-aerospace-engineer-who-played-an-integral-part-in-the-first-moon-landing-2173400.html.

[22] NASA Interview, 2003.

[23] Author's experience watching Apollo 13 with Gavin upon its release in South Hadley, MA.

[24] Neil A. Armstrong, "Joseph G. Gavin, JR. 1920-2010."

[25] Author's interview with Gavin, Amherst, MA, December 11, 1998.

[26] Author's interview with Gavin, Amherst, MA, December 11, 1998.

[27] NASA Interview, 2003.

[28] "Fly Me to the Moon: An Interview with Joseph G. Gavin, Jr.," *Technology Review* 97:5, (July1994): 62.

[29] IAC, 2002, 4.

[30] NASA Interview, 2003.

[31] NASA Interview, 2003.

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[38] NASA Interview, 2003.

[39] NASA Interview, 2003.

[40] NASA Interview, 2003.

[41] NASA Interview, 2003.

[42] NASA Interview, 2003.

[43] Neil A. Armstrong, "Joseph G. Gavin, JR. 1920-2010."

[44] David L. Chandler, "Aerospace engineer Joseph Gavin '41, SM '42 dies at 90: Former president of Grumman Aircraft led Lunar Module development for NASA, aided in the rescue of Apollo 13," *MIT News Office*, November 5, 2010, http://news.mit.edu/2010/obit-gavin.

[45] Neil A. Armstrong, "Joseph G. Gavin, JR. 1920-2010."

[46] NASA Interview, 2003.

[47] Author's discussion with Gavin, 2002.

[48] David L. Chandler, "Aerospace engineer Joseph Gavin '41, SM '42 dies at 90: Former president of Grumman Aircraft led Lunar Module development for NASA, aided in the rescue of Apollo 13," MIT News Office, November 5, 2010, http://news.mit.edu/2010/obit-gavin.

[49] Author's interview with Gavin, Amherst, MA, December 11, 1998.

[50] Author's discussion with former *Aviation Week & Space Technology* journalist Craig Covault, who accompanied Gavin on the trip.

[51] Back to Methuselah, Part I, Act I, 1921.