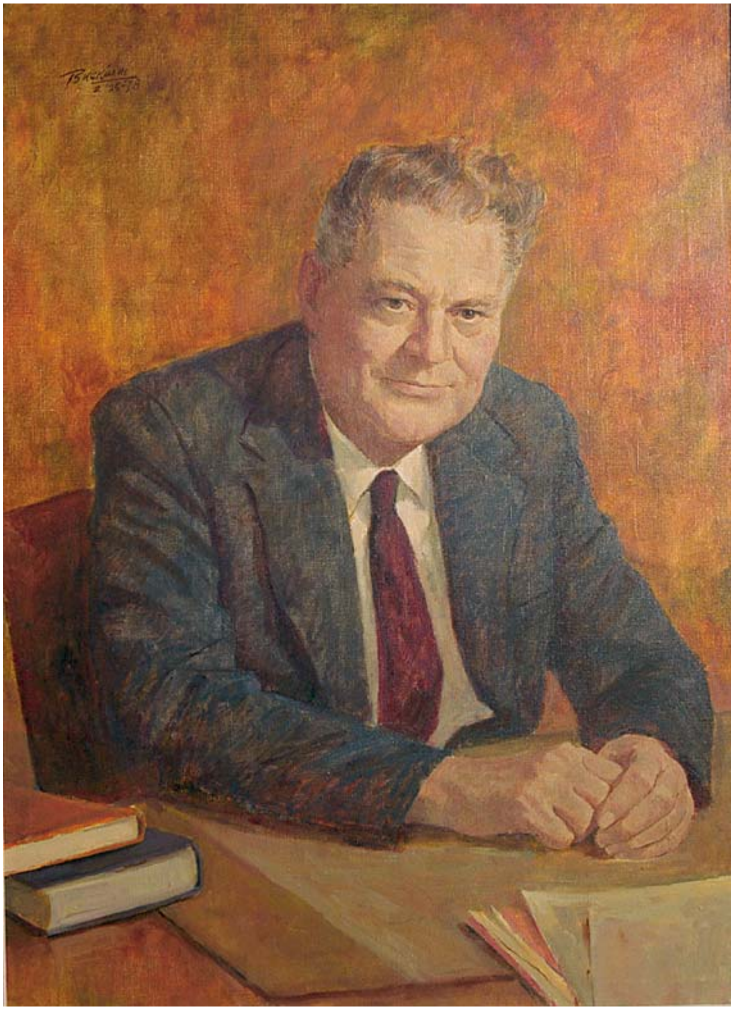

H. Julian Allen: An Appreciation*

Walter G. Vincenti,[1] John W. Boyd,[2]
and Glenn E. Bugos[2]

[1]Department of Aeronautics and Astronautics, Stanford University, Stanford, California 94305; email: sts@stanford.edu

[2]NASA Ames Research Center, Moffett Field, California 94035; email: John.W.Boyd@NASA.gov, Glenn.E.Bugos@NASA.gov

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Abstract

Harvey Allen is best known as the genius behind the blunt-body concept, published in 1953, which enables spacecraft to return safely home through Earth's dense atmosphere. He was also an extraordinary research leader, who led a world-class research program in hypersonics at the NACA Ames Aeronautical Laboratory. This paper reviews his career as one of America's leading theorists and experimenters, including his engineering education at Stanford, his work on the inverse problem of calculating the airfoil profile to obtain a desired pressure distribution, his hand in constructing wind tunnels and experimental facilities at Ames, and his pioneering and wide-ranging work on atmospheric re-entry. It concludes with an appreciation of his uniquely inspirational style of research management, and of his magnetic personality.

EARLY YEARS

Allen was born in Maywood, Illinois in 1910, on April Fools' Day. His father, Henry Judson Allen, had been attending the Art Institute of Chicago and, when Allen was still young, he moved the family to Palo Alto, California. Henry Judson Allen was the head interior designer for the upscale Gump's department store in San Francisco, and he traveled the world searching out new furniture trends. Allen grew up in a big house at 831 University Avenue, the main thoroughfare in Palo Alto, an environment rich with intellectual stimulation from nearby Stanford University. He built his own laboratory in the basement, where he fabricated, most memorably, an electric elevator for his sister's dollhouse. His mother took in boarders, frequently graduate students from Stanford.

Allen also enrolled at Stanford, where his interests evolved: "During high school I wanted to be an electrical engineer," Allen later reflected, "but by the time I got to Stanford I found aerodynamics was where my real interests centered. I decided then I wanted above all to work in theoretical aerodynamics; I wanted to work with the NACA; and I wanted to live near Stanford. In 1935 it wasn't clear how I was going to manage the first two—the third seemed just a dream" (Rudneff 1957). In fact, he lived his dream.

Allen earned his bachelor's degree from Stanford University in 1932. He continued in the aeronautics option, then in the mechanical engineering department at Stanford, working as a research assistant in Stanford's Guggenheim Aeronautical Laboratory. He won Stanford's William Robert Eckart Prize for outstanding aeronautics student, and in 1935 earned his professional degree of Engineer. For six months, happy for any job in the depression, he worked as a junior engineer for the Shell Chemical Company at its new Shell Point plant (near Pittsburg, California) where natural gas was converted into ammonia for fertilizers. In early 1936 he joined the National Advisory Committee for Aeronautics (NACA) and worked for the next four years as a junior engineer at its Langley Memorial Aeronautical Laboratory near Norfolk, Virginia.

Working in the Variable Density Tunnel Section led by Eastman Jacobs, Allen quickly made his mark. He offered key theoretical insight into Jacobs' development of the laminar flow low-drag airfoil. Allen's interest in the matter continued beyond his departure from Langley, and culminated in an important and useful theoretical paper published in 1945 (see below).

NACA AMES AERONAUTICAL LABORATORY

Early in 1940 Allen moved to the NACA's newly established Ames Aeronautical Laboratory at Sunnyvale, California. He had worked on preliminary planning for Ames for almost a year before. While still at Langley, Allen turned his talents to refining plans for Ames' complex of wind tunnels, anticipating how they could be made more efficient and versatile. Laboratory Director Smith J. DeFrance recruited Allen early on, and some of Langley's best engineers moved west as well.

From 1941 to 1945–for the duration of World War II–Allen served as chief of the Ames Theoretical Aerodynamics Section. In actuality, he devoted himself to experiment as much as to theory, and to consulting for other sections of the laboratory as well as leading his own. His consulting work included wind tunnel and flight tests of the innovative and later highly successful North American P-51 Mustang fighter plane, the first to incorporate the laminar-flow airfoil he had helped develop at Langley.

His experimental work included a proposal and design of the novel 1-by-3.5-foot high-speed tunnel, a cobbled-together tunnel optimized for testing airfoil shapes for aircraft approaching the then-intimidating speed of sound. One nonaerodynamic task also given his Section was to detail the structural design of the reinforced concrete buildings being built in the new laboratory. He was often heard to answer his telephone with "Theoretical Concrete and Reinforced Aerodynamics Section!"

The theoretical work begun at Langley, though, generated Allen's most influential accomplishment of the early 1940s—and one of the two most exceptional of his career. He presented this work in the 1945 report entitled "General Theory of Airfoil Sections Having Arbitrary Shape or Pressure Distribution" (Allen 1945). This completed the work he had begun at Langley in 1936 and refined for several years in airfoil design and testing work at Ames. By the early 1930s the direct problem of calculating the pressure distribution on an airfoil profile of given shape had received much attention and been solved satisfactorily. For a laminar-flow airfoil—and for the airfoils needed for the near sonic speeds being approached in the mid 1940s—it became necessary to attempt the more difficult inverse calculation of the shape to give a desired pressure distribution. A method for solving this inverse problem had been advanced in 1935, but it was complicated and laborious (Betz 1935). As in the well-known small-disturbance (i.e., linear) theory for the direct problem, Allen's theory separated the effects of airfoil camber and thickness. It then treated camber in the usual mathematically logical direct-problem way, as a small departure from a uniform stream. For thickness, however, the blunt shape of a profile at the leading edge creates a large departure in that vicinity, and a similar small-departure treatment gives unrealistic results. Allen avoided this difficulty by an ad hoc treatment of the profile as a small departure from a Joukowski base profile having a leading-edge radius approximately the same as that of the profile of concern.

Allen's theory gave realistic and useful results and, most importantly, provided solution of the inverse problem with reasonable effort. Allen and his coworkers at Ames employed it routinely in their study and development of the high-speed airfoils then becoming so important. It reduced the effort spent on parameter-variation tests done in high-speed wind tunnels. In 1944, Allen and Walter Vincenti had successfully used some of Allen's methods for a lengthy derivation of equations to correct airfoil measurements for effects of wall interference in a high-speed tunnel. These were needed for the Ames 1-by-3.5-foot tunnel, and became widely used elsewhere (Allen & Vincenti 1944).

Later in the 1940s, Allen, in collaboration with Edward Perkins, developed a well-known theory for predicting forces at supersonic speeds on slender bodies of revolution at angles of attack, which proved especially useful in designing missiles and jet-powered aircraft. He also studied oscillating vortices on wings at angles of attack, guided work in heat transfer and boundary layers at supersonic speeds, and worked on the interaction between shock waves and boundary layers. He also devised two experimental methods for visualizing air flows at supersonic speeds.

Allen obviously concerned himself with a wide range of challenges. His work easily crossed any boundary between theory and experiment. Designing wind tunnels, which continued to occupy him, required as much analytical insight as designing the objects tested inside them, and Allen envisioned the aerodynamics of tunnels and test objects as a continuum.

In 1945, Allen made a major experimental breakthrough when he devised a new type of nozzle to provide the throat adjustment needed to vary the speed in a supersonic tunnel. At a meeting on the nozzle problem with research workers from other NACA laboratories, Allen learned that Abe Silverstein and his associates at the Cleveland laboratory had been experimenting with a circular tunnel having a central plug. The plug could be pushed back and forth in the nozzle throat, thus changing the throat area and varying the speed in the downstream test section. With this arrangement, however, the test model lay in the turbulent wake of the plug.

Returning home, Allen reasoned that this unsatisfactory situation could be eliminated by using a square-cross-section tunnel having a suitably shaped asymmetric profile with a lower wall that could slide back and forth. Allen and his team then tested and refined shapes for such a sliding-block throat, first with a 2-by-2-inch model of the section and then an 8-by-8-inch model using blow-down air from an existing high-pressure tunnel. The resulting final shape was used in a new 6-by-6-foot tunnel, by far the largest supersonic tunnel of its day, and it later appeared in other large supersonic tunnels.

From 1945 to 1959, the most productive part of his career, Allen served as chief of the Ames High-Speed Research Division—a newly formed group dedicated to aerodynamic problems at high supersonic speeds. This division was on par with the two other research divisions at Ames. The Full Scale and Flight Research Division managed the 40-by-80-foot full-scale tunnel as well as all the flight research aircraft. The Theoretical and Applied Research Division managed the 7-by-10-foot low-speed tunnels, the 16-foot high-speed subsonic tunnel, and the 12-foot pressure tunnel. By 1947, Allen's group managed the 1-by-3-foot subsonic tunnel, the 1-by-3.5-foot transonic tunnel, and the 8-by-8-inch supersonic tunnel. The most active of these was the 1-by-3-foot tunnel, with Walter Vincenti as section head, managing a staff of 40 people. Renowned aerodynamicists R.T. Jones and his wife Doris Cohen reported directly to Allen.

By his example, Allen led this group of some of America's best and brightest aerodynamicists. In succession, they went on to build a 3.5-foot tunnel to test aircraft shapes at sustained hypersonic speeds, followed by a series of re-entry simulators to achieve realistic ballistic speeds and then by arc-jet tunnels for sustained heating of potential heat-shield shapes and materials. Allen also critiqued every step in the aerodynamic design of the X-15 hypersonic research aircraft, which further refined his theories on blunt-body heating as applied to lifting-body shapes.

During the 1950s, Allen achieved his legendary status as a research leader. Allen had derived his team-building spirit from his early years with Eastman Jacobs at Langley. Other examples of such team building are how John Stack at Langley and

Wernher von Braun at the Army Ballistic Missile Agency infused their research groups with an *esprit de corps* and a sense of research as a team. Allen convinced those who worked with him that they truly were interdependent and that the success of the group would be shared as a whole. Indeed, Allen often inspired research projects for which he took no credit in the written reports. While other parts of the NACA were becoming increasingly noted for their top-down bureaucratic management, Allen's group continued to reflect the small-group structure at the heart of the earlier NACA. Edwin Hartman, in his history of Ames, noted of Allen: "his team lunged forward like a pack of beagles with Harvey baying in the lead" (Hartman 1970, p. 183).

BLUNT-BODY CONCEPT

Allen's second exceptional accomplishment—indeed the major breakthrough in hypersonic aerodynamics—was his concept of the blunt-body shape for atmosphere-reentry vehicles. For any shape, the kinetic energy from the high re-entry speed goes into both heating the body and heating the airflow around the body. The intense friction from the boundary layer heats the body; the shock wave caused by the nose heats the airflow.

At the time, in the early 1950s, it was taken for granted that, like an artillery shell or ballistic missile, a re-entry body should have a conical-shaped nose with a sharp tip. With the conical nose cone, the attached conical shock wave was relatively weak, doing little to heat the airflow, while the high boundary-layer heating went into the vehicle. The resulting temperature could melt the sharp nose and even destroy the body structure.

From a brief analysis based on reasonable engineering assumptions, Allen showed that if more of the re-entry energy was put into the airflow, then less was left to heat the vehicle. This could be done by using a blunt nose to create a strong normal shock wave standing ahead of the vehicle. The disastrous heating problems could thus conceivably be solved. Allen's revolutionary idea occurred to him sometime in 1951. He first introduced the idea over lunch, remembered Alfred J. Eggers, then a 29-year-old aerodynamicist in Allen's group. Allen asked, seemingly jokingly, but probably after much private thought, for the table to consider "a spherical shape . . . something like an old Civil War cannonball" (*Conquest* 1958).

In the summer of 1952, DeFrance allowed Allen to specifically address issues of space flight. That summer the NACA leadership approved work that would, after a decade of refinements, lead to the X-15 hypersonic research aircraft. As America entered the space age, the NACA expected the military to focus on rockets and space flight and that its work in hypersonics would focus on atmospheric flight in something like an airplane (Swenson et al. 1966). Within the NACA's research purview, Allen easily found time to refine his blunt-body concept. The analytical details of the blunt-body concept, worked out in collaboration with Eggers, were circulated for peer review within the government in September 1952, then published in April 1953 (Allen & Eggers 1953). However, the work was at first highly classified as the U.S. Army and Air Force pondered whether to rely on it to define the shape of the nuclear warheads then under development for ballistic missiles like the Thor, Atlas, and Jupiter.

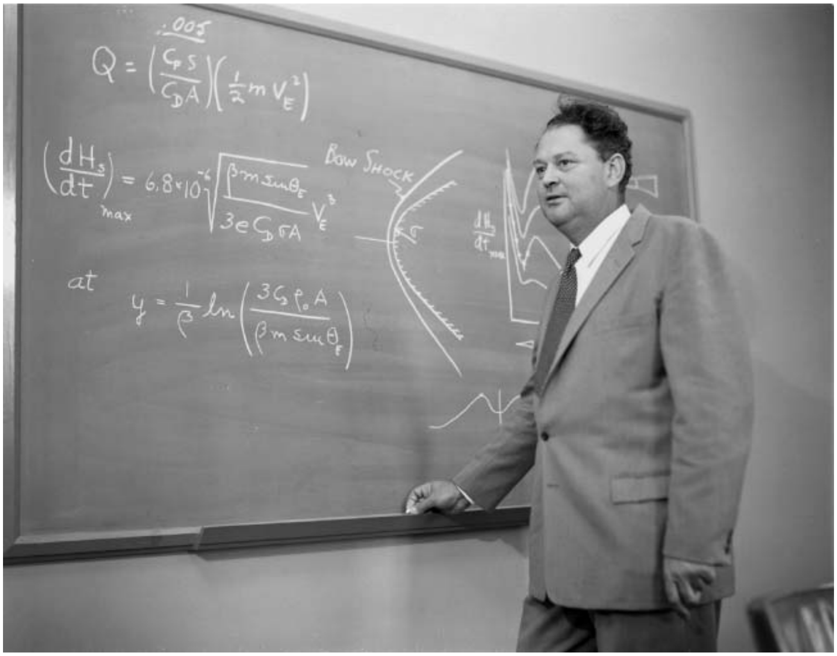

Figure 1

Harvey Allen, 1956, explaining his blunt-body concept.

The blunt-body analysis, like Allen's earlier airfoil theory, illustrates his creative engineering approach to difficult aerodynamic problems. He could use sophisticated mathematics when no other way was possible, but he preferred simplified analysis based on plausible physical assumptions (see **Figure 1**). Hartman again explained it well: "His interests lay not in trying to build a mathematical Taj Mahal. He was much more interested in useful results than in the virgin beauty of his mathematical edifice. He was not above using approximations, reasonable assumptions, unique analogies, and special devices with the result that he often found working solutions to problems that had baffled more polished mathematicians" (Hartman 1970, p. 108). Because of Allen's work, all successful re-entry bodies have been blunt.

Like most revolutionary ideas, Allen's concept met initial resistance. After a year of intense, organized skepticism, by the beginning of 1954 the U.S. Air Force completely changed the architecture of its ballistic missiles to embody the blunt-body concept. It helped that during the year American nuclear scientists had delivered the first practical hydrogen bomb—small enough to be delivered via missile—and that the Soviets had detonated their own hydrogen bomb–accelerating the American need for a solution. Even though his initial reports were still highly classified, for his body of work Allen in 1955 received the Sylvanus Albert Reed Award, recognizing the greatest achievement in experimental or theoretical work, from the Institute of Aeronautical Sciences (now the American Institute of Aeronautics and Astronautics).

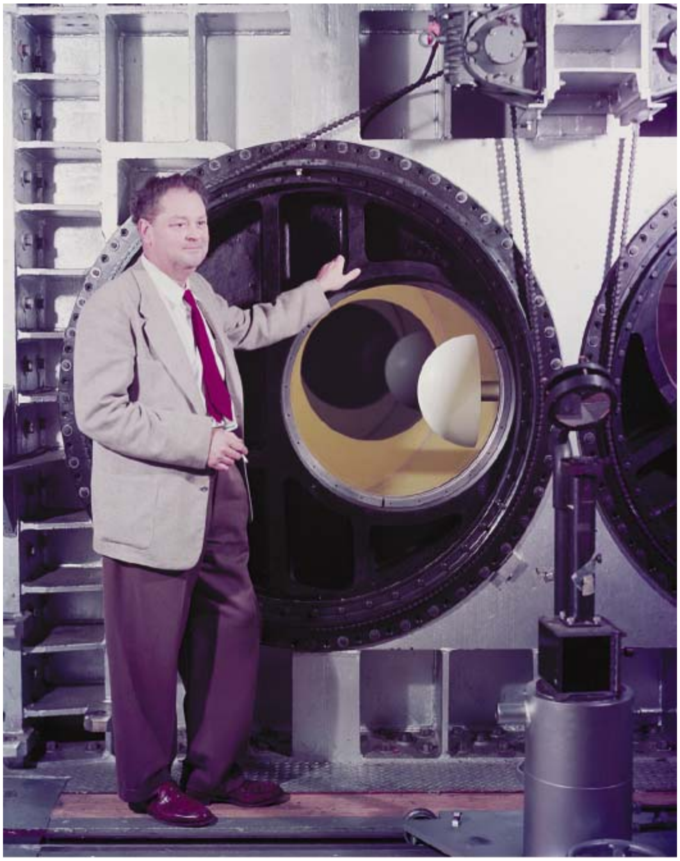

Figure 2

Harvey Allen posed with a blunt-body model in the 8-by-7-foot test section of the Unitary Plan Wind Tunnel, December 1957.

Over the next few years, additional aerodynamic analyses and experiments, mostly by Allen and his associates at Ames, confirmed the superiority of blunt re-entry bodies (see **Figure 2**). Allen and Eggers collaborated with Sanford Neice on a comparative study of the aerodynamic performance of three types of blunt-body vehicles on three types of re-entry trajectories—simple ballistic, gliding through the atmosphere with some lift, or skipping off the atmosphere during descent (Eggers et al. 1954). Their goal was to improve re-entry range by attention to lift-drag ratios, and thus outline ways that nose cones could be made smaller and lighter. Completed in December 1954, this report was the first complete presentation of the concept and advantages of the hypersonic glide vehicle, later called the lifting-body, and the concept that eventually drove the design of the Space Shuttle.

Allen also did a compelling theoretical study of the worse case scenario—of what would happen if a ballistic blunt-body nose cone was tumbling or misaligned from the flight path as it entered the atmosphere (Allen 1956). The Soviets chose a spherical shape for their Vostok capsules because they considered a sphere more forgiving of misalignment problems. Allen demonstrated that misalignment—yaw or pitch—would result in oscillations that would dampen out without excessive heating, force, or effect on miss distance of the target. Tumbling prior to re-entry, he showed, required more active correction. With these three papers—on the solution to heating, on re-entry flight performance, and on the prospects of aerodynamic stability—Allen laid a firm theoretical foundation for all re-entry body designs.

Anticipating the day when humans would ride in nose cones, Allen considered how to design a gentler re-entry scenario. He increasingly noted that humans had a lower tolerance for heating and G forces than satellites, and supported Dean Chapman's efforts to calculate the best, shallower trajectory for human-bearing re-entry vehicles.

Allen also led his group at Ames in generating important collaborating data. He had earlier devised a shock tunnel into which a tiny model of a re-entry vehicle was shot from a gun upstream into a supersonic rush of air traveling the opposite direction. The superposition of the speeds of the airflow and model resulted in relative airspeeds as high as Mach 4.5. Allen designed the Ames Supersonic Free Flight Facility (SSFFF) to use blow-down air—that is, pressurized air exhausted from the interior of the nearby 12-foot wind tunnel—as it passed through the outmoded fixed nozzles used on the 1-by-3-foot tunnel. That way, Allen built the tunnel for only $125,000, most of which went toward high-precision shadowgraph cameras capable of viewing the model as it sped through the tube. Unveiled at the July 1950 NACA Biennial Review, the Ames SSFFF was used for a series of important tests of aerodynamic stability in supersonic flight.

Allen's SSFFF also launched a decade of refinement to, and investment in, the free-flight range concept. By 1955, Allen's group had devised a free-flight tunnel capable of reaching 10,000 feet per second. Using the free-flight ranges Allen had designed, other researchers at Ames demonstrated that, with careful attention to the aerodynamic forces around the blunt face, Allen's blunt-body shape was indeed largely self-correcting in terms of aerodynamic stability (see **Figure 3**). Other tests in the Langley vertical wind tunnel showed which nose-cone designs would remain stable at slower speeds and denser atmospheres.

With little fanfare, largely because information about nose-cone design was being published elsewhere, in April 1957, the reports done by Allen and Eggers were made public. On May 15, 1957, NACA Chairman James H. Doolittle presented Allen with the NACA Distinguished Service Medal for his work in solving problems of hypersonic flight. The next day, Allen and NACA Director Hugh L. Dryden held a press conference to explain the blunt-body concept. Allen, at 47 years of age, briefly became a national celebrity.

On August 18, 1957, the scaled-down nose cone of a Jupiter C rocket (the C stood for Composite Re-entry Test Vehicle) designed by the Army Ballistic Missile Agency in Huntsville, Alabama, reached outer space—up 270 miles—and was recovered 1149 miles down range. The nose cone had a blunt nose, with an ablative coating. This was the first American object safely returned from beyond the earth's atmosphere (although the Soviets, using a spherical shape, had beat the United States by a week). Inside was a letter on plain paper, which survived without any scorching.

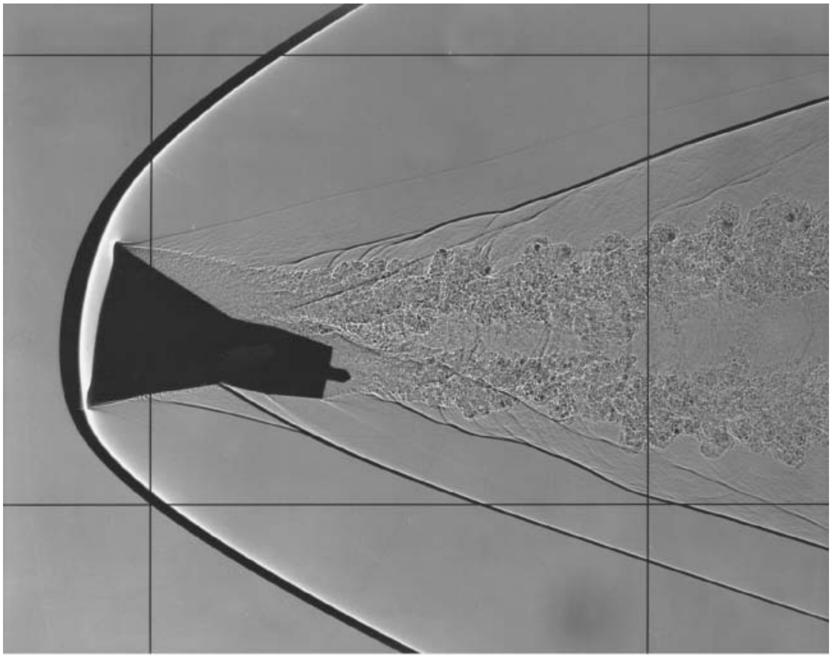

Figure 3

A free-flight test of an early capsule design in the Ames Supersonic Free Flight Facility (SSFFFF).

President Dwight Eisenhower displayed the recovered nose cone on television from the Oval Office on November 8, 1957 and, in the aftermath of Sputnik, proclaimed it America's first space success.

"One difficult obstacle on the way to producing a useful long-range weapon," Eisenhower declared, "is that of bringing a missile back from outer space without it burning up like a meteor because of friction with the Earth's atmosphere. Our scientists and engineers have solved that problem" (*Conquest* 1958).

In the weeks that followed, Allen was featured on a television show hosted by Eric Severeid and on Arthur Godfrey's radio program. With bemused understatement likely appreciated only by his friends, Allen told a newspaper reporter that "It's all in the physics book . . . All I did was apply known laws." The reporter, in reflecting on his technical acumen, described this genius "as an $11,000-a-year engineer" who worked for the government (*Washington Post* 1957). But at a time when Congressmen were publicly bemoaning poaching by aerospace companies of government employees, Allen claimed he had no plans to leave NACA. "I'm a research man," he told a reporter from *Time* magazine, "The NACA gives me freedom to work. I'm sticking with them" (*Time* 1957).

The U.S. Air Force presented Allen with its Air Power Trophy, and the Institute of Aeronautical Sciences chose him to deliver the prestigious Wright Brothers Lecture on December 17, 1957. That morning Avco Manufacturing Company announced that they chose a blunt shape for the U.S. Air Force Titan missile warhead.

The press portrayed Allen's insight into the blunt-body concept as a Eureka moment notable for its genius. Allen downplayed the genius in his insight. He had spent the previous five years exploring the various elements of supersonic flow—shock waves, boundary layers, turbulence. When the problem of atmospheric re-entry was presented to him, he used the tools he had, and focused on the shock wave and boundary layer. His 1953 report setting forth his ideas was beautiful in its simplicity and directness. But the true genius lay in Allen's epistemological strategy, that is, not what he knew about hypersonics but how he knew it. In the decade following his 1951 theoretical work, Allen invented a variety of test instruments to refine and experimentally validate his concept of the blunt body. Until the Jupiter nose cone validated Allen's work in real-world conditions, the entirety of what was known about re-entry vehicles came from theory and laboratory apparatus. But Allen, who designed or inspired this laboratory apparatus, had reason to believe the data they produced provided a firm foundation for the detailed design that would be done by the military and defense contractors. Allen began to push his theories further into the space age.

In his 1957 Wright Brothers Lecture, Allen presented a passionate anticipation of the next phase in America's use of hypersonic aerodynamics–of how better to use the earth's atmosphere to optimize travel in space (Allen 1957). Having proposed the advantages of lifting-body vehicles in December 1954, Allen then largely turned over the mathematical details to bright young engineers—Eggers and others, but continued to provide leadership and simplifying assumptions. Because so much of the weight of a re-entry vehicle could need to be allocated to a coolant system, Allen opined, " . . . there are two closely connected questions which the designer must ask himself: 'Can the rocket vehicle be made reasonably efficient compared with the airplane?' and 'What can be done to minimize the aerodynamic heating problem?'" (Allen & Neice 1956). In a series of papers and speeches in the late 1950s and early 1960s, Allen persuasively argued that advanced work in hypersonic aerodynamics would make it possible to travel farther in space even without dramatic improvements in rocket boosters (Allen 1960, Allen 1962a).

DIRECTOR FOR ASTRONAUTICS

In November 1959, Allen was appointed the NASA Ames Assistant Director for Astronautics, responsible for finding ways that Ames experts and facilities could provide answers to get America into space. On October 1, 1958, DeFrance had submitted to NASA headquarters an organization chart that displayed little change over recent years. However, in September 1959 he was pushed by NASA headquarters to report a more fundamental reorganization. The most important part of DeFrance's Center reorganization was that Allen, as the new Ames Assistant Director, became directly responsible for guiding research and operations in the Space Physics and Structures Division, the Aero-Thermodynamics Division, and the Supersonic Aerodynamics Division. Russell Robinson continued as the other Assistant Director, inheriting most of the lower-speed and flight-testing work being done at Ames.

With his increased responsibility, Allen led the creation of a world-class gas-dynamics group. This included the design and construction of arc jets to learn how materials melted or combusted under intense direct heat. Allen convinced DeFrance to buy a Linde arc jet, a small fan that pushed air through an electric arc to get a sustained hot stream. Linde was a German company specializing in gas manufacture. Immediately, Allen collected a group of engineers interested in improving the arc jet to simulate the sustained convective heating of re-entry. He also increasingly considered the problem of radiative heating—that is, heat from the luminous gas caps, created by ionized air molecules, that blazed in front of re-entry vehicles. He calculated the potential for radiative heating, and then suggested an arc jet that could more realistically combine radiative and convective heating (Allen 1962b).

Another group, primarily chemists and metallurgists, looked at the impact of heat on various materials. Allen had decided an ablative covering on a nose cone could work better than an actively cooled one, but it still took a fair amount of research to derive the best ablative material. The material had to withstand the cold of space as well as the heat of re-entry. It also needed to be flexible enough to accept the optimal aerodynamic shape, and had to withstand structural stress. Meanwhile, the development of more precise data on heat flows allowed for better design of ablative materials. With the results of this work, Ames was able to suggest which ablative materials were best suited to the blunt-body shape of the Mercury capsules.

President John F. Kennedy stood before the world on May 25, 1961 in his Special Message to Congress and declared: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth" (Kennedy 1961). Many people have since forgotten that clause " . . . and return him safely to Earth" but, simply and eloquently, it validated Allen's immense contribution to America's conquest of space. Kennedy reinforced his point a few minutes later, proposing additional funds "for one purpose which this nation will never overlook: the survival of the man who first makes this daring flight." Thereby, Kennedy defined the terms of the race. It was not enough to get to the moon, you also needed to get back. The Soviets already had bigger boosters able to hit the moon, but most likely they did not have the complex of technologies needed for the return trip. That trip would end in a fiery streak into the earth's atmosphere, and to get through that Kennedy seemed confident in Allen's array of re-entry technologies.

Despite the change in organizational culture as the basic-research-driven NACA was converted into the applied-technology-driven NASA, Allen kept a fan club within the new administration. Allen shared his curiosity in the wonders of fluid flows with Hermann Kurzweg, who headed the NASA headquarters Office of Aeronautical Research and Technology that funded Ames. Kurzweg came to Ames once a year to review research programs, and always delighted in the playful way Allen described very serious research efforts. This relationship in large part helped Ames secure some important new areas of research during the early NASA years, notably in fundamental space biology and flight simulation.

"Throughout his career," remembered Stanford aeronautics department head Nicholas Hoff, "Harvey Allen combined the fundamental curiosity of the natural scientist with the practical thinking of the engineer" (Hoff 1979). One example of his wide-ranging curiosity arose from his work on ablation of hypersonic objects. In 1961, Allen began to look ahead to re-entry problems on a return trip from Mars or Venus. Working with Alvin Seiff, an Ames aerodynamicist who did much pioneering work on entry into nonearth atmospheres, Allen looked at re-entry speeds higher than earth parabolic speed, then revisited the heating and melting of conical shapes. New ablative materials could keep a conical shape intact during re-entry melting, and thus could be more efficient than a blunt body because the decrease in radiative heat transfer from the heated air would be greater than the increase in convective heating (Allen & Seiff 1963).

In thinking about ablative materials and the blunt-body concept, Allen examined collections of meteorites, wondering how they might have survived the intense heat of entry into the earth's atmosphere—at angles much steeper and speeds many times faster than man-made spacecraft. In doing so, he grew curious about their aerodynamic stability. Furthermore, the life sciences had arrived at NASA, and more people grew interested in the chemical composition of meteors and how heating might have altered it. Even as his administrative duties at Ames grew, Allen would spend hours plotting the trajectories of meteorites. He worked with astronomer Fred Whipple and relied on data gathered from Whipple's Prairie Network, which monitored meteor events throughout North America. Allen was especially interested in an acceleration anomaly as meteors entered Earth's atmosphere, which he attributed to ablation that resulted in frothing and sloughing (Allen & Baldwin 1968).

NASA AMES CENTER DIRECTOR

Allen became Center Director at Ames in October 1965, upon the retirement of DeFrance, the founding director. Allen took the position reluctantly. Becoming Director would take him farther from his own research; then again, his research might suffer more if the Center was run by someone less prepared for the post.

Allen used a simple technique for managing research that scaled up brilliantly. He would identify people of talent, suggest challenging problems, and then stand back and let nature take its course. He was a hands-off as opposed to over-the-shoulder manager. "This technique really worked," remembered Jack Boyd, "since Harvey was such an excellent judge of ability."

Allen continued his tradition—after lunch, when Washington bureaucrats stopped trying to reach him on the telephone—of perambulating about the Center, showing up in laboratories unannounced and helping younger engineers puzzle through their toughest challenges. Bill Harper remembered, "No matter who you worked for, you could expect to find Harvey dropping by to learn of your progress and constructively criticize what you were doing" (*Astrogram* 1977). Thus, Allen remained well informed about the hopes and dreams of those at his Center and inspired them to work hard to keep Ames' essential atmosphere as a research center.

Still, his personality remained effusive and driven by his friendships. Allen would rush home by four o'clock every afternoon so he could watch *Perry Mason* on television. Like Mason, Allen perhaps appreciated the ability to find flexibility in the law and proof in unexpected places. One of the accomplishments during Allen's tenure as Center Director was prompted by Jack Glazer, Ames's legal counsel, who initiated outreach programs with universities to conduct grant research. To establish an agreement with the University of New Mexico, Harvey decided that he, Glazer, and Boyd should travel there by train. They took some good books, plenty of good spirits, and by the time they arrived in Albuquerque were prepared to sign a Memorandum of Understanding for research into the geology of other worlds.

Allen resigned as Center Director in 1968, but remained as acting Center Director until his replacement was named in February 1969. Two of his best friends—Jack Stalder and Bob Crane, both researchers at Ames—had recently died, and Allen told those who asked that the fun had simply gone out of the job. Perhaps he also recognized that an Ames in a post-NACA, post-Apollo period would need a Director who understood newer research tools and fields. Indeed, Hans Mark, who succeeded him, worked computing into every facet of Ames in the 1970s, notably in pioneering the field of computational fluid dynamics. A few months before his retirement, Allen appointed Clarence "Sy" Syvertson as his deputy. Allen thought Syvertson had the ability to be a good Center Director, though he was too young at the time. Mark kept Syverston as his deputy, and Syvertson later succeeded Mark as Director (see **Figure 4**).

Retirement freed Allen to pursue new research, for the simple fascination of it. The more Allen learned about the aerodynamics of it, the more curious he grew about how owls could swoop down on their prey so silently. He examined some owl wings and discovered that protruding from the leading edge were countless needle-like feathers. Running the wings through his bathtub at home, he observed how these feathers changed the fluid flow by creating a small bubble just behind the leading edge. Once he retired, Allen took a research contract through nearby Nielsen Engineering and Research, Inc. for an experimental and theoretical analysis of leading-edge serrations, expecting to find applications that would quiet helicopter rotors. Back at Ames, he mounted some similar needle-like protuberances on fan blades and discovered they did quiet the blade, apparently by changing the vortical flow over the blade into quiet laminar flow (Allen & Schwind 1973). As a remembrance of Allen's perpetual curiosity, and as a note of their affection for him, the retiree's club of Ames professional employees calls themselves "The Owl Feather Society."

A PERSON AND A FRIEND

His personality and passions were a source of constant and loving amusement to Allen's coworkers at Ames. Harvey, a lifelong bachelor, loved life: gregarious by nature, a world traveler, a lover of Oriental cuisine and of classical music. As Hartman noted, Allen's enthusiasms included "ancient Isotta-Fraschini automobiles, symphonic music, and great Saint Bernard dogs—preferably with kegs attached" (Hartman 1970, p. 109).

Beside the Isotta-Fraschini, he at various times owned a 1931 Duesenberg, a Rolls-Royce, a 1936 Mercedes-Benz touring car, and a Cadillac. His house in the Professorville section of Palo Alto was full of museum-quality Asian art and furniture. He returned from one trip to the Far East with so much furniture that he had to build

Figure 4

Allen and Ames Center leadership at his retirement party inside the NASA Ames Flight Research Hangar, October 24, 1968. Left to right: Arthur Freeman, Smith J. DeFrance, Allen, Jack Boyd, Clarence Syvertson, Charles Hall, Harold "Chuck" Klein.

an addition to his house. At the same time, he remodeled the kitchen so he could display the new culinary skills he had acquired. A reporter for *Time* magazine, who called Allen "a great shaggy bear of a man," likened his house to "a highbrow junk pile. Some items: five aquariums for tropical fish, antique oriental sculpture, a reed organ, a library on Mayan architecture" (*Time* 1957). He played the piano well and often liked to have his guests guess what piece he was playing. He thought an appreciation of classical music was all that was required to consider his friends to be culturally refined.

Allen was a bon vivant and a skilled conversationalist and bartender. He attracted a party wherever he went socially. He animated lunchtime conversations at the Ames cafeteria. He had a warm sense of humor that blended with his highly creative mind and his informal and sincere approach to people. His parties, at his home in Palo Alto, started after work and continued long into the night. He was known as a great cook.

His guests especially remember his stews, which he probably grew expert at because they could feed the large numbers of people who came through his door.

Allen was as dedicated to his family as to Ames. "He took care of people his whole life," remembered his niece, Suzanne Aldrich. He had one brother and two sisters, and was closest to his sister Josephine. After her husband died in 1935, Allen helped raise her three children. When Allen's parties needed a hostess, JoJo stepped up.

Harvey Allen had a nickname for everybody, often the same name. In the early years at Ames, he took to greeting everyone with the title "Doctor." Actually, no one in his group then had such a degree. Most were still in their mid 20s—too young to have even theoretically earned the degree. As it happened, however, his small theoretical group soon did hire a mathematician with a Ph.D. One day, Milton Van Dyke, a new young employee who looked even younger, walked into the group's office, and Allen greeted him with "Doctor Van Dyke!" The mathematician could take it no longer and exploded: "My god! Does everybody here have a doctor's degree?" The room broke out with hilarious laughter. The fact that only the mathematician really had a doctorate didn't matter in what the group accomplished. With only one such degree present, Allen's people did some of the best academic-type research in the world.

Allen also went through a period of calling everybody "Harvey," after the invisible rabbit-pooka drinking buddy in the hit 1944 Broadway play by that title by Mary Coyle Chase. The name stuck to him in return, and he loved it. (The H in H. Julian Allen was for Harry, which only members of his family seem to remember.) Late in the play, Elwood P. Dowd explains, in words also fitting to Harvey Allen: "Science has overcome time and space. Harvey has overcome not only time and space, but any objections from it." Indeed, time, space, and speed all seem to warm to Harvey Allen's charm.

ALLEN'S LEGACY

Allen died suddenly, of a heart attack, at the age of 66 on January 29, 1977. In 1970, NASA Ames had created one of its top awards in his honor—the H. Julian Allen Award for the Best Paper by a NASA Ames Researcher over the previous two years. To establish the award, an extraordinary inaugural Allen Award—to designate it as an exemplar of the best in scientific and technical research—was presented retroactively to the Allen & Eggers (1957) paper on re-entry aerodynamics.

Allen remains one of NASA Ames' true legends—for his scientific and engineering genius, his experimental prowess, his innate leadership skills, his spirit of imaginative inquiry, and the force of his personality. Like the blunt-body re-entry shape that was his greatest invention, Allen himself blazed through aerodynamic research generating a shock wave of novel insights.

AWARDS AND FELLOWSHIPS EARNED BY H. JULIAN ALLEN

Member, National Academy of Engineering (elected 1966)
Fellow, American Institute of Aeronautics and Astronautics (elected 1968)
Fellow, Royal Aeronautical Society (elected 1968)

Fellow, Meteorical Society

Sylvanus Albert Reed Award, Institute of Aeronautical Sciences (1955): "for contributions and leadership in solving problems in the design of supersonic airplanes and missiles, especially the thermal problems at hypersonic speeds."

Wright Brothers Lectureship, Institute of Aeronautical Sciences (1957)

Distinguished Service Medal, National Advisory Committee for Aeronautics (1957)

Airpower Trophy, Air Force Association (1958)

Exceptional Scientific Achievement Medal, National Aeronautics and Space Administration (1965): "for his contributions and leadership in solving problems in the design of supersonic airplanes, missiles, and spacecraft, especially the thermal protection problems at high velocities, culminating in applying meteor phenomena as a unique tool (unavailable in laboratories) for examining the heating problems associated with future interplanetary missions."

Daniel Guggenheim Medal, American Institute of Aeronautics and Astronautics, American Society of Mechanical Engineering, Society of Automotive Engineers (1969)

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Contents

Indexes

Errata

An online log of corrections to *Annual Review of Fluid Mechanics* chapters (1997 to the present) may be found at http://fluid.annualreviews.org/errata.shtml