From Durand to Hoff:
The history of aeronautics at Stanford University,
The founding and early years of the Department of Aeronautics and Astronautics

On December 19, 1958, Dean of Engineering Joseph Pettit wrote a letter to Provost Fredrick Terman requesting that, “the title of Division of Aeronautical Engineering be changed to the Department of Aeronautical Engineering, and that all prerogatives of the departmental status be accorded the Aeronautical Engineering faculty.” Pettit noted that the division had been functioning entirely like a department for the past two years. When it was founded, it was the first department at Stanford to be dedicated to interdisciplinary research. By that time high-speed flight and access to space had developed into two of the most important forces shaping modern culture. It was recognized that to effectively impact the development of aircraft and space vehicles a new department was needed where the research would span the disciplines of fluids, structures, control, and navigation. In the five decades since, the faculty and students of the department have made major contributions to all these fields, particularly in the areas of precision navigation, aerodynamic design, flow simulation, propulsion, composite structures, robotic systems and control of complex systems.

Beginnings

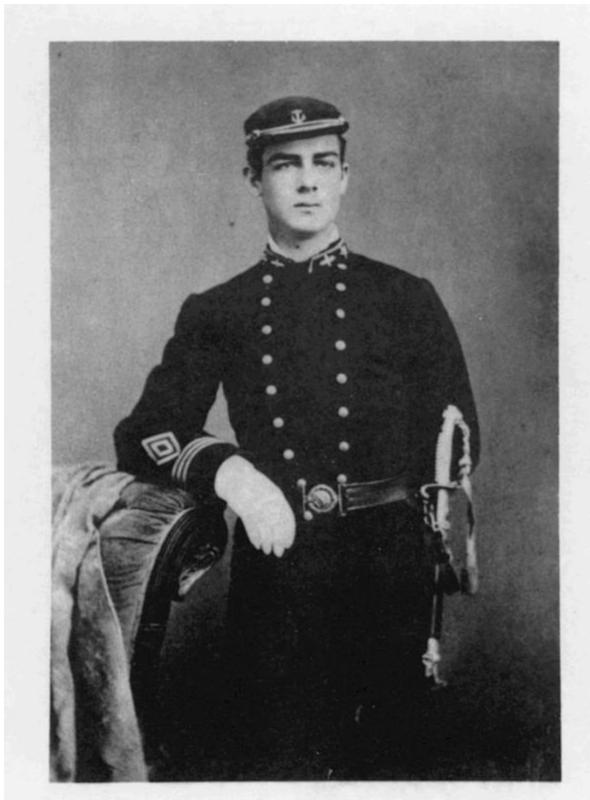
The history of aeronautics at Stanford began long before the founding of the department and is almost as old as the university itself. It started with the appointment of William F. Durand in 1904, only a year after the first flight of Wilbur and Orville Wright. Stanford University opened its doors on October 1, 1891. The first student body consisted of 559 men and women. There were fifteen members of the faculty, seven of whom came from Cornell. After the death of Leland Stanford in 1893 the university went through a prolonged period of financial uncertainty until the release of his estate from probate in 1898. Only the determination of his wife Jane Lathrop Stanford and the skill of the first president, David Starr Jordan, kept the dream of a university alive during that uncertain period. In 1903 Mrs. Stanford finally transferred full control of university affairs to the board of trustees and the university has continued to grow and thrive ever since. In contrast to the great educational institutions of the East, Stanford was co-educational from the outset, non-denominational, and above all practical, designed to provide an education that would produce cultured and useful citizens.

After 1903 one of the first departments created was the Department of Mechanical Engineering. A former naval officer and Annapolis graduate William F. Durand was recruited, like so many others, from Cornell University, and became chairman of the department. He served in that capacity until 1924. At Cornell, Durand had been a marine engineer and acting director of the Sibley College. At Stanford he became essentially a hydraulic engineer and was heavily involved in the design of dams and the development of the precious water supply system of the West. He served as a consultant on the Hoover, Grand Coulee and Shasta dams. But the compelling developments in aeronautics that occurred during the period leading up to World War I eventually demanded more and more of his attention and in 1915 at the age of 56 Durand established the second course in aeronautics offered at any institution of higher learning in the United States, the first being at MIT.

Durand was instrumental in forming the National Advisory Committee for Aeronautics (NACA), the forerunner of NASA, in 1915. Durand was appointed a member and shortly thereafter he became its first civilian chairman. As such he helped to plan the committee’s first laboratory at Langley field. In 1917 he served as scientific attaché to the American embassy in Paris where he helped organize the post-war Inter-allied Inventions Committee. During this assignment he made the acquaintance of a young Naval Lieutenant and aviation enthusiast named Harry Guggenheim. This chance friendship was eventually to have a profound impact on the development of aeronautics research and education in the United States.

Durand’s world-wide eminence continued to grow and in 1918 he was the first American to deliver the annual Wilbur Wright lecture to the Royal Aeronautical Society of Great Britain. Durand retired from academic life in 1924, only to begin what was to become one of the most important chapters in his extraordinary career. In 1925 he became a member of the President’s Aircraft Board. This famous “Morrow

Board" led to the appointments of assistant secretaries for Air in the War and Navy Departments and fostered passage of the basic Civil Aeronautics Act by Congress. In 1926 he became a trustee of the Daniel Guggenheim Fund for the promotion of aeronautics. Much of the enthusiasm with which Harry Guggenheim prevailed on his father to establish this fund came from his association with Durand during the war. This fund was used to establish and support new aeronautics departments throughout the country. This early and timely endowment has served the country extraordinarily well and provided many of the trained engineers that enabled the United States to reach a position of preeminence in aeronautics.



First Classman William Frederick Durand, United States Naval Academy, 1880

Another great engineer at Stanford at the time was Everett Parker ("Bill") Lesley. Lesley received his bachelor's degree from Stanford in 1897, his master's degree from Cornell in 1905 and joined the Stanford faculty in 1907. This was shortly after the great earthquake and Lesley spent a good deal of his time on the reconstruction of the university. Durand was already an acknowledged expert on marine propellers when he came to Stanford. Aircraft propeller design became vitally important in World War I and in 1915 Durand began his famous research on propellers with Lesley with a $4000 grant from NACA. Using only these funds they built their own wind tunnel and did the tests. Durand and Lesley tested 125 propellers designed in families that varied by blade twist and several aerodynamic shape characteristics. Fifty of these propellers are now on display in the Engineering Library housed in the Terman Engineering Center. The result of their research was a large catalog of propeller data used by aircraft engineers for many years.

Durand's and Lesley's tests were finished by 1926 after which Stanford's aeronautical engineering program moved ahead with a substantial grant from the Guggenheim Foundation in 1927. Two appointments were made using Guggenheim support. Elliott Grey Reid came to Stanford from the NACA Langley laboratory in Virginia in 1927 as the youngest full professor (age 27) at the university. He was a graduate of the University of Michigan. Reid was known as a superb experimentalist with uncompromising standards and one who, according to the memorial written after his death, "insisted on a precision of understanding and expression beyond that required by most teachers." He is best known for his book, *Applied Wing Theory*, published in 1932. Professor emeritus Walter Vincenti recalls that "Reid was a strict taskmaster; once when I handed in a big airplane design report, he insisted that I re-draw the figures which had gotten wet in a water fight at my eating club and do it by 8 PM that day." Reid said, "that is the way you will find things when you go to work in industry". At Reid's retirement dinner many of his former students praised him for the discipline he had taught them. Many of Reid's students went on to become outstanding leaders in industry and at NACA.

Durand with some early workers in Aeronautics at Stanford in 1941. From left to right: Elliott G. Reid, Alfred S. Niles, William F. Durand, Everett P. Lesley, Henry Jessen, Ralph Huntsberger.

The second faculty member brought in with Guggenheim support was Alfred Salem Niles, who had received his degrees from Johns Hopkins and MIT. Niles was the head of the structures unit at Hope Field, Ohio, near Wright-Patterson Air Force Base. While Reid specialized in aerodynamics, Niles did teaching and research in aircraft structures. Niles is best remembered for his book *Aircraft Structures*, co-authored with Joseph Newell of MIT. This book remained the bible of aircraft structural design well into the 1950's.

In 1929 Durand began work as editor of a six-volume summary of the knowledge in aerodynamics entitled *Aerodynamic Theory* under the sponsorship of the Guggenheim fund. The set was completed in 1936, and it remains today a primary reference in the field of aerodynamics. It contains chapters by famous aerodynamicists from all over the world. Durand himself translated the French, Italian, and German contributions.

In 1933 Durand resigned from the NACA and in 1935 he became chairman of a special Committee on Airships that was to recommend future design practices after the loss of the airship Akron off the New Jersey coast and the Macon lost off the California coast at Big Sur. The Macon had been based near Stanford at Moffett Field (The remains of the Macon were recently surveyed using underwater robotic technology developed by Professor Steve Rock.) Stephen Timoshenko served on this committee. Durand found that no one on the committee had ever seen an airship, so he arranged for them to fly to the Navy base at Lakehurst, New Jersey to see the airship Los Angeles, a sister ship to the Macon. According to Vincenti, "This was Timoshenko's first ride in an airplane, and he was frightened as he watched the metal wings bend and the thin skin wrinkle under changing loads. He knew that the airplanes of that time were designed with only a 50% safety factor. Apparently, he didn't know that the wrinkling was normal and expected behavior."

In 1936 Durand was awarded the Daniel Guggenheim Medal for "great achievements in aeronautics." Today this award is administered by the AIAA, SAE and ASE and is considered the highest award in aeronautics. Durand was a skilled diplomat and an eloquent speaker and was much in demand for national and international committees. He was elected president of the World Power Congress and at the opening meeting in Washington in 1936 he addressed the delegates in English, then in French, German and Spanish, all languages he had mastered.

Durand's *Aerodynamic Theory* was re-published at Cal Tech shortly after WWII at the urging of Theodore Von Karman. In 1958, only a few months after he died, the Durand Centennial Conference was held with famous aeronautical engineers and scientists invited from all over the world. One of those invited was Theodore Von Karman. In his remarks he said, "It seems to me that Dr. Durand's major influence was in bringing about a transition from purely empirical, practical engineering to a physically understood, scientific engineering; and I believe that Timoshenko's influence, and perhaps my own, would not have been possible if Durand had not laid the foundation to a scientific philosophy of engineering in the generation before."

In Durand's autobiography, which he wrote at age 93, he says, "I have often been asked if I have any special formula or philosophy of life to account for my relatively good health with advancing years. In reply I have sometimes said I have no special philosophy of life or formula for growing old beyond perhaps the following: Have interesting work, keep busy, eat wisely, get a good night's rest every night and don't worry. In any event, I have generally endeavored to live according to this formula, and it seems to have worked out pretty well so far."

Today a memorial in Stanford's Durand Building reads: "His first professional assignment in 1880 was on the USS Tennessee, a full rigged wooden ship with auxiliary steam power. His last, 1942-46, was as chairman of the National Aeronautical Commission for the development of jet propulsion for aircraft." A true aeronautical pioneer whose career spanned the era from steam-power to jet-flight, Durand died in 1958 at the age of ninety-nine.

Timoshenko and Applied Mechanics

Another major thread in the development of aeronautics at Stanford came from the increasingly strong group in applied mechanics led by Stephen P. Timoshenko. Timoshenko came to Stanford in 1936 from the University of Michigan to join the Mechanics faculty in Mechanical Engineering. He was already famous for his books on *Strength of Materials* (1908) and *Elasticity* (1909) and for the worldwide influence these books had on making engineering more soundly based on basic science and mathematics. He was born in a small village in the Ukraine in 1878 and received his education at the Institute of Railroad Engineering in St Petersburg and with Ludwig Prandtl in Germany. After the Russian revolution he moved to the University of Zagreb (1920) and then to the United States (1922). He worked for Westinghouse until 1927 when he became a professor at Michigan.

Among Timoshenko's doctoral students were Nicholas Hoff, Erastus Lee, James Goodier, Donald Young, Nicholas Hetenyi, and Ernest Chilton, all of whom became professors at Stanford. He was also instrumental in bringing Wilhelm Flugge and Irmgard Flugge-Lotz to Stanford in 1950. He was the star in an Applied Mechanics group at Stanford that was acknowledged to be one of the best in the world. He started the *Journal of Applied Mechanics* and in 1957 the ASME established a medal in his name, awarded annually for the best research work in applied mechanics. He taught at Stanford until he retired in 1955.

Flugge was already highly regarded for his work on plates and shells. He is also known today as the editor of the *Handbook of Engineering Mechanics* (1962) that is still an important reference book for engineers.

Irmgard Flügge-Lotz was well known for her method of calculating the span-wise load distribution on wings. At the time she came, Stanford had a rule that a husband and wife could not both be tenured faculty. She was given a non-tenured position as a lecturer in ME. After considerable pressure from other faculty members, Stanford made an exception and gave her a tenured faculty position. She was the first woman on the engineering faculty at Stanford to become a full professor. When she arrived, she had switched her research interest from aerodynamics to automatic control, in particular ‘bang-bang’ or relay control. Her book on ‘bang-bang’ control (also called contactor or relay control) was the first to give some analysis of this difficult nonlinear subject.

Timoshenko came to Stanford in 1936 when Vincenti was an undergraduate. Nicholas Hoff (PhD ’42) came about the same time to study under Timoshenko, who was doing basic theoretical work on plates and shells. When Timoshenko retired in 1955, he lived at Stanford until his wife died and then moved to Germany (1964) to be with his daughter. Before he left, he said to Vincenti, “you know this is the first time in 50 years I haven't been writing a book.” Vincenti recalls an interesting story about Timoshenko and von Karman: Vincenti's parents lived in Pasadena three blocks from CalTech where von Karman taught. Vincenti worked for Timoshenko at Stanford making figures for his books. One day he said, "Walter, I know you're going to Pasadena. Would you take these papers to von Karman?" He started reminiscing about von Karman when they both were studying under Ludwig Prandtl: "You know I wish I could produce ideas one after another like that man Karman." When Vincenti went into von Karman's office at Caltech to give him the papers, Karman just happened to come out and invited him in. He talked about his relationship with Timoshenko: "You know, I just finished writing ‘Mathematics for Engineers’ with Biot and it was difficult. I wish I could write books like that man Timoshenko”.

A New Start

By 1939 there were 42 Stanford aeronautics graduates active in the airframe and airline industry, in the military and in government research. The area next to Moffett Field was designated the Ames Research Center by the NACA in 1939 and became active in a range of aeronautical research activities. However, after World War II, activity in aeronautics slowed greatly at Stanford just as it did in industry during the postwar slump.

In the 1950s, aeronautics was still in the ME Department, where it had been since its inception by Durand. The two remaining professors, Elliott Reid and Alfred Niles, were both nearing retirement. The Guggenheim fund had long since run out of money in 1939 and by the late 1950’s with the retirement of Reid and Niles approaching and with the number of students down to a trickle of four or five a year, Dean of Engineering Frederick Terman seriously considered discontinuing what was then the Aeronautics Division of Mechanical Engineering. When graduates heard this, they offered to raise money from the aircraft industry to save the program. A group led by John Buckwalter (’24, Engr. 32) of Douglas Aircraft and Philip Coleman (’34) of Lockheed formed a committee and asked each major western aircraft company to contribute $5,000 per year for five years to help re-invigorate aeronautics at Stanford and get it back to a position where it could attract students and research support. Douglas, Boeing, Convair, Northrop, North American, Hughes, and Lockheed all agreed to provide support. This committee was the predecessor of the Aero/Astro affiliates program that has remained the department’s primary connection to industry for the last fifty years.

In 1956 Hoff was head of the aeronautical engineering department at the Brooklyn Polytechnic Institute. Hoff had gained a reputation as a superb researcher and administrator at Brooklyn and was one of the rising stars in aeronautics. He was one of the worlds foremost experts in structures and a top consultant for the Lockheed Company. Willis Hawkins, head of Lockheed’s missile program, offered Hoff a full-time job, and when Hoff declined Hawkins asked if he would consider going to Stanford as a professor. Lockheed would cover one-third of his salary for five years and provide him with consulting opportunities.

The success of the fundraising effort and the leadership that Hoff had demonstrated at Brooklyn greatly impressed Terman. This was a time of resurgence for aeronautics and emergence of the new field of astronautics. Sputnik, the first satellite, had launched the Space Age in October 1957, and soon afterward the importance of high-speed flight and space travel would be widely recognized. At first Hoff was hesitant, but eventually Terman made him an offer he couldn’t refuse, and in the Fall of 1957, Hoff came to Stanford with the understanding that he would lead the founding of a new department. In September 1957 the Division of Aeronautics within the School of Engineering was formally established with Hoff as its Executive Head. Two years later Terman would approve Pettit’s request and in 1959 the Department of Aeronautics admitted its first class of students as a graduate-only department. By 1961, the name was changed to the Department of Aeronautics and Astronautics. A Centennial Conference in honor of Durand in August of 1959 (Reference

3) pointed to the growth of the department with a substantial student body and research contracts and assured Terman that the new department could stand on its own. Housed in the building named after Durand, the department is a continuing, vibrant tribute to the individual whose life meant so much to the American aeronautical enterprise.

Aerodynamics

The close connection between the newly founded department and local industry, as well as the nearby NACA Ames Research Center, would have a profound impact on the shape of the department for many decades. In January 1957 Terman hired Walter Vincenti from Ames as the first professor in the newly planned department. Hoff arrived 8 months later in September. A month later the Soviets launched "Sputnik" and the space age was born. Hoff had known Vincenti since their student days together at Stanford. Soon afterward Vincenti recruited his Ames colleagues John Spreiter, an expert in transonic flow, and Milton Van Dyke who, together with his thesis supervisor at Caltech Paco Lagerstrom, had pioneered methods for analyzing the complex flow field about aerodynamic shapes in subsonic and supersonic flow. In addition, Hoff brought to Stanford Lockheed scientist Daniel Bershader, an expert in high temperature gas dynamics, to teach part-time for free. Bershader's appointment was eventually converted to a full-time tenured one as were several others at the time. Another of Vincenti's colleagues at Ames was Dean Chapman who had gotten his PhD under Hans Liepmann at Caltech. In the mid 1970's Chapman would play a major role in bringing the new field of Computational Fluid Dynamics to NASA Ames and then soon afterwards to Stanford as a member of the AA faculty.

Vincenti had become well known for his work in transonic and supersonic aerodynamics. At Ames he had supervised research in supersonic wing design and had begun to move into the emerging area of aero-thermo-dynamics that involved flight at extreme speeds where air begins to undergo chemical reactions. Vincenti's research moved the department for the first time into space and re-entry applications and he worked with Ronald Smelt who developed a hot-shot wind tunnel for studying hypersonic flow at Lockheed. Smelt had designed such a wind tunnel for the Air Force research facility at Tullahoma, Tennessee. Hoff and Vincenti decided to build a similar facility at Stanford to do fundamental research. They needed to hire someone to help with the work, so got in touch with Prof. Hans Liepmann at Caltech for a recommendation. Vincenti knew Liepmann from his work at Ames. Liepmann recommended his former student Krishnamurti Karamcheti who was then on the faculty at USC. In 1958 Karamcheti moved to Stanford and he and Vincenti built the hot-shot tunnel at Stanford. Some years later Vincenti approached Liepmann again looking for another faculty member in high speed aerodynamics. As a result, Donald Baganoff came to the department and he and Vincenti worked together on high temperature gas dynamics with Krish and a very good graduate student, Dale Compton who would later become Director of NASA Ames.

In November 1973 Krish Karamcheti together with David Hickey of NASA Ames put together a memorandum of understanding creating a new cooperative program called the NASA-Stanford Joint Institute for Aeroacoustics (JIAA). The purpose was to train students and do research in the relatively new field of flow generated noise that had taken on new importance with the advent of commercial jets. Over the next twenty-five years the Institute would graduate forty five PhD students many of who would go on to distinguished careers in industry and academia.

Guidance and Control

Terman wanted to have leadership in automatic control. He did a careful study and in 1957 he offered Gene Franklin, a PHD student of Lotfi Zadeh at Columbia University, a position in Electrical Engineering. Hoff also wanted someone in the increasingly important field of guidance and control, and in 1959 he hired Robert Cannon from MIT. Cannon had worked on the design of the inertial guidance system that was chosen to navigate the USS Nautilus on its famous voyage under the North Pole in 1958. Franklin and Cannon became good friends and co-taught an introductory course in automatic control. The all-engineering-school controls course quickly became and continues to be a strong core part of the Stanford engineering curriculum.

In the early 1960's Cannon used Air Force and NASA sponsorship to rapidly build up a world class research group. Hoff and Cannon recruited more faculty from Lockheed including John Breakwell, a superb theorist in orbital mechanics and optimization. They brought in Benjamin Lange, who worked on the so-called drag-free satellite, a concept originated by George Pugh at MIT. Soon Daniel Debra joined the department. Debra a superb experimentalist and designer, applied the drag-free satellite idea to a family of Navy navigation satellites.

In 1966 this group awarded a PhD to a young Naval Academy graduate by the name of Bradford Parkinson. Six years later Parkinson would become the director of the department of defense's new GPS joint program office where he would play a key role in utilizing the best features of several competing designs to create the basic GPS architecture in use today. For this work and his subsequent research in industry and later as a faculty member in the Aero/Astro department, the National Academy of Engineering would honor Brad Parkinson and Ivan Getting of the Aerospace Corporation with the 2003 Charles Stark Draper Award; the most prestigious award in engineering.

Aeronautics and Astronautics Faculty in January 1968 together with faculty jointly appointed from Mechanical Engineering. Top row, left to right: Daniel DeBra, Jean Mayers, Charles Steele, Erastus Lee, Holt Ashley. Middle row, left to right: Donald Baganoff, John Breakwell, Irmgard Flugge-Lotz, Walter Vincenti, Nicholas Hoff, Daniel Bershader, Bryan Noton, Benjamin Lange. Bottom row: I-Dee Chang, Milton Van Dyke, Howard Seifert, David Chandler, Chi-Chang Chao, Krishnamurty Karamcheti, Max Anliker. Inset, upper right: Robert Cannon, inset upper left: Alfred Niles, just below right: Elliott Reid.

The drag-free satellite would become a key enabling technology for the Stanford Gravity Probe B experiment conducted by AA and Applied Physics faculty under the auspices of the Hansen Experimental Physics Laboratory. This experiment is designed to use an orbiting gyroscope to measure two very small effects predicted by Einstein's General theory of Relativity. The project began auspiciously with a conversation at the faculty men's pool between Bob Cannon, William Fairbank and Leonard Schiff in October 1959. By the early 1980s most of the technologies needed for GP-B were established, often in PhD theses by Stanford students, and NASA began to put significant funding into the project. Brad Parkinson was recruited by Bob Cannon to join the AA faculty in 1984 and soon thereafter became the Co-principal Investigator on the GP-B project with Francis Everitt who had led the program since joining the Stanford physics department in 1962. The first preliminary results of this remarkable forty-eight-year project were reported to the physics community by Everitt in April of 2007 (Reference 8).

Aeronautics and Astronautics Faculty, Pajaro Dunes retreat 1985. Left to right: Brian Cantwell, Richard Shevell, Daniel Debra, Lambertus Hesselink, William Reynolds, I-Dee Chang, Dean Chapman, Bradford Parkinson, John Spreiter, Holt Ashley, Ilan Kroo, George Springer, Robert Cannon, Fu-Kuo Chang, Robert MacCormack, Daniel Bershader, Donald Baganoff, David Powell, Leonard Roberts, Arthur Bryson (missing Krishnamurty Karamcheti, Milton Van Dyke).

National Leadership

More appointments soon followed. These included: Howard Seifert an authority on propulsion and in 1960 President of the American Rocket Society, Jean Mayers a renowned expert in aircraft structures, and I-Dee Chang a superb theoretician and another student of Lagerstrom. Using his persuasive charm and the lure of a California lifestyle, Hoff continued to recruit highly visible faculty from the East coast and in 1966 he brought Holt Ashley from MIT, one of the nation's foremost researchers in high-speed flight and aeroelasticity. In the early 1960’s Art Bryson came for a sabbatical from Harvard. Vincenti had known Bryson when he was a student working on transonic flow with Hans Liepmann at Caltech. Stanford offered Bryson a position in AA that he turned down. Six years later, Bryson was recruited again. By then he was working in controls and had become recognized as one of the most creative researchers in the field of optimal control. He accepted the offer and joined the department in 1968.

This remarkable series of appointments under Hoff's leadership solidified Stanford’s position at the forefront among research universities. The department continued to grow throughout the 1960’s and by 1970, with the new Durand building in place (funded by NASA and the Air Force through the efforts of Cannon and Hoff), more than a million dollars yearly in research, and over two hundred graduate students, Stanford surpassed MIT as the nation’s largest producer of PhD graduates in Aeronautics and Astronautics. In 1980 Hoff became the second Stanford faculty member to be honored with the Daniel Guggenheim medal for his remarkable contributions to aeronautics.

In commemoration of the 100th anniversary of the Wright Brothers first flight the AIAA Journal published a special issue (Volume 41, number 7A, July 2003) devoted to reprinted articles of special significance that have appeared in the journal and its predecessors going back to 1934. Four of the thirty-six landmark papers selected for this issue were authored by current and former faculty members of the department including, Holt Ashley, Dean Chapman, Bob MacCormack, and Milton Van Dyke. In the centennial year of flight Holt Ashley became the third Stanford faculty member to be awarded the Daniel Guggenheim medal for his pioneering contributions to aeroelasticity.

Aeronautics and Astronautics faculty, November 2005. Left to right: Brian Cantwell, Lynn Kaiser (Student Services Manager), Steve Rock, Daniel Debra, Ilan Kroo, Matthew West, Sanjay Lall, Per Enge, David Powell, Holt Ashley, Claire Tomlin, Richard Christensen, Fu-Kuo Chang, Charles Steele, George Springer, Robert MacCormack, Sanjiva Lele, Juan Alonso, Bradford Parkinson, Robert Cannon, Walter Vincenti, Ralph Levine (Department Manager). Inset upper left: Arthur Bryson. Inset upper right: Antony Jameson.

Fifty-Year Anniversary

Today, on the occasion of the half centenary of the department, modern flight systems and space systems continue to be two of the most important technology pillars that support a worldwide aerospace enterprise that fuels economic growth, brings together people and cultures, strengthens national security, enables the study of the whole Earth and supports the exploration of distant worlds. The industry is by far the largest U.S. exporter. In fact, the trade surplus of this enormous industry is roughly equal to that of all other manufacturing industries with a positive trade surplus put together.

Aerospace transportation is a key underpinning of the world economy, and it is undergoing rapid change. A few decades from now air and space travel will be completely different from today. The nations of the developed and developing world will be increasingly connected and heavily dependent upon the air transport of people and goods between them. There will be more than twice as many commercial airliners sharing the airspace with large numbers of small aircraft operating at a wide range of altitudes and speeds. Fleets of UAVs will be patrolling borders and autonomous freighters will carry goods and material across the world. New kinds of vehicles will be moving passengers and payloads in increasing numbers to and from space for commerce, research, and exploration. Overlaid on this will be the requirement for security and safety at all levels.

This worldwide air and space network must operate seamlessly, efficiently, and robustly to sustain a stable, growing world economy, to minimize environmental impact, and to ensure the safety of passengers and property. For our department this is an enormous challenge as well as a source of new opportunities. To help achieve this future vision, key advances are needed in aerospace design, space systems, position technology, decentralized control, engineering simulation, optimization, propulsion, high speed flow and aerospace structures and materials. We look forward to the endeavor.

My thanks to Walter Vincenti, Art Bryson, Bob Cannon, and Don Baganoff for their help. Any errors of fact or omission are mine alone.

Brian Cantwell, April 26, 2008

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