FOREWORD

This volume is a tribute to a very remarkable man. It has been my great pleasure to have been associated with him for the past six years and, since I came late to the business of aeronautics, I had never had the pleasure of meeting Dr. Robert T. Jones before. During the period that I have had the opportunity to work with him I have developed an enormous respect for his technical abilities and also for his character as a man. His grasp of the physical sciences is as broad as that of anyone I know. It ranges from practical aeronautical engineering to the most advanced and abstruse statistical mechanics. What is more remarkable is that R. T.'s understanding is not superficial. In an amazingly short time R. T. can master a field to the point where he can make original contributions. R. T. is also an excellent teacher. He has a profound influence on those around him. In addition, his critical faculties are also exceedingly sharp. The Ames Research Center is indeed fortunate to count R. T. as one of us. He is unique and his work has added greatly to the Center's scientific and technical reputation. It is a genuine pleasure as well as an honor to have him here.

Hans Mark
Director

Ames Research Center

INTRODUCTION

The publication of this remarkable collection commemorates the 65th birthday of a very remarkable man, Dr. Robert Thomas Jones, Aeronautical Engineer, who first went to work for NACA 41 years ago. During this long Civil Service career, he has become one of the world's leading aerodynamicists, made discoveries that have changed the history of aeronautics, and received important honors. What sort of man is this, whose career has been so long and whose contributions have been so many and so important?

This question is, of course, a loaded one - as many will realize who know him - for nothing about Bob Jones is commonplace!

First, consider how he got into aeronautics. A fascination with aviation in the 1920's was, to be sure, commonplace among us who were schoolboys then. In Macon, Missouri, where he lived, young Bob read *Aero Digest*, treasured its cover pictures of the airplanes of the day, and pored over its technical articles on performance estimation, stability and control, and stress analysis. Assembling these and NACA Reports, he began the design and construction of a small, motorcycle-engined airplane, upstairs in his house. An unusual high-school mathematics teacher, Iva Z. Butler, helped him to understand stress and strain, but high-school graduation intervened, the airplane remained unfinished, and Bob went off to the University of Missouri in 1927.

But the aviation bug had bitten him badly. He discovered Walter Diehl's famous *Engineering Aerodynamics* and found it more exciting than the required courses of his freshman year. He left the university after that first year and entered the aviation industry - by working for Charles Fower's flying circus, which flew Standard J-1 biplanes; Bob carried gasoline cans, patched wing tips, and was paid in flying lessons!

In about 1929, there was considerable activity in aviation in the United States, including the Middle West. There were names like Alexander-Eaglerock, Beech, Cessna, Travel-Air, and Waco - some still around in 1975 and others nearly forgotten. A great demand for a "family flivver of the air" was expected. In Marshall, Missouri, the Nicholas-Beazley Company began manufacture of the Barling NB 3, a sporty, three-place, low-wing, cantilever monoplane. Bob, with his highly practical (if brief) background in the flying circus and a good recommendation from Charles Fower, landed a job there. It was not, at first, an engineering job, but young Jones made it clear that the engineering office was where he wanted to be - and when a vacancy suddenly occurred, there he was! Together with the company's chief engineer, Thomas Kirkup, Bob applied Diehl's aerodynamics, carried out stress analyses, and performed (late into the night) static tests to failure. But Nicholas-Beazley, with many others, was wiped out in 1930 by the business collapse.

The aviation industry recovered later in the '30's, and surely Bob's first jobs had prepared him admirably - even typically - to become an aircraft manufacturer or chief engineer - another Glenn Martin, Donald Douglas, or John K. Northrop. But whatever fates control the destinies of aeronautical engineers, with or without college degrees, had other plans for Robert Jones.

When Nicholas-Beazley folded, he returned home to study Glauert's *Aerofoil and Airscrew Theory* and Munk's *Fundamentals of Fluid Dynamics for Aircraft Designers*. His father was chairman of the local Democratic committee, and this helped young Bob get a job running an elevator in the House Office Building in Washington, D.C. Surely the above-mentioned fates had a hand in this, for the building was across the street from the Library of Congress. Bob paid visits to Dr. Albert F. Zahm, the Library's Director and once a member of the NACA. They must have talked about mathematics, for Bob decided to study that field. He began with Hamilton's quaternions! And when a Congressman, Honorable David J. Lewis, went to Dr. Zahm to request instruction in mathematics and physics - the Congressman was 65 and had finished with law and government - Dr. Zahm sent him to the bright elevator boy across the street. Bob taught the Congressman algebra and calculus.

At about this time, Bob made another friend whose influence on his career was tremendous: Dr. Max M. Munk, who had left the NACA, set up an office in Washington as consultant and patent attorney, and was giving evening courses at Catholic University. (He had also studied law, passed the bar exams, and learned Russian.) When he discovered that the elevator boy had studied his book, he suggested that he take his evening course - a graduate course. When Bob said that he might not be prepared for it (a suggestion that was certainly not characteristic of young Bob!), Dr. Munk gave him a little oral exam and enrolled him. Bob took Munk's evening courses for about three years - vector analysis, airfoil theory, and relativity theory - and drew upon this sound early teaching throughout his career. Thus Bob is truly one of the "Prandtl grandchildren" and an heir to that great tradition, with its deep, intuitive appreciation of the power of applied mathematics, without attraction to mathematics or mathematical elegance for its own sake.

The election of Franklin D. Roosevelt (1932) brought the Public Works Administration, and PWA opened up emergency jobs at Langley Memorial Aeronautical Laboratory. Dr. Zahm and Congressman Lewis saw Dr. George W. Lewis, NACA Head, and recommended Robert Jones for one of these jobs; Bob went to Langley, reporting to Carl J. Wenzinger, Charles Zimmerman, and Fred Weick, on a nine-month assignment as Scientific Aid. The fates had their way: It required a sequence of unlikely events and remarkable people, but Robert T. Jones was embarked on a career in research in the NACA and under the supervision of some unusually capable bosses.

Not surprisingly, ordinary linear differential equations was a subject missing from Bob's informal educational background - although he did know the quaternions and had read Grassmann's *Ausdehnungslehre* and similar classics in the original - so with Weick's and Zimmerman's guidance, he "learned by doing" differential equations. He published some of the earliest results of step-by-step solutions of the equations of airplane motion (obtained on desk calculating machines), such as the transient motions following abrupt, unit-step control deflections and gusts. He recalls that he became a sort of local authority on linearity after once calculating the transient motion following a two-unit step input, and comparing the results with unit-step results! He was also one of the first to apply Heaviside's operators to problems of airplane dynamics.

But the nine-month temporary appointment was about to expire. Bob's bosses, Fred Weick, and Henry Reid, Director of the Langley Laboratory, tried to arrange for him to take a Civil Service exam so they could hire him permanently, but the Civil Service rules specified a Bachelor's degree. Weick and Reid then thought to issue a special Civil Service exam that would require everything that Bob knew. In due course a special Civil Service examination was issued with questions on Hamilton's quaternions, operational calculus, aircraft stability and control, wing theory, and a few other subjects. To the surprise of those at Langley, a fellow showed up who offered this exotic combination and a Bachelor's degree as well. Weick assigned him to Bob Jones, who put him to work. Bob finally got a permanent appointment on a subprofessional grade. Some years later, when he approached the first professional grade P-1, he again encountered the requirement for the Bachelor's degree. This time the NACA was more ingenious - the stated requirements for grade P-2 did not mention any degree, so NACA promoted him directly to that grade!

By the time World War II began, Bob had published important papers, including a most ingenious way to find the transient lift on finite-span wings (page 193). He had become deservedly well-known in aeronautical circles, expecially as an expert in stability and control. At Northrop Aircraft we were struggling with the problems of the all-wing airplanes - XB 35, YB 49, etc. - and every trip to Langley Field, for wind-tunnel tests or other business, included a visit to Bob to discuss stability and control, and especially the properties of sweptback wings. When the first guided missiles were developed, Bob worked closely with the Army Special Weapons unit. In those days the missiles were actually pilotless airplanes, and one of them was a Northrop all-wing design with turbojet power (a rebuilt turbo-supercharger). The autopilot was made by the Hammond Organ Company. Mr. Laurens Hammond startled us by proposing one black box in the right wing with a pitch gyro, and another in the left wing with a tilted gyro for lateral control. Each of these controlled only its own "elevon" (combined elevator and aileron); there was no connection between the two autopilots and no connection between the two elevons. Even Bob Jones was horrified by the idea, but the little aircraft flew with faultless stability and control; there was, after all, aerodynamic coupling between its left and right sides, although the dynamics of the system could certainly not be divided into lateral and longitudinal motions. Bob was impressed with the unimportance of bilateral symmetry!

He first worked out his famous theory of low-aspect-ratio wings in 1944 (page 369). He was embarrassed when it was referred to under his name, because he thought it was an obvious extension of Dr. Munk's classical and well-known work. The rest of us have never found that the extension, involving as it does the recognition and treatment of the trailing vortices that lie behind all trailing edges, is at all "obvious". Bob did not even publish it at first, but later realized that it applied to high-speed flow, including supersonic, as well as to low-speed, because the flow near the axis of the Mach cone is similar to incompressible flow.

At about the same time, he remembered from an old NACA Technical Note of Munk's - T.N. 177 (1924) - that you can calculate the effects of sweepback and dihedral angle in a wing by an "independence principle": The two-dimensional flow around the wing due to the stream component perpendicular to the wing axis is independent of the flow due to the stream component along this axis. Bob realized that this independence principle did not depend upon incompressibility, and thus he discovered the "theory of simple sweepback" (page 377), which is certainly one of the most important discoveries in the history of aerodynamics. At first he made the mistake of putting the low-aspect-ratio and the sweep theories in the same paper, but the NACA editorial committee, which had to approve the paper, believed the former and not the latter. As Bob says, "It has to be remembered that at that time there was thought to be a very great difference between subsonic and supersonic flow," so that it seemed, to some skeptics, impossible to render a supersonic flow essentially subsonic by such a simple device as sweepback.

While the argument with the editorial committee was still in progress, Bob's colleague, Robert Hess, read Adolph Busemann's 1935 paper concerning supersonic flow, and they realized that Busemann's argument would lead to the same result as Jones's, if the wing was swept behind the Mach cone. But Busemann had not discussed this case in his paper, so the editorial committee remained unconvinced. Bob divided the troublesome paper in two parts, and the low-aspect-ratio part was published. NACA began experiments in an effort to confirm the startling conclusions of the simple-sweep theory. Before the experiments were completed, V. E. Day occurred, Allied engineers went into Germany, and the news came back that the Germans knew about the effect of sweep and were using it on all of their new designs.

For his discovery of the sweep effect and other contributions, Bob was given the Sylvanus Albert Reed Award by the Institute of the Aeronautical Sciences in 1946. It was also in 1946 that he left the Langley Laboratory and moved to Ames.

About the time he moved to the West Coast, Bob acquired a new interest: telescopes. In characteristic fashion, this led him to a deep study of geometrical optics. He learned the art of grinding spherical mirrors and set up an impressive optical shop in the garage of his Palo Alto home. Also typically, he made inventions and original discoveries (which he calls "minor") in this field. The lens described starting on page 917 had a speed of f/0.66 and was "a sort of conjugate of the Schmidt telescope."

When the Space Age began in 1957, Bob and his wife expected telescopes to be much in demand. They formed the Vega Instrument Company, and went into production on a six-inch telescope of the type described starting on page 895, selling for about $800. They sold about ten of these and went on to a more elegant instrument: a six-inch Newtonian-Maksutov, selling for $1700. The idea was to make fewer telescopes and more money. Bob's son, Edward, worked for the Vega Instrument Company, as did a machinist and an optician. Although thirty of the Maksutovs were made, the company's profits hovered near zero.

Of course, Bob's interest and knowledge in astronomy was very timely: NACA became NASA, the "space agency," and Bob was one of the few aeronautical engineers who knew his way around the sky. He served for several years on the Astronomy Subcommittee. He had been fascinated by relativity theory since taking Munk's night courses in Washington. Now that space travel at great speeds was a real possibility, he followed up a number of original ideas in this field (pages 927-956).

But he also continued to make profound discoveries in aerodynamics. One was the "supersonic area rule" which correctly carries into the supersonic regime the concept of equivalent body of revolution, which had been found so useful in the transonic regime (page 609). He thought about the effects of sweepback on boundary-layer behavior (page 473) and discovered an "independence principle" here, as well. (Professor Prandtl, V. V. Struminskii, and the present writer all came independently to this result at the same time! Dr. Munk was somewhat skeptical but told me, "Bob Jones says the same thing, so it must be right.") Another discovery was the existence of a new kind of leading-edge singularity in thin-wing theory (page 533). All of these papers are typical examples of Bob's insight and his direct, intuitive style of writing. 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.

In 1956 Bob and Doris Cohen were asked to write an important section of the Princeton Series, *High Speed Aerodynamics and Jet Propulsion*. This collaboration produced the section entitled "Aerodynamics of Wings at High Speeds." One of the features of this section is the analysis of the drag of elliptical wings, including those that fly at an angle of yaw. Thus Bob returned to the consideration of sweepback effects and asymmetrical configurations.

The analysis showed Bob that elliptic wings are ideal and that, at high speeds, they should be yawed. He remembered the unimportance of bilateral symmetry. In a series of papers (pages 657-883), he has pointed out the attractive properties - both aerodynamical and structural - of yawed (oblique) wings for supersonic aircraft. The spars of such wings carry the bending moment right across; it is not put into the variable-sweep mechanism. Bob and his NASA colleagues are pursuing this idea vigorously. The aeronautical world still seems hesitant to accept configurations without symmetry. Nevertheless, I, for one, fully expect to see future transport airplanes with "Jones oblique wings."

Here again are examples of Bob's insight into engineering problems: The aeroelastic properties of the oblique wing have frightened a number of engineers, for the upstream panel surely wants to deflect aeroelastically upward and the downstream panel downward. To Bob it seems obvious that these effects simply do not occur in flight. A study of the equilibrium of rolling moments will confirm that he is right. The details are left to the reader; it must be said that the conclusion is not quite "obvious," even to most aeronautical engineers!

Pages 957-1017 represent still another facet of R. T. Jones's career: studies of the bio-mechanics of blood flow. These were investigations carried out at the Avco Everett Research Laboratories.

But there is still another, most important side of Bob Jones, and one that this all-too-brief biographical sketch has ignored to this point. He is the father of six children (two adopted), of whom the eldest, Eddy, is now a man of 41 years. Bob's relationship to them has been exceptionally warm and rewarding. A typical example comes to mind: Daughter Patty is a violinist, and by about 1956 had progressed so well that she needed a good violin. Her remarkable father agreed, and decided that he would study the acoustics of good violins and make one for Patty! Here, in his own words, is the story:

"Milton Van Dyke gave me some reprints of scientific articles on the violin by his old physics professor, W. A. Saunders of Harvard. Saunders had made electronic-acoustic tests of many violins, including some valuable old Italian ones, and had elicited the help of Jascha Heifetz. By following Saunders' frequency-response curves, I should be able to make Patty a super-violin! So I set up the electronic testing, bought the wood, and after some months of spare-time work turned out a very good-looking violin. Unfortunately its tone seems to have deteriorated with time, or perhaps it wasn't as good as we thought at the time, and so I had to make her a second one (see page 1019). The second one seems to be really good, and Patty plays it at recitals and in the LaJolla Civic Symphony. I am now (1975) finishing number 6, but No. 2 has been the best until now. Am experimenting with 1500-Hz vibration dampers (this is the "nasal" range) and have made an electronic violin which my friend Irwin Hahn of the Berkeley Physics Department, and a violinist, thinks is very good."

In 1971, Bob was awarded the degree of Doctor of Science, *honoris causa*, by the University of Colorado, "in acknowledgement of his scientific eminence and his service to society." In 1973 he was elected to the National Academy of Engineering.

Aeronautical engineer, applied mathematician, astronomer, designer of telescopes, bio-mechanicist, maker of violins, inventor, author, discoverer of profound principles, civil servant, devoted father - our friend Bob is all of these. He is also a man of exemplary character and a most delightful companion on any occasion, whose intelligence and intellectual honesty shine brightly from those clear, big, blue eyes. No one really believes he has reached 65 years, for he is obviously ageless! He has no intention of retiring for some time. We can be certain that airplanes, fluid flow, violins, the stars, and perhaps many other things will continue to fascinate him and lead him to new truths in the future!

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