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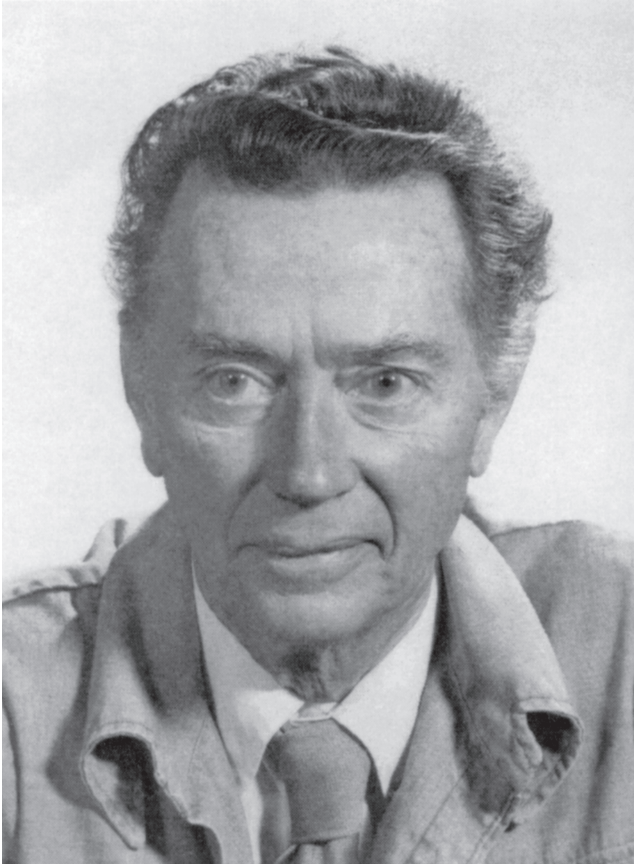

Robert T. Jones

ROBERT THOMAS JONES

May 28, 1910–August 11, 1999

BY WALTER G. VINCENTI

THE PLANFORM OF THE wing of every high-speed transport one sees flying overhead embodies R. T. Jones's idea of sweepback for transonic and supersonic flight. This idea, of which Jones was one of two independent discoverers, was described by the late William Sears, a distinguished aerodynamicist who was a member of the National Academy of Sciences, as "certainly one of the most important discoveries in the history of aerodynamics." It and other achievements qualify him as among the premier theoretical aerodynamicists of the twentieth century. And this by a remarkable man whose only college degree was an honorary doctorate.

Robert Thomas Jones—"R.T." to those of us fortunate enough to be his friend—was born on May 28, 1910, in the farming-country town of Macon, Missouri, and died on August 11, 1999, at age 89, at his home in Los Altos Hills, California. His immigrant grandfather, Robert N. Jones, after being in the gold rush to California, settled near Macon, where he farmed in the summer and mined coal in the winter. His father, Edward S. Jones, educated himself in the law and practiced law in Macon; while running for public office, he traveled the dirt roads of Macon county in a buggy behind a single horse. R.T. later contrasted this with his own experience flying nonstop from London to San Francisco over the polar regions behind engines of 50,000 horsepower.

Writing later about his days in Macon High School, R.T. paid tribute to “a wonderful mathematics teacher, Iva S. Butler, who took us along the intricate path through exponents, logarithms, and trigonometry.” Like most boys of his time, he and his friends strung wires from the house to the barn, wound coils on oat boxes, obtained Model T spark coils from junkyards, and made spark-gap transmitters. With these, he said, “We showered the ether with noisy dot-dash signals that could be heard clear across the country and beyond.” “My consuming interest,” R.T. wrote, “however was aviation.” He built rubber-band-powered model airplanes from the kits of the Ideal Model Airplane Supply Company and “devoured eagerly” the technical articles in aeronautical magazines and the research reports from the National Advisory Committee for Aeronautics (NACA), little suspecting that for most of his life it (and its successor, NASA) would be his employer.

Following high school, R.T. attended the University of Missouri, but found it unsatisfying and dropped out after one year. Returning to Macon, he joined the locally based Marie Meyer Flying Circus, a stunt flying group typical of the time. As an employee of the circus he received flying lessons in exchange “for carrying gas and patching wing tips,” though he would not solo until over 50 years later. He never would return to the university.

In 1929 the fledgling Nicholas-Beazley Airplane Company in the nearby town of Marshall found itself without its one engineer. One of the owners of the flying circus, aware of R.T.’s self-education with the NACA reports, recommended R.T. for the job. As R.T. wrote, “I was hired immediately; 19 years old, a college dropout, and chief (or only) engineer at a salary of 15 dollars a week." Later the company hired an experienced engineer who taught R.T. about airplane design, especially stress analysis. R.T.'s job concerned mainly the production of the Barling NB3, a new type of three-place, low-wing, all-metal monoplane, and he also "worked from early morning until midnight" on the design of a small racing plane for the 1930 air races. These experiences apparently fostered his ambition to become a skilled engineer. Nicholas-Beazley was successful for a time, but in the early 1930s in the Great Depression the company, like many others, went out of business.

R.T. returned home to Macon, where he used his time to study books on aerodynamics, such as Max Munk's *Fundamentals of Fluid Mechanics for Aircraft Designers*. Needing work, he obtained a ride with neighbors to Washington, D.C., where his local congressman provided him with a "wonderful" job as an elevator operator in the House Office Building. With typical dry humor, he writes that the "ups and downs of this job" gave him an opportunity to observe the inner workings of the government. Realizing that he would need to know considerable mathematics to be a successful engineer, R.T. used his spare time in the nearby Library of Congress studying original works on various mathematical topics. He also struck up an acquaintance with A. F. Zahm, a well-known aerodynamicist in charge of the library's aeronautics collection and an ex-member of the NACA. One day a Maryland congressman, David J. Lewis, who also knew Zahm, got on R.T.'s elevator and asked whether R.T. would tutor him in mathematics. Congressman Lewis was then 65 years old and completely self-taught, with no formal education of any kind. R.T. brought him through algebra and up to calculus, "learning a lot from him on the way."

After arriving in Washington, R.T. also attended graduate evening classes in aerodynamics at Catholic University from the brilliantly creative but difficult Max M. Munk. Munk had received his doctorate in aerodynamics with the great Ludwig Prandtl at Göttingen and worked for the NACA at its laboratory at Langley Field. When told that R.T. had studied his book on fluid mechanics, Munk suggested that R.T. take his classes. R.T. did so for three years. They would have profound influence on his later achievements.

In 1934 the new Public Works program, started by President Roosevelt to help combat the Depression, made available a number of nine-month positions as a scientific aide at the NACA's Langley Aeronautical Laboratory in Virginia. With the recommendations of Zahm, Munk, and Congressman Lewis, R.T. obtained one of these positions. By the time his nine months were up, his exceptional talents had become apparent, and his supervisors retained him at subprofessional levels by temporary and emergency reappointments. A permanent professional appointment as an engineer at the initial civil-service grade, however, required a bachelor's degree. A professional appointment thus seemed impossible until someone noticed that the next higher grade, usually attained by promotion from the initial grade, had no such stated requirement. In 1936 he was therefore promoted directly to that level and became officially an engineer. Thus began R.T.'s career with NACA and its successor NASA, which, except for a period in the 1960s, would occupy him until his retirement in 1982 from the Ames Research Center in California.

R.T.'s work in his first 10 years with the NACA dealt mostly with airplane stability and control, in which he became a recognized authority. In the process his lack of knowledge of applied mathematics rapidly disappeared. He quickly became a pioneer in the application of Oliver Heaviside's operational methods in the theoretical analysis of the transient motion of airplanes following a transient disturbance. In this he introduced some perceptive, ingenious, and mathematically sophisticated procedures. By 1944 he published, alone or occasionally in collaboration, about 20 reports on stability and control, mostly theoretical but some involving discussion of related wind-tunnel and flight results. One of these was an exhaustive résumé and analysis of NACA lateral-control research written in collaboration with Fred Weick, assistant chief of aerodynamics at Langley (1937). Weick also asked R.T. to see whether he could design a satisfactorily maneuvering airplane with simplified controls on the assumption that it shouldn't require both hands and feet to move them. R.T.'s analysis showed that two-control operation would best be achieved by controlling the ailerons instead of the rudder, preferably with a small amount of rudder movement linked directly to the aileron motion. After leaving Langley, Weick used the concept to design the famously successful two-place low-wing Ercoupe, which went into production in 1940.

In his first 10 years with the NACA only three of R.T.'s publications had to do with aerodynamics—in those days low-speed (i.e., incompressible) flow. In the mid-1940s that would quickly change. He would spend the remainder of his career mostly in high-speed (i.e., compressible) aerodynamics, coming up at the outset with a fundamental concept for the aerodynamic design of aircraft to fly at supersonic or high subsonic speeds.

This idea originated in 1944 in the course of a wartime assignment to help develop guided missiles. It derived from the design by the Ludington-Griswold Company of a dart-shaped glide bomb having a wing of narrow triangular planform. The company's engineers had calculated the aerodynamic lift of the wing using the usual lifting-line theory; they had misgivings because the theory was devised for wings wide relative to the flight direction. In a visit to Langley the president of the company asked R.T. whether he could think of a better way to calculate the characteristics of a long and narrow triangular wing, pointed in the direction of flight. R.T. remembered a paper from 1924 “by my teacher Max Munk” in which the forces on a long, narrow body of revolution (an airship hull) at angle of attack had been analyzed on the assumption that the flow in planes *perpendicular* to the flight direction could be treated as two-dimensional. With this assumption, the only novelty for the flat wing, though far from a trivial one, was how to satisfy the necessary condition at the trailing edge of a wing (i.e., the condition that there be no flow around the sharp edge). R.T. devised a way to do this, and the rest was relatively simple. So simple, in fact, that he thought “nobody would be interested in it,” put the analysis in his desk drawer, and temporarily forgot about it.

R.T.’s slender-wing analysis, like the lifting-line theory, used the linear equations of incompressible flow. A few months later while exploring the more complex nonlinear equations of compressible flow, he realized that introducing the approximation of the long, narrow wing gave him the same results as his incompressible analysis. This result implied that for slender wings there was no effect of compressibility, that is, no effect of Mach number (the Mach number being the speed of flight divided by the speed of sound, a measure of compressibility). In particular, there was none of the undesirably large increase in drag characteristic of straight wide-span wings at flight speeds approaching and exceeding the speed of sound.

In trying to understand physically why the slender wing should show such Mach-number independence, R.T. wondered whether it might have to do with the large sweepback of the wing’s leading edge. Again he remembered another paper by Max Munk, this one dealing with the effect of dihedral and sweepback on the performance of wings at low speeds. In it Munk assumed that the air forces on a swept wing of large span and constant chord depend only on the component of flight velocity perpendicular to the leading edge and are independent of the component parallel to it. R.T. wondered whether this independence principle might not apply also to the components of the flight Mach number (i.e., in high-speed flight) and decided that it did. Thus the effective Mach number, on which the air forces depend, decreases continuously with increasing sweep; it follows that even at supersonic flight speeds, the air forces can be made to have the advantageous properties found at low subsonic Mach numbers simply by introducing sufficient sweepback, in particular, that the enormously increased drag of conventional unswept wings at supersonic speeds can be reduced to subsonic levels. R.T. thus discovered the theory of high-speed sweepback, which William Sears described as "certainly one of the most important discoveries in the history of aerodynamics."

With his new insights R.T. quickly resurrected his incompressible slender-wing analysis, modified it to start from the compressible-flow equations, and added his reasoning about sweepback. The resulting report was then submitted in early 1945 to the customary editorial committee, chaired in this case by Langley's top senior theoretician. To R.T.'s surprise the committee accepted his special slender-wing theory—which was published as a separate unrestricted NACA Report dated May 1945 at Langley Field (1946,1)—but rejected his general finding about sweep. Subsonic and supersonic flow were conceived at that time as of entirely different nature, and the committee chairman could not accept that an essentially subsonic result could be obtained in a supersonic free stream. NACA management therefore held up publication of the sweep theory until transonic experiments, conducted at R.T.'s suggestion, showed 45-degree swept wings to have much less drag than straight wings. The sweep analysis appeared in circulation-restricted reports later in 1945 and as an unrestricted report in 1946 (1946,2). R.T.'s reports on slender wings and sweep are among the most consequential in the history of aerodynamics.

At the time of R.T.'s work no one in the United States appears to have been aware that the eminent German aerodynamicist Adolf Busemann had used the independence principle to examine the theoretical high-speed possibilities of sweep as one of a number of topics in his lecture to the Volta Congress in Rome in 1935. His idea received little notice perhaps because Busemann's thinking considered only supersonic flight speeds and sweep angles for which the effective Mach number remained supersonic—speeds that seemed far beyond practical attainment at that time. In early May 1945 while the events at Langley were taking place, a group of U.S. engineers investigating German wartime research came upon a large collection of unpublished swept-wing data from high-subsonic-speed wind tunnels at Busemann's institute at Braunschweig. R.T.'s idea of high-speed sweepback occurred independently of German thinking, and he and Busemann are credited jointly with the concept.

In early 1946 R.T. transferred from Langley to the NACA's Ames Aeronautical Laboratory south of San Francisco. It was there that I came to know him, when we spent hours together in the next few years laying out what we hoped would be optimum swept-wing configurations for testing in Ames's first supersonic wind tunnel. Except for seven years in the 1960s when he went elsewhere and worked outside aeronautics (as described later), R.T. was employed at Ames until his formal retirement in 1981. After that he served until 1997 as a consulting professor in the nearby Department of Aeronautics and Astronautics at Stanford University, at the same time maintaining a close, informal relationship with Ames.

R.T.'s work at Ames and later at Stanford dealt mostly with sweepback. His nonsweep concerns, however, also have fundamental importance. One of these dealt with a basic but previously unnoticed mathematical singularity that occurs when thin-airfoil theory is applied to an airfoil having a rounded leading edge (1950). Another put the "area rule" for flight speeds near the speed of sound, which transforms the pressure-drag problem for a wing-body combination into that for an equivalent body of revolution, on a firm theoretical foundation and extended it to supersonic flight speeds (1956,1). Both these topics appear in any complete text on aerodynamic theory.

R.T.'s dealings with sweep after his move west show a wide range of concerns. For the first 10 or so years his papers focused mostly on the theory, elaborating its foundations and techniques and exploring its results (1947, 1951, 1952). In 1957 he and Doris Cohen incorporated these and the findings of others into an important 241-page section with the title "Aerodynamics of Wings at High Speeds" in the Princeton series *High Speed Aerodynamics and Jet Propulsion* (1957,2).

In the second half of the 1950s R.T.'s concerns began to shift from sweep theory itself to the implications of sweep and other theoretical findings for the design of airplanes for high-subsonic and supersonic flight. He voiced his ideas especially in papers at several meetings (1955; 1956,2; 1959). In several of his writings in this period and earlier, including the section in the Princeton series and the papers from the meetings, he mentioned the idea of an oblique (or yawed) wing, though mainly as a matter of theoretical interest rather than a practical configuration. Following return to Ames from his absence in the 1960s this changed, and he devoted himself wholeheartedly to the startlingly unconventional concept of the oblique wing and its potential for a high-performance airplane.

The planform of a conventional swept wing, as we see it flying overhead, has bilateral (mirror) symmetry, that is, it is swept back on both sides of the fuselage (or plane of symmetry). Sweep can equally well be embodied in a wing that is swept back on one side and forward on the other, that is, a wing that is oblique to the line of flight. R.T.'s theoretical work showed, moreover, that such an oblique wing would have superior aerodynamic performance at high speed to a swept wing of conventional planform. Because both the conventional and the oblique wing present problems at the much-reduced speed of landing, there may be virtue in having a wing adjustable at landing to the zero sweep of low-speed aircraft. Such adjustment is mechanically and structurally easier for an oblique wing with a single pivot atop the fuselage than for a conventional swept wing with its required pair of pivots, one on each side. Along with its potential aerodynamic and mechanical virtues, the oblique wing raised questions about stability and control and about aeroelastic deformation and hence structural design.

Whether the concept of the oblique wing was original with R.T. is not clear. The idea was current in the sweep developments in Germany during the war. Evidence exists of stability-and-control tests, under R.T.'s inspiration, of an oblique-wing airplane model in the Langley low-speed free-flight wind tunnel in 1946, but whether he had heard of the German work we do not know. The idea was and still is startling because, as R.T. wrote, "Artifacts created by humans show a nearly irresistible tendency for bilateral symmetry."

R.T. and people associated with him produced a considerable body of work, mostly in the 1970s, on problems of the oblique-wing airplane. This included (1) transonic wind-tunnel tests that showed clear drag superiority of the oblique wing over a conventional sweptback wing; (2) comparative design studies, one under contract with the Boeing Company, giving careful consideration to stability-and-control and aeroelastic problems as well as aerodynamics; (3) low-speed flight tests of radio-controlled models (designed and built by R.T.) for which the sweep angle of the pivoted wing could be adjusted in flight; and (4) low-speed tests of the control response and pilot feel of a full-scale single-seat aircraft at the NASA Dryden Flight Research Center in southern California.

This work concerned an oblique wing with a fuselage and tail. R.T.'s interests following his formal retirement at Ames centered on the even more startling concept of the oblique flying wing. This consists simply of an oblique wing without fuselage or tail and large enough to carry its load internally. Here the variable sweep must be achieved by aerodynamic means, and the wing-mounted engines must be pivoted so they can be pointed in the direction of flight. The concept had been in R.T.'s mind for some years; he included it in his discussions of sweep in his papers at meetings. This he accompanied with a striking demonstration of the low-speed stability of an oblique flying wing by means of a balsa-wood glider.

R.T.'s work on the flying wing took place mainly in the late 1980s and early 1990s, much of it in his association with Stanford. Mostly it was as an advisor to people at Ames and other local research groups and to Professor Ilan Kroo and his doctoral students at Stanford. Kroo and his students, with R.T.'s inspiration and help, studied the aerodynamic-design and control-system problems in detail, using a radio-controlled model, in order to become familiar with the low-speed flight characteristics. Kroo and engineers at local research companies did a comprehensive design layout to examine the packaging within the aircraft of the payload, fuel tanks, retracted landing gear, and other internal components and their strong coupling to the exterior aerodynamic geometry. The resulting Mach 1.6 aircraft would accommodate 440 passengers inside a wing with a span of 400 feet.

Thanks to R.T.'s impetus and vision, there now exists a large body of practical knowledge of possible oblique-wing airplanes in both the pivoted and flying-wing versions. Sears, writing in 1976 with regard to the pivoted wing, said, "I, for one, fully expect to see future transport airplanes with 'Jones oblique wings.'" Though aircraft companies have studied the possibilities, what Sears expected has not, for a complex of reasons, come to the pass with either version. The crystal ball for the future is unclear.

As the foregoing materials suggest, R.T.'s interests ranged widely. Within aerodynamics itself his concerns went far beyond the problems discussed above. This range appears in papers shortly before and after his retirement from Ames on such miscellaneous topics as the motion of ultralight aircraft in vertical gusts, the dive recovery of hang gliders, the aerodynamics of flapping wings, and the efficiency of small transport aircraft. And in his previously mentioned absence from Ames from 1963 to 1970 he worked in a field of fluid motion far removed from aerodynamics. This he did at the Avco Everett Research Laboratory in Massachusetts, where he chaired the laboratory's Medical Research Committee. In this work he studied the characteristics of blood flow in the human body and application of such knowledge to the design of cardiac-assist devices and development of one of the earliest artificial hearts. These efforts led to a number of articles in medical and biomechanical publications (e.g., 1970). His studies also ranged far outside fluid mechanics. Pieces by him appeared at various times in physical journals under such titles as “Analysis of Accelerated Motion in the Theory of Relativity” (1960) and “Relativistic Kinematics of Motions Faster than Light” (1982).

Those who worked with R.T. marveled at how he arrived at his ideas, seemingly intuitively and frequently in terms of physical models and analogies. He could use highly sophisticated mathematics deductively when necessary, but he did so mostly to support his ideas and explore their consequences. In the initial report on his concept of sweepback he began conventionally with a mathematical derivation followed by three physical arguments and explanations. Events at the time suggest that the mathematics actually came to R.T.’s mind after the physical concepts and had been put into the report in response to editorial-committee objections. Whatever the situation, the fact is that things that seemed clear and obvious to him in his physical explanations often caused the rest of us difficulty and struggle to master. As Sears wrote, “Lesser aerodynamicists often find his arguments too concise and the literature of the field includes papers in which authors re-do Bob’s work providing longer proofs, and discover again Bob’s results.”

As part of his association with Stanford, R.T. offered an occasional quarter-long lecture course on problems in aerodynamic theory. Connected with this, he published in 1990 an exceptional book entitled simply *Wing Theory* (1990). Sears, on the flap of the dust jacket, calls it “surely . . . one of the most important books on aerodynamics written in our time.” In 200 pages with numerous figures and frequent comparison with experiment, R.T. focuses on the basic principles and principal findings of the theory at both subsonic and supersonic speeds. To do so he uses a minimum of mathematics and a great deal of the intuitive physical thinking characteristic of his creative work. It is a book that only R.T. could have written.

As his construction of radio-controlled flying models of pivoted-wing airplanes might suggest, R.T. also had a talent for craftsmanship. In his spare time in the 1950s he devised and constructed (grinding the mirrors himself) an improvement on a type of reflecting telescope and published a number of related articles (e.g., 1957,1). In 1957 he and his wife formed the Vega Instrument Company, which made and sold some 40 six- and eight-inch telescopes of this kind.

In the 1950s as well, R.T.'s daughter Patty reached the point in her violin studies where she needed a better but discouragingly expensive instrument. With characteristic resourcefulness R.T. undertook to make her one. After putting together equipment for electronic acoustic testing, he made a first attempt that turned out to be disappointing. His second effort was a notable success. Patty has since played it in recitals and as a member of the La Jolla Civic Symphony. Over the years R.T. built somewhat more than a dozen fine violins and violas.

R.T. also had a passion for airplanes that became unmistakably visible in the mid-1980s (R.T. was in his mid-seventies). It was then that he obtained a pilot's license and bought the two-place Ercoupe mentioned earlier. He also went frequently (though not in his Ercoupe) to the annual Experimental Airplane Association Fly-In at Oshkosh, Wisconsin, where he gave occasional talks on airplane aerodynamics.

Besides his interest in telescopes, violins, and airplanes, R.T. read widely and thought seriously about human affairs. This is exemplified by an extraordinary piece entitled "The Idea of Progress" that he contributed to the journal of the American Institute of Aeronautics and Astronautics on the fiftieth anniversary of the institute (1981). In it he recounts something of the advances in his lifetime of technology plus the concurrent increases in food production and living standards and the related and troubling increase in population and appearance of the nuclear bomb. He cites Gerard O'Neill as telling how a scientist brought to life from 200 years ago would be completely bewildered by what he saw, whereas a politician would recognize perfectly well the kind of thing that was going on in politics and the general conduct of human affairs. In the discussion R.T. mentions or draws upon the ideas and writings of such a diverse group as (in the order in which he refers to them) R. A. Millikan, Frederick Soddy, Malthus, Hendrick Willem van Loon, Jay Forrester, Paul Ehrlich, Marx, J. B. Bury, Giordano Bruno, Gerard O'Neill, Voltaire, Machiavelli, and Max Born. He ends with the conclusion that "the idea of progress, in the form responsible for the revolution in science, must somehow find its way into political thought." The mainly technical audience of the institute can only have been startled by what they encountered.

R.T. was elected to both U.S. national academies: the National Academy of Engineering in 1973 and the National Academy of Sciences in 1981. His many other honors included the Sylvanus Albert Reed Award of the Institute of the Aeronautical Sciences in 1946, the Prandtl Ring of the Deutsch Gesellschaft für Luft und Raumfahrt in 1978, the Langley Medal of the Smithsonian Institution in 1981 (an award shared with such aviation notables as the Wright brothers and Charles Lindbergh), and the Fluid Dynamics Prize of the American Physical Society in 1986. His lone college degree—the honorary doctorate mentioned earlier—came from the University of Colorado in 1971.

I cannot think of a more fitting way to close than to repeat what I have written elsewhere: R.T.'s friends knew him as a modest, considerate person of absolute integrity. According to Ilan Kroo of Stanford, "Those of us privileged to call him a colleague . . . were continually surprised and inspired by this maverick scientist who contributed so much to our understanding of flight. In addition to his well-known technical contributions . . . he captivated a generation of students with fresh insights and new ways of looking at problems ranging from hang-glider dynamics and optimal bird flapping to supersonic aircraft." Most important for his various activities, he seemed to have a quiet confidence that he could accomplish whatever he set out to do—even if it was to make a fine violin. We do not see his like very often.

THIS IS A CONSIDERABLY shortened and revised version of a piece I wrote for the *Annual Review of Fluid Mechanics* (vol. 37, 2005); passages are reproduced here with the permission of Annual Reviews, Palo Alto, California. In preparing the work I have relied upon the writings of Jones, John D. Anderson, Jr., James R. Hansen, and William R. Sears as listed under References below, together with various unpublished patent-related materials. I have also drawn on my own and others' memories, especially for R.T.'s later career at Ames and Stanford, and on studying a number of R.T.'s technical reports listed under Selected Bibliography below and cited in the text.

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