Alvin R. Eaton (1920–2011)

Al Eaton, an aerodynamics pioneer whose designs formed the basis for modern guided missile weapon systems, died at his home in Clarksville, Maryland, on 20 October 2011. Al built a distinguished 66-year career at the Laboratory, a career that continued right up until his death. He had few peers in the quality and quantity of contributions made to the technology of guided missile warfare and ballistic missile defense. During his career, Al held several influential Laboratory leadership roles and served with distinction in multiple government scientific advisory capacities. A review of Al's career affords us rare examples of extraordinary contributions and accomplishments in engineering, leadership, and, ultimately, the defense of this nation.

Al grew up in Toledo, Ohio, and attended Oberlin College where he received an A.B. degree in physics in 1941. After graduation, he began work at the California Institute of Technology on a master's degree in aeronautical engineering, which he completed in 1943. Al remained at Caltech to continue his research, developing mathematical equations for the purpose of wall corrections in an octagonal high-speed subsonic wind tunnel, and soon thereafter became interested in supersonic aerodynamics with a particular focus on supersonic wind-tunnel and nozzle design techniques. He began tackling model-support problems relating to the stability of wind-tunnel flow conditions at supersonic speeds for the Ballistic Research Laboratory in Aberdeen, Maryland, and the Ordnance Aerophysics Laboratory in Daingerfield, Texas. While Al was researching techniques never before used in the Unites States for the purpose of wind-tunnel design, the U.S. Navy challenged APL with the development of a supersonic, long-range, ramjet-powered antiaircraft missile for the defense of Navy vessels. Recognizing the potential contributions that his research and expertise could make to both his country and the field of aerodynamics, Al accepted APL's offer to join the Laboratory and arrived in September 1945.

Supersonic aerodynamics appropriate to missile design was in its infancy in the mid-1940s. Only limited wind-tunnel lift and drag data obtained from testing in small tunnels were available for projectiles and airfoils. At the time there was no supersonic wind tunnel capable of providing adequate data for missile design. Consequently, the capability to calculate stability and control parameters to the required degree of accuracy was nonexistent. Simple linear theories were available for bodies of revolution or thin wings in isolation, but basic aspects of wing–body–tail or even wing–body interactions remained a mystery. Recognizing that the existing aerodynamic calculations were only good enough for preliminary designs, the Navy Bureau of Ordnance, as part of the secretive Bumblebee program, agreed to invest in the tools APL needed to advance the science. A modest-scale wind-tunnel facility was built at APL, and a more extensive facility for large-scale engine models was configured in Texas. Al immediately went to work directing APL's wind-tunnel studies required to develop a supersonic, long-range, ramjet-powered antiaircraft missile for the defense of Navy vessels. His efforts would soon produce revolutionary results.

Early flight-test telemetry revealed to aerodynamics engineers that the first supersonic surface-to-air missiles rolled unexpectedly at supersonic speeds—an anomaly that led to flight failures and nearly terminated the project. The condition, described as reverse aerodynamic roll, produced inaccuracies in early versions of supersonic surface-to-air missiles.

Tests of the APL supersonic test vehicle (STV) indicated that reverse roll could occur at supersonic velocities for missiles that obtained their roll control through differential deflection of small lifting surfaces located on a body forward of larger lifting surfaces. The STV had fixed, large aft lifting surfaces (tails), forward movable surfaces (wings) to provide pitch and yaw control, and small flippers (rollerons) located between the wings to furnish roll control. When the first test flights were conducted, roll was achieved on schedule, but the direction of the roll was opposite to that which was predicted from theory and subsonic experience. Al would recount later in life how he was challenged by two colleagues to explain and solve the problem: One evening at a hotel bar in Texas, Al solved the mystery by working out diagrams in pencil on a number of cocktail napkins to illustrate that, contrary to existing theory, a strong interaction of pressure fields at the wing–body juncture was occurring. He woke his colleagues in the middle of the night and met them at the wind tunnel to demonstrate his discovery. After several additional flight tests, and when the tail surfaces were differentially deflected, the roll performance was entirely consistent with expectations. It became apparent that predictable roll control could be achieved by using aft surfaces. This finding led to roll control by using roll flippers located at the extremes of the tail surfaces. Flight success was immediate, and today most modern supersonic guided missiles feature tail control: four tail surfaces typically used in a cruciform arrangement to provide all aspects of pitch, yaw, and roll control. Although some missiles have fixed forward lifting surfaces and some are wingless, tail control is now the prevailing choice for high-performance missiles. The missile designs now in use worldwide are, in large part, a result of Al's persistence in achieving high levels of performance.

In the early 1950s, when the Secretary of Defense pushed for the development of guided missiles, the Navy accelerated the schedule for the development and production of the Terrier missile. As the supervisor of the aerodynamics group during the early phase of the development of the Terrier guided missile program, Al was personally responsible for most of the aerodynamic design of the Terrier and for the tail-control Terrier program from inception into production. In fact, the Terrier and Tartar missiles, which evolved into the current Navy Standard Missile, were all developed on the basis of guided missile principles discovered in the Bumblebee program. While involved with the Standard Missile, Al applied two APL ideas that enabled Standard Missile to successfully evolve: (*i*) a noncritical aerodynamic configuration that minimizes the effect of changes in weight or center of gravity and (*ii*) a functionally sectionalized design that minimizes the overall effect of changes in a given element of the missile. In 1957, Al received the Navy Meritorious Public Service Citation, the Navy's second-highest recognition, for his revolutionary contributions in guided missile design, as exemplified by the Terrier missile, and contributions to the air defense capabilities of Navy ships.

Al always devoted extra effort to the projects in which he was involved. Much of his extra effort over the years improved various Fleet combat effectiveness areas, e.g., anti-air and anti-ship warfare, close-in and area defense weaponry, counter-countermeasures, command and control, and strategic communications. Al played a major role in the definition of the ship-fired version of the Harpoon. He placed special emphasis on the electronic countermeasures (ECM) resistance of the Harpoon seeker and campaigned for an exhaustive test program, including the development of an ECM hut, which was placed on target ships to provide ECM test environments that the Navy could not otherwise generate with available ECM equipment. This extra effort assured the Navy of an extremely effective seeker.

Al's guidance and recommendations have also been cited for many of the successes of the Fleet Operational (F/O) 210 Investigation sponsored by the Chief of Naval Operations during the 1960s for the purpose of reducing U.S. naval aircraft vulnerability to enemy surface-to-air missile systems. Before the Navy's request for technical assistance, the effectiveness of enemy surface-to-air missile systems was running at more than 20%. Within 3 months, the level was reduced to less than 2% and, despite enemy adjustments, stayed at 2% during the remainder of the conflict. Al achieved this success by developing a refined capability in the Navy's surface-to-air missile systems and then adapting those capabilities to the problem of searching out the weaknesses in enemy surface-to-air missile and gun systems in Southeast Asia.

Naval air planning in Vietnam in the mid- to late 1960s required detailed reports from pilots and other aviation organizations participating in combat operations. The detail and volume of data obtained through these reports grew rapidly to high levels as the scope of combat operations was extended. Al devised a means for reducing these data and extracting essential information for dissemination and action on a rapid basis. Many thousands of operational reports were subjected to analysis, yielding information on trends and operational effectiveness that had been obscured by the volume of data. Al developed an analytic capability hard to duplicate; in fact, he introduced new ways of thinking about operational testing and evaluation, e.g., the benefits of a tightly knit team of technical and operational personnel conducting comprehensive analyses and designing tests intended to provide an in-depth understanding of the capabilities and limitations of equipment in expected operational environments as well as tactics for using individual and complementary systems developed on the basis of quantitative estimates of effectiveness, with recommendations directly related to operational forces.

In light of such success in Southeast Asia, the Naval Air Systems Command established the Echo Range, a facility to permit testing of the performance of the Navy aircraft against enemy surface-to-air missile systems. Al requested to undertake the design, hardware production, and system integration to implement the desired capability. Al led the system design, and a contracting team was mobilized to produce the necessary equipment on a very short timescale. The installation at China Lake, California, was of value to the Navy and other air arms of DoD. It was Al's foresight in the control and instrumentation systems for Echo Range that permitted the system to accommodate changes in the threat as it evolved with time.

For his contributions to the Navy's Southeast Asia needs, in May 1975 Al received the Navy Distinguished Public Service Award, the highest Navy recognition that the Secretary of the Navy can award to a citizen who is not an employee of the Department of the Navy.

In 1973, Al wrote a paper for the Joint American Institute of Aeronautics and Astronautics/American Ordnance Association (AIAA/AOA) Tactical Missiles Meeting on "What Does Technology Offer?" This paper established the foundational concepts for U.S. Navy Battle Force coordination and proposed how various technologies like radar, missiles, navigation equipment, and communications systems on ships and aircraft could be used in a coordinated manner to defend against threats that no individual system or platform could handle individually. These concepts created a road map for the development of many of the present-day systems capabilities and force-coordination tactics and procedures used in modern air and missile defense as well as proposed advanced capabilities that we are only recently starting to implement. The concepts Al proposed almost 40 years ago are still providing the road map to a future that we will only realize in decades to come.

One of Al's most notable contributions was his influence on the Patriot missile program. His vision and leadership while chairing the Anti-Tactical Missile Panel for the Department of the Army throughout the 1980s were cited by U.S. Army leadership as central to maintaining a Patriot missile capability, which entered engineering development 30 years earlier yet remained the world's best-fielded air defense system when called on during Operation Desert Storm in 1991. His panel's evaluations and recommendations in large part led to decisions to continue to develop the missile and determined the direction of the Patriot program. Allied soldiers participating in Operation Desert Storm are alive today because of Al's hard work.

Al held numerous influential leadership positions at APL. He became head of the Missile Systems Division in 1965 and, in 1973, head of the Fleet Systems Department. Later in 1973, Al was appointed the Laboratory's assistant director for tactical systems. In 1979, Al was named the Laboratory's assistant director, and he became chair of its Program Review Board in 1980. In these positions, Al influenced all of the Laboratory's programs and long-range planning. His responsibilities were expanded in 1986 when he was appointed associate director, APL's second-highest post at the time. The associate director was the principal advisor to the Laboratory's director and shared with the director many of the overall management and operational responsibilities. Al served in this capacity until 1989, at which time he was appointed a senior fellow, a status conferred by The Johns Hopkins University on the basis of his exceptional contributions to the Laboratory.

In public service, formal citations and recognition often serve as measures of a person, and such is the case with Al. Appreciative senior government officials from the executive and legislative branches, including countless admirals, generals, military service secretaries and other political appointees of various military secretariats, NATO officials, chief executive officers of the largest defense contractors, as well as the country's leading engineers and scientists shared their personal thanks for the contributions Al made to their respective organizations, science boards, and interests. Al's pioneering efforts were formally recognized in 2008, with the Missile Defense Agency's Technology Pioneer Award for Technical Achievement in Missile Defense. The award recognized Al's unique contributions in the development of supersonic missile technology that ultimately led to the surface-to-air interceptors we use today for missile defense as well as his leadership in the development of specific interceptor systems, including Patriot, Terminal High-Altitude Area Defense (THAAD), and Standard Missile. The volumes of citations underscore the diversity of Al's interests, influence, energy, and passion for public service. As it turned out, Al's citations also served the Laboratory well in recent times because they functioned as catalysts for Al as he recalled history and first-order principles that he shared with APL directors and assistant directors until the time of his death.

Al's leadership and passion for public service were also apparent at the local level. He spoke with immense pride about the roles he played at Howard County

General Hospital (HCGH). Appointed in 1977 by the president of the university to serve as the Johns Hopkins representative on the HCGH Board of Trustees, Al went on to be elected as a trustee in his own right in 1981. He was most active as the chair of the Finance Committee where he oversaw a stable system of financial management. His interests expanded to hospital management and board operations, and, from 1983 to 1985, Al served as the chair of the Board of Trustees. He summed up his guiding principles as chair by stating "that strong, effective leadership was important in the board, administration, and medical staff. It is important for each to represent its functions strongly but always to be able to work together for the benefit of the patients, high-quality care, and the long-term benefit of the Hospital." Al's commitment to the citizens of Howard County continued as he played the lead role in establishing HCGH's Community Relations Council. Al's contributions were formally commended in 1993 by the governor of the state of Maryland.

Al formally retired from APL in 2002 but remained a consultant and an active member-at-large of the *Technical Digest* Editorial Board until the time of his death. Although retired, Al stayed active in Laboratory events and shared his oral history in 2009. In October 2010, Al became the first APL staff member to be awarded a 65-year service pin, an accomplishment he could cleverly introduce into every conversation.

Al had a rare talent for rising to the upper echelon in every aspect of his life. He was a special member of the Navy family of technical experts, constantly consulted on a broad array of problem areas and widely sought as a contributor to technical studies. He earned a great reputation as an inter-Navy and interservice technical planning coordinator who promoted coordination between disparate organizations. He made contributions to the scientific progress and operational effectiveness of the Navy's operating forces, and he dedicated decades to conceiving, developing, evaluating, introducing, and improving tactical systems for the Navy. Al was admired not only for his technical contributions but also for inspiring others to think innovatively and work tirelessly. His subtle but sharp sense of humor, his unconventional approaches to problem solving, his clever manipulation of the English language, and his penchant for accuracy are as much a part of his legacy as are his countless scientific and engineering contributions. Al's life's purpose coincided perfectly with the mission of The Johns Hopkins University: public service. In carrying out that mission, he provided a rare blend of integrity, technical expertise, and leadership skills and brought a special touch of class to everything in which he was involved.

Douglas B. Hudson

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