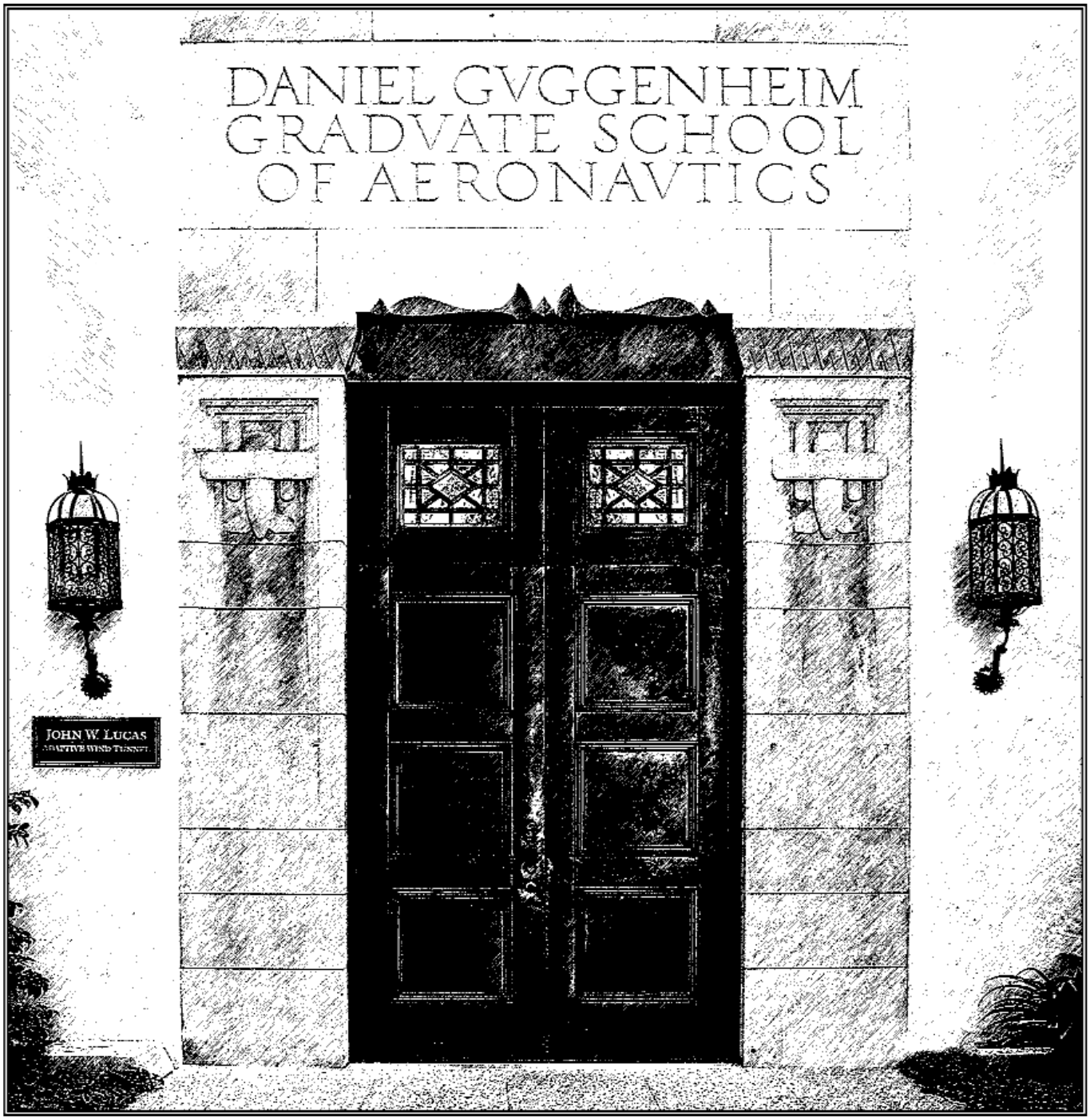
GALCIT 75



NOVEMBER 2003 CALIFORNIA INSTITUTE OF TECHNOLOGY

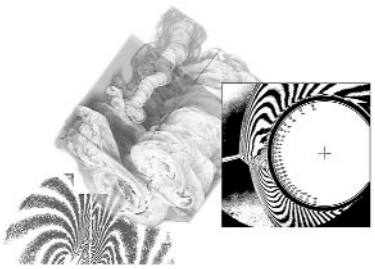
Celebrating 75 Years of Experimental, Theoretical, and Computational Innovation

GALCIT 75

75th Anniversary of the Founding of the Graduate Aeronautical Laboratories

November 14 and 15, 2003

California Institute of Technology
Pasadena, California



Celebrating 75 Years of Experimental, Theoretical, and Computational Innovation

WELCOME

This year, GALCIT celebrates the 75th anniversary of the founding of the Guggenheim Aeronautical Laboratory. We have had four distinguished Directors: Theodore von Kármán, Clark Millikan, Hans Liepmann, and Hans Hornung; students and faculty that have made substantial contributions to education, research, and science policy in the United States and throughout the world; awarded over 1,800 degrees, and today continue our mission of research and education in fluid and solid mechanics.

Although there are still many activities at GALCIT related to aeronautics and aerospace, equally or more prominent today are activities related to applications in areas such as microelectronics, biomechanics, active materials, geophysics, and applications of high-performance computing to mechanics. The Aeronautics Option continues to contribute broadly to graduate education at the Institute, and the faculty are engaged in a wide range of research pursuits, many in collaboration with other groups throughout the campus and world. In the last twenty-five years, we have initiated the rehabilitation of the original Guggenheim Building, replaced the original wind tunnels with modern subsonic, supersonic, and hypersonic facilities, developed a number of specialized smaller facilities, and moved the library to the new Sherman Fairchild Library. We have seen an almost complete turnover in the administrative staff and faculty, adding seven new faculty members, with ten having retired or been lost to illness. Through all these changes and those of the preceding years, the basic theme continues to be grounded in von Kármán's vision of a graduate school that emphasizes fundamental research.

Anniversaries are a time for reflection on past accomplishments, renewal of old friendships, summing up the present state of affairs, and anticipation of the future. We plan to do all of these. Highlights from the past are sketched out in the illustrated historical time line in this booklet. A day-long seminar on Contemporary Research in Solid and Structural Mechanics will be presented on Friday. A first-hand, close-up look at the present state of research and education at GALCIT is available on Friday afternoon through the open house and tour of the laboratory facilities. Friday evening, we will renew old friendships at an informal dinner and slide show. On Saturday, we have invited a cross-section of our more recent graduates to present their current research and perspectives on the past. A panel of distinguished alumni will examine the challenges that we face in graduate education today. No celebration at Caltech would be complete without a banquet at the Athenaeum, which we will hold on Saturday night.

The GALCIT Faculty

Donald E. Coles, Fred Culick, Paul Dimotakis, Morteza Gharib, Hans Hornung, Wolfgang Knauss, Anthony Leonard, Hans W. Liepmann, Frank E. Marble, Michael Ortiz, Dale Pullin, Guruswami Ravichandran, Ares Rosakis, Anatol Roshko, Joseph E. Shepherd, Homer Joseph Stewart

Quick Look **November 14–15, 2003** Schedule

Friday

10:00am–5pm *Registration Winnett Center*
Noon *Buffet Lunch Winnett Center*
1:00pm–5:00pm *Lab Tours and Open House Assemble outside Guggenheim*
5:30pm *Alumni Cocktail Reception, Dining and Slide Show Chandler Dining Hall*

Friday (concurrent with the above events)

Contemporary Research in Solid and Structural Mechanics Lees-Kubota Lecture Hall

7:30am *Registration and Continental Breakfast*
8:15am *Introductory and Welcoming Remarks*
8:30am SESSION I: Composites (Hegemeier, Geubelle, Waas, Brinson)
10:10am *Break*
10:35am SESSION II: Dynamic and Failure Mechanics (Ravi-Chandar, Narasimhan, Molinari)
11:50am *Lunch*
1:00pm SESSION III: Micro and Nano Mechanics (Liechti, Krishnaswamy, Lu)
2:40pm *Break*
3:05pm SESSION IV: Materials and Processes (Chen, Deng, Lew)
4:30pm *Poster and Lab Tours*

Saturday *Baxter Lecture Hall* (except where noted)

7:00am *Registration, Breakfast*
8:15am ***Richard Murray*** and ***Hans Hornung*** *Welcoming Remarks*
8:30am ***Hans Mark*** *The Dream of Yesterday is the Hope of Today and the Reality of Tomorrow*
9:30am *Coffee Break*
10:00am ***Brian Cantwell*** *Cheap, Safe Access to Space—New Meaning for the Phrase "Let's Light this Candle!"*
11:00am ***Stelios Kyriakides*** *Solid Mechanics: GALCIT Reflections*
Noon *Lunch Chandler Dining Hall*
1:30pm ***Petros Koumoutsakos*** *Bio-Inspired Flow Optimization*
2:30pm ***Raul Radovitzky*** *Affording Microstructural Details in the Analysis of Material Response through Direct Numerical Simulation*
3:30pm *Coffee Break*
4:00–5:30pm *Panel Discussion* with ***Arthur Bryson, Sébastien Candel, Paul MacCready, Yuan-Cheng Fung, Roddam Narasimha, Tom Tyson, and Max Williams***
6:30 pm *Gala Celebration Dinner Athenaeum*, Guest Speaker: ***Paul Bevilaqua*** *The Challenge of Heavier Than Air Flight*

Friday November 14, 2003 Schedule

Morning: *Winnett Center*
10:00 *Registration*
Noon *Buffet Lunch*

Afternoon:
1:00–5:00 *Lab Tours and Open House Guggenheim*
1:00–5:00 *Registration and Hospitality Winnett Center*

Evening: *Chandler Dining Hall*
5:30 *Alumni Cocktail Reception, Dinner, and Slide Show*

All Day: *Lees-Kubota Lecture Hall, Guggenheim*
7:30–5:30 Special Solids Symposium: *Contemporary Research in Solid and Structural Mechanics* (Schedule follows below)

Contemporary Research in Solid and Structural Mechanics

7:30–8:15 *Registration and Continental Breakfast*

8:15–8:20 ***G. Ravichandran*** Caltech
Introductory Remarks

8:20–8:30 ***Wolfgang Knauss*** Caltech
Welcoming Remarks

SESSION I: Composites
(Session Chair: ***G. Ravichandran***)

8:30–8:55 ***Gilbert Hegemeier*** UCSD
Advanced FRPs in the civil infrastructure: New tools for old threats

9:20–9:45 ***Phillipe Geubelle*** University of Illinois, Urbana-Champaign
Quasi-static and fatigue failure of a self-healing composite

8:55–9:20 ***Tony Waas*** University of Michigan
Microstructural instabilities in textile composites

9:45–10:10 ***L. Catherine Brinson*** Northwestern University
Why nanoreinforced polymers? Mechanics issues

10:10–10:35 *Break*

SESSION II: Dynamic and Failure Mechanics
(Session Chair: ***N. Lapusta***)

10:35–11:00 ***K. Ravi-Chandar*** University of Texas, Austin
Physical aspects of dynamic fracture

11:00–11:25 ***R. Narasimhan*** Indian Institute of Science
Effects of crack tip constraint on dynamic ductile crack initiation

11:25–11:50 ***Jean-Francois Molinari*** Johns Hopkins University
Defects and stochasticity of material response

11:50–1:00 *Lunch*

SESSION III: Micro and Nano Mechanics
(Session Chair: ***K. Bhattacharya***)

1:00–1:25 ***Ken Liechti*** University of Texas, Austin
Adhesive contact of a self-assembled polymer with an interfacial force microscope probe

1:25–1:50 ***Sridhar Krishnaswamy*** Northwestern University
Photo-acoustic characterization of the mechanical properties of thin films and coatings

1:50–2:15 ***Hongbing Lu*** Oklahoma State University
Measurements of viscoelastic functions using nanoindentation

2:15–2:40 ***Pradeep Guduru*** Brown University
Mechanics of multi-walled carbon nanotubes under compression

2:40–3:05 *Break*

SESSION IV: Materials and Processes
(Session Chair: ***Y. M. Leroy***)

3:05–3:30 ***Weinong Chen*** University of Arizona
Loading/unloading SHPB experiments on ceramics

3:30–3:55 ***Xiaomin Deng*** University of South Carolina
Solid mechanics-based simulation of the friction stir welding process

3:55–4:20 ***Adrián Lew*** Stanford University
Beyond the p-v equation of state: The role of shear in stress-induced phase transformation of iron

4:30–5:30 *Posters and Lab Tours*

Saturday **November 15, 2003** Schedule

Companions Program, 9:15am - 4:30pm; pick-up for the Getty Excursion is the turn-around on Holliston near Avery Center, just south of Del Mar.

The main program will take place in Baxter Lecture Hall (breaks in the foyer). Wireless access for laptops will be available.

Morning: *Baxter Lecture Hall*

7:00 *Registration, Breakfast*

8:15 *Welcoming Remarks*
Richard Murray (BS '85) Chair, Division of Engineering and Applied Science at Caltech

Hans Hornung C. L. "Kelly" Johnson Professor of Aeronautics GALCIT Director, Emeritus

8:30 ***Hans Mark*** Professor of Aerospace Engineering and Engineering Mechanics, John J. McKetta Centennial Energy Chair In Engineering, The University of Texas at Austin

The Dream of Yesterday is the Hope of Today and the Reality of Tomorrow

9:30 *Coffee Break*

10:00 ***Brian Cantwell*** (MS '71, PhD '76) Edward C. Wells Professor in the School of Engineering and Professor of Aeronautics and Astronautics and Mechanical Engineering, Stanford University

Cheap, Safe Access to Space - New Meaning for the Phrase "Let's Light this Candle!"

11:00 ***Stelios Kyriakides*** (MS '76, PhD '80) Professor, Aerospace Engineering and Engineering Mechanics, Temple Foundation Endowed Professorship No. 1, The University of Texas at Austin

Solid Mechanics: GALCIT Reflections

Noon *Lunch Chandler Dining Hall*

Afternoon: *Baxter Lecture Hall*

1:30 ***Petros Koumoutsakos*** (MS '88, PhD '92) Professor of Computational Sciences, ETH Zurich

Bio-Inspired Flow Optimization

2:30 ***Raul Radovitzky*** (PhD '98) Charles Stark Draper Assistant Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology

Affording Microstructural Details in the Analysis of Material Response through Direct Numerical Simulation

3:30 *Coffee Break*

Panel Discussion

4:00 - 5:30 ***Arthur Bryson*** (MS '49, PhD '51), Stanford University

Sébastien Candel (MS '69, PhD '72), Laboratoire d' Energetique Grande Voie des Vignes, École Centrale, Paris, France

Paul MacCready (MS '48, PhD '52), AeroVironment Inc.

Yuan-Cheng Fung (PhD '48), University of California, San Diego

Roddam Narasimha (PhD '61), Director, National Institute of Advanced Studies, Indian Institute of Science, Bangalore, India

Tom Tyson (BS '54, PhD '67), General Electric (founder Energy and Environmental Research Corporation)

Max Williams (MS '47, Eng '48, PhD '50), University of Pittsburgh, Dean of the School of Engineering, Emeritus

Evening: *Athenaeum*

6:30 *Gala Celebration Dinner*
Paul Bevilaqua (Chief Scientist, Advanced Development Projects, Lockheed Martin Skunk Works)

The Challenge of Heavier Than Air Flight

Time Line

1891

September—Pasadena philanthropist **Amos Throop** (1811–1894) rents the Wooster Block building in Pasadena for the purpose of establishing Throop University, the forerunner of Caltech. In November of that year, Throop University opened its doors to 31 students and a six-member faculty.

1903

Astronomer **George Ellery Hale** (1868–1938) arrives in Pasadena. He is the first Director of the Mount Wilson observatory. Hale becomes a member of Throop's board of trustees in 1907; under Hale's leadership, the transformation of Throop begins.

December 17—**Wright Brothers** first powered flight at Kitty Hawk, North Carolina. The Wrights pioneered many of the basic tenets and techniques of modern aeronautical engineering, such as the use of a wind tunnel and flight testing as design tools.

W. Wright and A. Merrill, 1910.

1917

Harry Bateman (1882–1946). Professor of Mathematics, Physics, and Aeronautics (1917–1946). One of the two first faculty members in Aeronautics, he was already an accomplished mathematical physicist when Hale recruited him. Taught and carried out research in hydrodynamics, elasticity, and mathematical methods. Author of four textbooks. His shoe boxes full of notes on special functions kept several mathematicians busy after his death on the "Bateman Manuscript Project," editing his notes into three classic volumes entitled *Higher Trancendental Functions*.

Hale solicits donation and trustees approve construction for the first wind tunnel (4 by 4 ft) built in southern California.

1918

Albert A. Merrill (1875–1952). Instructor in Aeronautics, 1918–1930, 1940–1952. First Instructor in Aeronautics at Caltech. In 1894 he started the Boston Aeronautical Society and in 1911 learned to fly, first at Squantum and later at the Wrights' place in Dayton. At Caltech, Merrill operated the first wind tunnel and complemented Bateman's theoretical instruction with wind tunnel measurement practice and airplane design. He was self-taught but very knowledgeable; holding several patents and building several airplanes, including the "Dill Pickle" with Klein and Millikan.

Speaker Biographies

In alphabetical order

Paul Bevilaqua

Chief Scientist, Advanced Development Projects, Lockheed Martin Skunk Works

Dr. Paul Bevilaqua has spent much of his career developing Vertical Take Off and Landing Aircraft. He joined Lockheed Martin as Chief Aeronautical Scientist of the Lockheed Advanced Aeronautics Company, and became Chief Engineer of Advanced Development Projects in the Lockheed Martin Skunk Works. During this time he played a leading role in creating the Joint Strike Fighter program. He invented the Lift Fan propulsion system that made it possible to build a stealthy, supersonic Vertical Take Off and Landing aircraft, and led the engineering team that demonstrated the feasibility of building variants of this aircraft for the Air Force, Navy, and Marine Corps. For this accomplishment, the development team won the 2002 Collier Trophy that recognizes "the greatest achievement in aeronautics and astronautics in America demonstrated during the year."

Prior to joining Lockheed Martin, Bevilaqua was Manager of Advanced Programs at Rockwell International's Navy aircraft plant. He began his career as a Captain in the US Air Force and Deputy Director of the Energy Conversion Laboratory at Wright-Patterson Air Force Base. He has a BS in Aerospace Engineering from the University of Notre Dame, and MS and PhD degrees in Aeronautics and Astronautics from Purdue University.

He is a Fellow of the American Institute of Aeronautics and Astronautics, and recipient of AIAA and SAE awards for his contributions to VSTOL technology and aircraft design. His publications include articles in the journals of the AIAA and the Royal Aeronautical Society, and in the proceedings of many meetings and symposia.

L. Catherine Brinson (PhD '90)

Professor of Mechanical Engineering, Northwestern University

Cate Brinson is currently a Professor in the Mechanical Engineering Department at Northwestern University, with a secondary appointment in the Materials Science and Engineering Department. After receiving her PhD in 1990 from Caltech, Dr. Brinson performed postdoctoral studies in Germany at the DLR and since 1992 she has been on the faculty at Northwestern University. Her primary research focus is on the modeling and characterization of advanced material systems, including high performance composites and intelligent mate-

rials. Current research investigations involve studies of aging in polymeric based systems, nanomechanics of nano-reinforced polymers, characterization of titanium foams for bone implants, and experiments and modeling of shape memory alloys, where investigations span the range of molecular interactions, micromechanics and macroscale behavior. Brinson has received many awards, including the 2003 ASME Special Achievement Award for Young Investigators, a 2000 Alexander von Humboldt Research Award, the 1995-99 NSF CAREER Award, the ASEE New Mechanics Educator Award, an ASEE Summer Faculty Fellowship and an AAUW Postdoctoral Fellowship; she held the June and Donald Brewer Junior Chair at Northwestern University from 1992-1994, and was a member of the Defense Science Study Group (1998-99). She has made numerous technical presentations on her research and has co-organized symposia at many ASME and SES conferences. She is a member of several professional societies and served 5 years on the Society of Engineering Science Board of Directors, including one year as President of the society. She has also been an Associate Editor of the Journal of Intelligent Material Systems and Structures and the Journal of Engineering Materials and Technology.

Arthur E. Bryson Jr. (MS '49, PhD '51)
Pigott Professor of Engineering, Emeritus, Stanford University

After earning his MS and PhD degrees from Caltech, Bryson became a research engineer at Hughes Aircraft. In 1953, he joined the faculty of Harvard University, and remained affiliated with Harvard until 1968. He was the Hunsaker Professor at MIT from 1965–1966, and joined the faculty of Stanford University in 1968. Bryson became Professor Emeritus in 1994.

He is a member of the National Academy of Engineering and the National Academy of Sciences, and is the recipient of many prizes and awards, among them the AIAA Mechanics & Control of Flight Award, the IEEE Control Systems Award, the ASME Oldenberger Award, and the AACC Control Heritage (Bellman) Award.

Bryson is the author of 30 papers and four books: *Applied Optimal Control* (1969 with Y.C. Ho), *Control of Spacecraft and Aircraft* (1994), *Dynamic Optimization* (1998), *Applied Linear Optimal Control* (2002).

Sébastien Candel (PhD '72)
Professor of Aerospace Engineering and Head of Mechanical and Aerospace Studies École Centrale Paris

1920

Donald Douglas starts his aircraft company in Santa Monica.

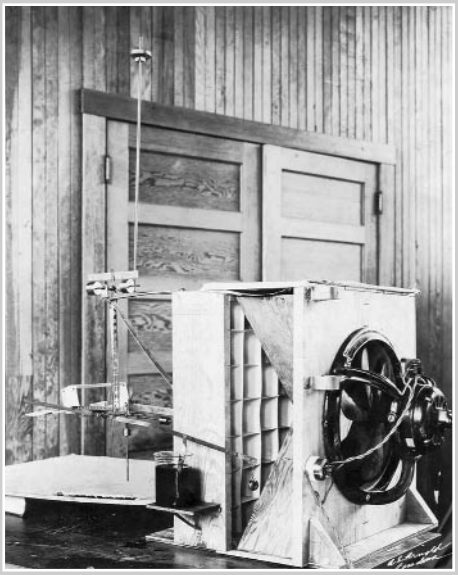

Guggenheim building, 1927.

1921

Hale is joined by chemist **Arthur A. Noyes** (1866–1936) and physicist **Robert A. Millikan** (1868–1953). These three men set the school, which by then had been renamed the California Institute of Technology, firmly on its new course. Millikan serves as Chairman (effectively the president) until 1945.

1926

Daniel Guggenheim sets up $2.5 million fund to jumpstart seven aeronautical schools in seven universities, including Caltech. $300,000 earmarked for Caltech for the construction of a laboratory and the establishment of a graduate school in aeronautics.


A. Merrill wind tunnel, circa 1928.

1927

Arthur Emmons Raymond (1899–1999). Assistant Professor of Aeronautics (1927–34). Chief Engineer, Douglas Aircraft Company (1925–60). Raymond works for Douglas during the week and begins teaching a Saturday class on airplane design to von Kármán, Klein, Bateman, Clark Millikan, Sechler, and Merrill; serves as long-time GALCIT connection to Douglas Aircraft for testing of DC-1 through DC-8 aircraft. Becomes VP of Douglas Aircraft.

Charles Lindbergh completes first solo flight across the Atlantic Ocean in May, Roosevelt Field near New York City to Paris in 33.5 hours.


Theodore von Kármán.

1928

Birth of GALCIT through the Daniel Guggenheim Fund for the Promotion of Aeronautics. From 1926–1928, the Guggenheim Laboratory was built, wrapping itself around the 10-foot wind tunnel. The academic staff consisted of mathematician Professor Harry Bateman, Professor Theodore von Kármán, Assistant Professors Arthur L. Klein, Clark B. Millikan, and Arthur E. Raymond. Albert A. Merrill was Instructor. Others on staff included William H. Bowen, Ernest E. Sechler, and Baily (Ozzie) Oswald.

1929

Arthur Louis "Maj" Klein (1898–1983). (BS 1921, MS 1924, PhD 1925). Professor of Aeronautics 1929–1968. In addition to his significant contributions as a teacher of aeronautical engineering, Klein was a legendary designer, and responsible for the engineering and building of the GALCIT 10-foot wind tunnel and related equipment (especially balances and rigging). In 1937 he began spending half his time with Douglas Aircraft, where he had been an intermittent consultant since 1932, and he was instrumental in the design of many of their aircraft over the next 20 years.

C. Millikan and Maj. Klein with DC-2 model in 10-ft tunnel.

1930

Theodore von Kármán (1881–1963). Professor of Aeronautics 1930–1949. First Director of GALCIT, 1930–1949. In 1926 von Kármán was invited to Caltech to give talks on aerodynamics, and review plans for the new wind tunnel. In 1928 he returned to Caltech for an exchange semester, and finally joined the Institute in 1929 as a research associate in aeronautics. In 1930, he was appointed professor of aeronautics and Director of GALCIT. Among his accomplishments were the first computation of drag for a supersonic projectile; application of dimensional analysis to turbulent flow, the log-law and Kármán constant for turbulent boundary layer velocity distribution (law of the wall); fundamental studies on turbulence; the discovery of the similarity law of transonic flow; and the use of stiffened panels in aircraft construction. He spent most of his time in Washington after 1942. Stepped down as director in 1949 and became professor emeritus. In 1962, at age 81, he was awarded the first National Medal of Science, bestowed in a Whitehouse ceremony by President John F. Kennedy. On his characteristic of never declining a lecturing opportunity, he once joked "I can never pass up the opportunity to dominate the conversation for an entire hour."

1930

December—the first complete scale model airplane, the Northrop *Alpha*, was installed in the 10-foot wind tunnel for design and development testing.

1932

Maurice Biot (1905–1985). (PhD 1932). Biot earned the first PhD awarded by GALCIT. He would become well known in solid mechanics, large deformation continuum mechanics (geology), thermodynamics of solids, and dynamics applied to earthquake engineering. He was a research associate and technical adviser to the National Defense Research Committee at Caltech (1940–43). Biot wrote three

C. Millikan and Maj. Klein, 1929.

Sébastien Candel received his engineering degree from École Centrale Paris in 1968, obtained a DEA in Plasma Physics from the University of Paris 6 also in 1968, a PhD in Mechanical Engineering and Applied Mathematics from the California Institute of Technology in 1972, and the Doctorat d'Etat from the University Paris 6 in 1977. He was research scientist at ONERA (the French aerospace research office) from 1973 to 1987 and assistant professor at University of Compiègne from 1975 to 1978. Since 1978 he has been a professor at École Centrale Paris where he is the leader of the combustion group of the EM2C laboratory (CNRS). In 2001 he was appointed as a senior member of Institut Universitaire de France. His current research interests include aeroacoustics, turbulent combustion, combustion dynamics, combustion control, and propulsion. He is the recipient of the d'Aumale prize (1987), and the Marcel Dassault Grand Prize (2000) from the French Academy of Sciences. He was awarded the silver medal of CNRS in 1993, was promoted to Officier des Palmes Académiques in 1998, and elected as Chevalier de la Légion d'Honneur in 2000. He is a Corresponding Member of the French Academy of Sciences (since 1994) and a member of the Academy of Technology (since 2000) of the IEEE, the ASA and the Combustion Institute and an associate fellow of the AIAA. Candel is currently Vice-President of the Combustion Institute, a member of the High Scientific Council of ONERA, and a member of the launch committee of CNES. He is the Chairman of the Supersonic Aircraft Research Network (2000); deputy editor of Combustion and Flame (since 2000); associate editor of the Comptes Rendus de l'Académie des Sciences (since 1994); and a member of the editorial boards of Combustion Science and Technology, Progress in Energy and Combustion Science, and the Journal of Propulsion and Power. He is the author or co-author of two books and of more than 260 articles and papers.

Brian J. Cantwell (MS '71, PhD '76)
Professor of Aeronautics and Astronautics and Mechanical Engineering, Stanford University

Brian Cantwell is the Edward C. Wells Professor in the School of Engineering and Chairman of the Department of Aeronautics and Astronautics at Stanford University. He received the BA and BS degrees from the University of Notre Dame in 1967 and 1968. Following graduation he served for two years in the US Army. During active duty in Belgium, he received the diploma from the Von Kármán Institute for Fluid Dynamics. After military service, he attended graduate school at the California Institute of Technology, completing the MS in 1971 and the PhD in 1976. He has been a member of the Stanford faculty since 1978 and department chairman since

2001. In his research, Professor Cantwell uses similarity methods to investigate the space-time structure of turbulent flows. Research topics have included experimental and numerical investigations of variable density and reacting flows. Most recently his research has been concentrated on measurements of the mixing and combustion between a flowing oxidizer and liquid droplets entrained from the surface of a melting fuel. This research has led to the identification of a new class of very fast burning fuels for application to hybrid propulsion. His teaching duties have included courses on aircraft and rocket propulsion, compressible flow, turbulence, similarity methods and experimentation. He was given the excellence in teaching award by the Stanford student chapter of the AIAA in 1984 and 1988. He is a Fellow of the American Physical Society, a Fellow of the AIAA, a Fellow of the Royal Aeronautical Society, and a member of Sigma Xi. He is the author of four books including a new textbook on symmetry analysis published by Cambridge Press in September 2002.

Weinong Chen (PhD '95)
Associate Professor of Aerospace and Mechanical Engineering, University of Arizona

Weinong Chen, originally from China, received his PhD in Aeronautics at Caltech in 1995. He has extensive experience in dynamic experimental technique development and dynamic material characterization. His precision dynamic experimental methods have been transferred to numerous laboratories including Sandia National Laboratories, National Institute of Standard and Technology, and U.S. Army Research Laboratory.

Xiaomin Deng (MS '85, PhD '90)
Professor of Mechanical Engineering, University of South Carolina

Xiaomin Deng received his BS degree in Mathematics and Mechanics in 1982 from the Beijing University of Aeronautics and Astronautics, and his MS and PhD degrees in Applied Mechanics in 1985 and 1990, respectively, from the California Institute of Technology. Upon graduation from Caltech in 1990, Deng joined the University of South Carolina as an assistant professor of mechanical engineering and is currently a full professor there. Several current research projects include: nanomechanics using atomistic modeling techniques (e.g. molecular dynamics simulations); three-dimensional mixed-mode elastic-plastic fracture criteria, three-dimensional crack growth simulation and finite-element method code development for airframe materials; mixed-mode elastic-plastic crack growth in thin shells under impact loading conditions.

books, including a textbook co-authored with von Kármán, as well as more than 178 scientific and engineering papers on various topics including elasticity theory, thermodynamics, applied mathematics, soil mechanics, wave propagation and scatter, wing flutter, geophysics, and seismology.


W. Bowen, C. Millikan, and B. Oswald, 1930.

1932

Boeing Aircraft Company tests the YO-31A airplane in the 10-foot tunnel.

GALCIT Meteorology program, 1932–1944. Caltech was one of the five principal centers for training personnel for the Army and Navy during WWII.

1933

Wiley Post completes first solo flight around the world, July 1933. 7 days, 19 hours.

1934

The Douglas DC-1, DC-2 development begins. Over the years, Douglas Aircraft uses the GALCIT 10-foot tunnel more than any other company.

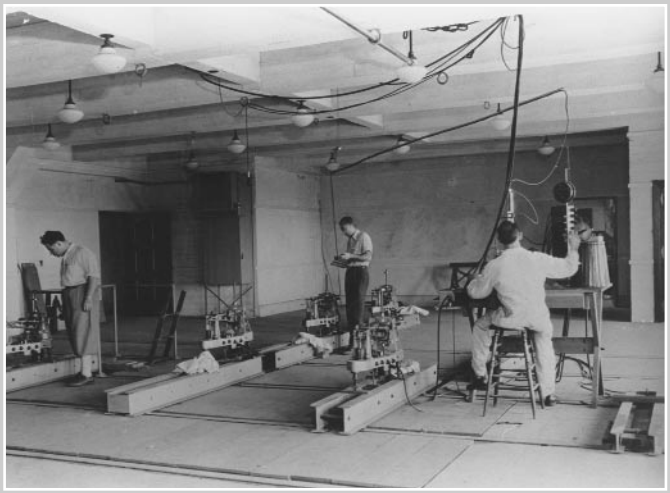

The Suicide Squad.

1935

Amelia Earhart becomes the first person to solo the 2,408-mile distance across the Pacific between Honolulu and Oakland, California; first flight where a civilian aircraft carried a two-way radio.

1936

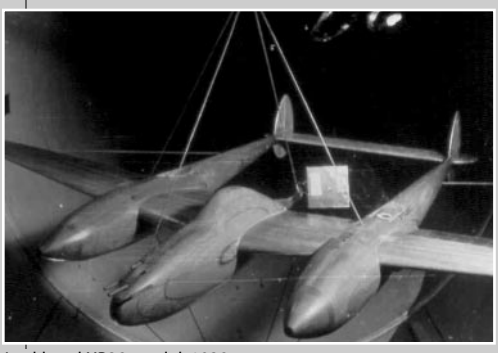
The Suicide Squad—John W. Parsons, Edward S. Forman, and Caltech graduate students Frank J. Malina, Apollo Milton Olin Smith, and Hsue-shen Tsien carry out their first rocket firing on Halloween, 1936, in the Arroyo Seco, the site of the future JPL. The initial tests sparked von Kármán's interest, and he set up Molina with a rocket test facility on campus. Twice their experiments resulted in explosions; the group was sent back to the Arroyo Seco. Malina, Tsien, and Smith carry out theoretical analyses on the feasibility of rocket propulsion and flight. From these modest origins, JPL was soon to take form.


Balance room for 10-foot wind tunnel, circa 1930's.

1937

Ernest Sechler (1905–1979). (BS 1928, MS 1929, PhD 1933). Professor of Aeronautics 1937–1976. Sechler became well known in the aircraft structures field through his pioneering work (with von Kármán 1930–35) on buckling of stiffened plates of basic interest in metal aircraft construction. He was an early proponent of using continuum mechanics to analyze structures rather than the then-dominant strength-of-materials approach. In the words of Y.-C. Fung, Sechler was a person who always found a simpler way to deal with a complex problem, guided and checked by experiment rather than theory alone.

Start of boundary layer transition work at Caltech, funded by NACA, to look at effect of curvature on transition. Initial studies by Frank Wattendorf, Francis and Milton Clauser, and subsequently, Liepmann.



Lockheed XP38 model, 1938.

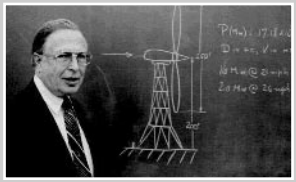
1938

William Rees Sears (1913–2002). (PhD 1938). Assistant Professor of Aeronautics 1940–1941. Chief of aerodynamics and flight testing at Northrop; headed the team that designed the P-61 (Black Widow) and the flying wing. Joined the faculty of Cornell University in 1946 as the founder and first director of its Graduate School of Aeronautical Engineering. Within a surprisingly few years, the Cornell Graduate School of Aeronautical Engineering was ranked among the world's best. Pioneered research in "ground effect," nonsteady airfoil response and flutter (with von Kármán), wing theory, unsteady flow, magnetohydrodynamics, and wind tunnel design to study transonic flight.

The growing use of thin metal structures in airplane manufacture, particularly at Northrop Aircraft, promoted von Kármán to revisit the problems of nonlinear buckling, the subject of his inaugural dissertation at Gottingen. With a team consisting of Tsien, Sechler, and Dunn, notable progress was made at GALCIT in understanding the failure of the linear theory and in establishing the appropriate view of post-buckling loads.

1939

GALCIT was approached by **Palmar C. Putnam**, who was backed by electric utilities, to design a large windmill to generate electrical power. von Kármán had Sears and Rannie carry out the aerodynamic design. The final product, a windmill 170 feet in diameter, was erected on Granpa's Knob in Vermont and functioned as planned. After an unusually high wind bent one blade, the sponsors withdrew their support.



E. Sechler, 1976.

Albert Eaton Lombard (? –1983). (BS 1928, MS 1929, PhD 1939). Assistant Professor of Aeronautics and Mechanical Engineering (1939–45/46). Consulting Engineer to Curtiss-Wright Corp 1929–1939. Lombard eventually joined McDonnell Aircraft Company.

Hans Wolfgang Liepmann, Theodore von Kármán Professor of Aeronautics, 1945-1985, Emeritus. Director of GALCIT, 1972–1985. Came to GALCIT as a Research Fellow in 1939. Research included: boundary layer transition, effect of curvature; turbulent shear flow; transonic flow and boundary layer separation on airfoils. Early work done using 2 x 20-inch transonic tunnel; motivated by "compressibility burble" and buffeting problems on the P-38. Later work with his students in skin friction in supersonic flow; aircraft buffeting; rarified gas dynamics; magnetohydrodynamics and plasma physics; liquid helium; chemistry in turbulent mixing; active boundary layer control. With Roshko wrote classic text, *Elements of Gasdynamics*. Recipient of the National Medal of Science and National Medal of Technology. Over 60 PhD students studied under him, and a large academic family has developed through the years. Many went on to be leaders in education and research, in universities, industry, and government throughout the world.

Yuan-Cheng Fung (PhD '48)
Professor Emeritus, Bioengineering, University of California, San Diego

Professor Fung is widely recognized as the father of biomechanics, having established the fundamentals of biomechanical properties in many of the human body's organs and tissues. He also studies remodeling, growth, and resorption of tissues as a foundation of tissue engineering. Currently, his focus is on growth and remodeling of blood vessels under stress in health and disease. He is inventing new techniques and developing new experiments to determine the zero-stress state and the constitutive equations of blood vessel components such as collagen, elastin, and smooth muscle; lumped layers such as the endothelium, the media, and the adventitia; and the vessel as a whole. He is developing theory to integrate morphology, mechanical properties, rheology, thermal environment, and boundary conditions into a pressure-flow relationship.

Fung joined UCSD in 1966 to initiate a program in bioengineering. Fung is the recipient of the President's National Medal of Science, the Founder's Award from the National Academy of Engineering, and numerous other prestigious honors and prizes. He is a member of the National Academy of Engineering, National Institute of Medicine, and National Academy of Sciences. He has written many books on biomechanics that are used as textbooks around the world, in addition to books on solid mechanics and continuum mechanics. Prior to joining UCSD, Fung was a faculty member in the Department of Aeronautics at the California Institute of Technology where he received his PhD in 1948.

Philippe H. Geubelle (MS '89, PhD '93)
Associate Professor in Aerospace Engineering, University of Illinois at Urbana-Champaign

Originally from Belgium, Philippe Geubelle got his BSc in Mechanical Engineering from the Catholic University of Louvain in 1988 and his Master's in Aeronautics at Caltech in 1989. In 1993, he obtained his PhD at GALCIT working with W. G. Knauss on the theoretical analysis of nonlinear effects in fracture. After completing his military service in Germany, he spent a year at Harvard as postdoctoral research associate, working with James R. Rice on the development of a spectral scheme for dynamic fracture simulations.

He then joined the University of Illinois at Urbana-Champaign (UIUC) in January 1995, where he is currently an associate professor in Aerospace Engineering, with joint appointments in Theoretical and Applied Mechanics and in Mechanical and Industrial Engineering. Since 1997, he has been serving on the Science Steering Committee of the DOE-

sponsored ASCI Center for the Simulation of Advanced Rockets. He is also serving as Director of the NASA Illinois Space Grant Consortium, a multi-year program involving primarily UIUC, Northwestern, IIT and U. Chicago.

His research interests pertain to the theoretical and numerical treatment of complex problems in solid mechanics, and, in particular, of quasi-static and dynamic fracture mechanics, functionally graded materials, multiscale modeling, composite manufacturing processes, failure events in solid propellant rockets and the self-healing composite concept. Other research activities involve computational aeroelasticity and parallel programming. In 1998, he received the NSF Career Award for his work on the mesoscale simulation of damage processes in structural ceramics. In 1999, he received the University of Illinois COE Xerox Research Award and was the recipient of the 2000 Everitt Award for Teaching Excellence. Other awards include the List of Teachers Rated as Excellent by their Students (1995-2003) and a Best Paper Award from the American Composite Society (2001).

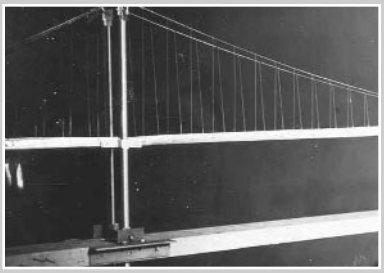
Pradeep R. Guduru (PhD '01)
Assistant Professor of Engineering, Brown University

Pradeep R. Guduru received his Bachelors degree in Mechanical Engineering from Sri Venkateswara University and Masters degree in Aerospace Engineering from Indian Institute of Science. He then joined GALCIT and received his PhD in 2001 where he worked with Professor Ares J. Rosakis. As part of his thesis, he worked on developing a 64 -element high speed infrared imaging system and used it to image temperature fields resulting from dynamic events in solids. During his stay at GALCIT, he received the Sechler memorial award for contributions to teaching and research and the Ballhaus prize for the best thesis. After graduation, he joined Brown University as a postdoctoral research associate where he worked on analytical modeling of fragmentation in ductile solids; and stress evolution during thin films growth. He joined the faculty of Brown University as an assistant professor in 2002. His current research activities are in the areas of: developing new nanofabrication methods using magnetic configurational forces; electromechanical coupling in carbon nanotubes; and biologically inspired discrete contact mechanics.

Gilbert Hegemeier (MS '60, PhD '64)
Professor of Structural Engineering, University of California, San Diego

Hegemier's research work focuses on large structures and composite materials. Author of numerous publi-

1940


Tacoma Narrows bridge model.

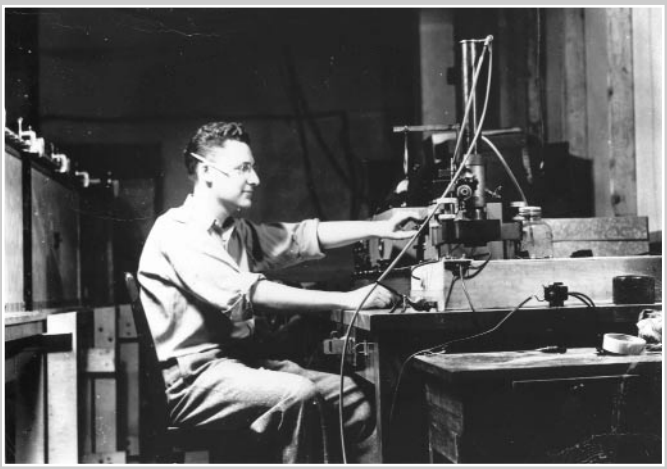
Homer Joe Stewart (PhD 1940). Professor of Aeronautics, 1942–1980. Starting as a graduate assistant at the GALCIT 10-foot wind tunnel, Stewart worked on meterology, theoretical and applied aerodynamics, particularly unsteady flow around supersonic airfoils and bodies of revolution. He also participated in many pioneering rocket projects, becoming a section manager of the analytical missile aerodynamics group at JPL.

The Tacoma Narrows Bridge collapsed following severe oscillations induced by wind. von Kármán, who was convinced that the accident resulted from aerodynamic instability, was appointed to a commission investigating the collapse. von Kármán had Rannie and Dunn carry out analyses and wind-tunnel experiments, the results of which proved vital in the redesign of the bridge.

1941

2-1/2 by 2-1/2 inch Supersonic Tunnel was designed by Tsien and Serrurier starting in 1940 and operated by Puckett in 1941–1942. First continuously operated supersonic wind tunnel to reach M > 4 in the US. Used by students until demolition in 1997.

Out of the initial work by Malina's group on rocket propulsion, GALCIT Project No. 1 was organized to apply jet propulsion to assisting the take-off of aircraft. The JATO rocket was born and first solid-propellant rockets shortened the take-off distance of aircraft by up to 50%.


S. Corrsin, circa 1943.

1942

Frank Joseph Malina (1912–1981). (MS 1935 and 1936, PhD 1940). Caltech Assistant Professor of Aeronautics, 1942–1946. Co-founder GALCIT Rocket Research Project and Jet Propulsion Laboratory (JPL). As a graduate student, he led the group that did the initial research on propellants, rocket motors, and theoretical rocket performance. Gave the first theoretical demonstration (with von Kármán) that long-duration solid propellant rockets were possible. Became the first Acting-Director of the Jet Propulsion laboratory and led effort to build the WAC Corporal. Developed with Parsons the basic formulations of solid and liquid propellants; variations of which have found widespread use up to the present time.

Aerojet Engineering Corporation founded by von Kármán and colleagues to manufacture jet-assisted take-off systems for the military.


F. Malina, 1978.

1943

At the request of the Air Technical Service Command. Army Air Force, von Kármán organizes a graduate curriculum in Jet Propulsion for a group of military officers. The courses and laboratories were taught by Caltech and JPL personnel. Tsien edited these courses into a massive book, "Jet Propulsion," which served as the standard for over ten years.

The GALCIT rocketry group under von Kármán, Tsien, and Malina draft a proposal (dated November 20, 1943) to the military to fund work to develop missiles. This document (the first official memo in the U.S. missile program) was the first to use the name "**Jet Propulsion Laboratory**."

1944

Transonic wind tunnel, 2-in x 20-in, built by Liepmann. Used by Liepmann with H. Ashkenas and J. Cole to carry out pioneering studies on shock-wave/boundary interactions on high-speed flow over airfoils. Demonstrated the importance of the state of the boundary layer, laminar vs turbulent, on resulting shock-wave pattern and pressure distribution. Later converted to 4-in x 10-in operation by Ashkenas, Satish Dhawan, and Roshko.

C. C. Lin (PhD 1944). Comprehensive analysis of the stability of two-dimensional parallel flow and stability of compressible boundary layer (with Lees), summarized in his book, *The Theory of Hydrodynamic Instability*.

1945

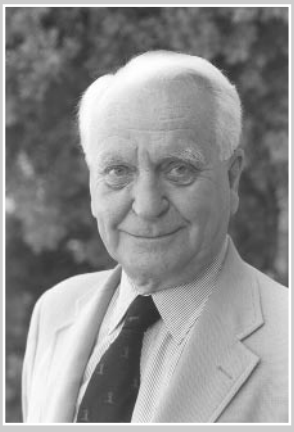
Louis Dunn (1908–1979). (BS 1936, MS ME 1937, MS Ae 1938, PhD 1940). Professor of Aeronautics 1945–1954. Director of JPL, 1947–1954. Dunn was a close colleague of Sechler and participated with him in the evolution of the "equivalent panel width" characterization of plates undergoing buckling. He became assistant director of the Jet Propulsion Laboratory in 1945–1946 and its director from 1947–1954, presiding over its early program in rocketry leading up to the development of the Sergeant missile. He left JPL to take over the beginning Atlas missile project for the recently formed Ramo-Wooldridge Corporation.

Southern California Cooperative Wind Tunnel. Clark Millikan, Director, 1945–1960.
Joint venture financed by five Southern California aircraft companies and managed and operated by Caltech. It was one of the first large supersonic wind tunnels. Upgraded to transonic operation in 1955, shut down in 1960 when it became uneconomical to operate.

1946

Paco A. Lagerstrom (1914–1989). Professor of Aeronautics 1952–1966. Professor of Applied Mathematics 1967–1981. Educated as a pure mathematician; recruited by Liepmann from Douglas Santa Monica in 1946. Applied elegant mathematical methods, including asymptotic expansions and similarity solutions based on group theory, to fluid mechanics problems. Wrote classic section on "Laminar Flow Theory" for Princeton Handbook series. Lagerstrom, Cole, van Dyke, and Kaplun pioneered the use of matched asymptotic expansions in solving fluid-flow problems.

Lee A. DuBridge (1901–1994). President of Caltech, 1946-1969.


P. Lagerstrom.

1947

W. Duncan Rannie (1914–1988). (PhD 1951). Robert H. Goddard Professor of Jet Propulsion 1947–1981. Early work while still a student on the aerodynamics of sustained and several patents, he has been honored for his research with the CERF (Civil Engineering Research Foundation) Charles Pankow Award for Innovation, and for his teaching with the Teacher of the Year, UCSD School of Engineering Annual Teaching Award (Mechanical Engineering). He is also the founder and Co-Director of the Powell Structural Research Laboratories, University of California, San Diego. After witnessing the devastation caused by the 1971 San Fernando Valley earthquake and the 1972 Nicaragua earthquake, Hegemier, then an aerospace engineer, decided to devote his research to developing systems to retrofit bridges, roadways and buildings. He and his colleagues have succeeded in creating and testing full-scale models of bridge column retrofit systems, which have been applied by the California Department of Transportation. These systems stood the ultimate test in the 1994 earthquake that hit Los Angeles, when 114 retrofitted bridges received only minor damage from the quake while several bridges scheduled for retrofit failed.

Petros Koumoutsakos (MS '88, PhD '92)
Professor of Computational Science
Swiss Federal Institute of Technology, Zurich (ETHZ)

Petros Koumoutsakos, a Greek citizen, was born in Gythion, Laconia, Greece in 1963. He studied at the National Technical University of Athens (1981–1986) and received his Diploma in Naval Architecture and Mechanical Engineering. He received a master's degree (1987) in Naval Architecture from the University of Michigan, Ann Arbor.

He continued his graduate studies at the California Institute of Technology where he received a master's degree in Aeronautics (1988) and a PhD in Aeronautics and Applied Mathematics (1992).

From 1992–1994 he was a National Science Foundation postdoctoral fellow in parallel supercomputing at Caltech. Since 1994 he has been a senior research associate and maintains an active affiliation with the Center for Turbulence Research (CTR) at NASA Ames/Stanford University. From September 1997 to June 2000 he was an assistant professor in Computational Fluid Dynamics at ETHZ. He became a full professor in 2000.

Koumoutsakos is currently the Director of the Institute of Computational Science (www.icos.ethz.ch) and the founder and director of the ETHZ Computational Laboratory (CoLab) (www.colab.ethz.ch). The ETHZ-CoLab is an interdepartmental research center emphasizing on research in multiscale simulations and machine learning algorithms as applied to materials and life sciences.

His research activities are in the areas of particle methods and bio-inspired optimization algorithms and the application of these techniques to problems in the areas of engineering and life sciences.

Sridhar Krishnaswamy (PhD '89)
Professor of Mechanical Engineering, Northwestern University

Sridhar Krishnaswamy obtained his B Tech degree in 1983 from the Indian Institute of Technology, Madras, and his PhD from Caltech in 1989. He then moved to the University of California, San Diego, as a post-doctoral fellow. In 1990, he joined Northwestern University where he is currently Professor of Mechanical Engineering.

Krishnaswamy's current research interests are in optical and ultrasonic methods of materials characterization. He and his co-workers are currently working on: photoacoustic characterization of thin films and coatings, multiplexed two-wave mixing interferometers for photoacoustic phased array imaging, and fiber and micro-optical sensors for structural health monitoring.

Stelios Kyriakides (MS '76, PhD '80)
Professor of Aerospace Engineering & Engineering Mechanics, University of Texas, Austin

Stelios Kyriakides received a BSc degree in aeronautical engineering from the University of Bristol in the United Kingdom and graduate degrees in aeronautics, with specialty in the mechanics of solids, from the California Institute of Technology. He joined the University of Texas at Austin in September 1980 where he was promoted to Associate Professor in 1985 and to Professor in 1989. Kyriakides' major technical interests are in the mechanics of solids with an emphasis on instability at both the macro (structural) and micro (material) levels. His work is motivated by practical problems and usually involves combined experimental, analytical, and numerical efforts. He has pioneered the area of propagating instabilities in solids, structures, and materials which affect the mechanical behavior of structures of larger size such as offshore pipelines, oil well casings, tunnel linings, etc. His work also demonstrates that such instabilities also govern the propagation of necks in polymers, the crushing in cellular materials, composites, wood, the propagation of phase transition fronts in shape memory alloys, the propagation of Lüders bands in metal alloys, etc. Kyriakides was recognized with the Presidential Young Investigator Award in 1984. He is a Fellow of the ASME and of the American Academy of Mechanics. He is a member at large of the US National Committee of Theoretical and Applied Mechanics and chaired the ASME Applied Mechanics Division from July '02–June '03. He also serves on several editorial boards of international journals.

pension bridges and wind power (unfortunately, his analytical findings regarding the stability of the giant windmill were not incorporated into the final design). Went to Northrop to work on the "Turbodyne" project and developed the theories and design procedures for axial compressors that became the basis for much of the progress in gas turbine technology that followed. Became chief of ramjet and combustion research at JPL in 1945, and a member of the faculty in 1947. His thesis on heat transfer in turbulent flow was interrupted by the war; was accepted and published in 1951.

Charles Yeager. First supersonic flight. On October 14, 1947, over dry Rogers Lake in California, Charles Yeager rode the X-1, attached to the belly of a B-29 bomber, to an altitude of 25,000 feet. After releasing from the B-29, he rocketed to an altitude of 40,000 feet. He became the first person to break the sound barrier, safely taking the X-1 to a speed of 662 mph, faster than the speed of sound at his altitude.

RAND Report No. 1. U.S. Army Air Forces receive the Douglas study proposing early development of an American communications satellite and attesting to the feasibility of the undertaking. A number of GALCIT faculty and alumni, including Frances Clauser, Paco Lagerstrom, and Hans Liepmann, were involved in the study.

The first analytical study of the detailed flow in axial turbomachines was published by Marble, leading to an extensive program of internal aerodynamics. This work included analysis and experiments of distorted inlet flow by Rannie, Marble, Katz, and Heiser, and extensive experiments by Iura and analysis by Oates and Burggraf to confirm the mechanism of stall propagation in compressor blade rows.

1948

Frank E. Marble (MS 1942, AE 1947, PhD 1948). Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering and Professor of Jet Propulsion, 1948–1989, Emeritus. Marble was appointed Instructor in Aeronautics in 1948 and Assistant Professor of Jet Propulsion and Mechanical Engineering in 1949 at the time the Jet Propulsion Center was established. That same year he organized a joint effort between The Jet Propulsion Center and JPL which was the focus of combustion research in propulsion systems over a period of ten years. He has carried out extensive research in the fluid mechanics of turbomachinery, combustion fluid mechanics, acoustics, dynamics of heterogeneous media, and a wide variety of problems associated with high Mach number propulsion systems. In 1999 was awarded the Daniel Guggenheim Medal for Notable Achievements in the Advancement of Aeronautics.

A continuously operating hypersonic tunnel was built in an extension to the original Guggenheim building. This had a 5-in x 5-in in test section; the M = 6 leg was put into operation first followed later by the M = 11 leg. These were operated as the Hypersonics Lab (funded by the Army) up to 1953 under Nagamatsu, and from 1953 to 1970 under Lees. Under Lees' leadership, extensive experimental and theoretical work was carried out on various hypersonic flow topics.

1949

Clark Blanchard Millikan (1903–1966). (PhD 1928). Professor of Aeronautics 1929–1966. Director of the Southern California Cooperative Wind Tunnel, 1945–1960. Director of the GALCIT, 1949–1966. Caltech physics graduate student with an early interest in aeronautics. Produced his thesis, "The Steady Motion of Viscous Incompressible Fluids" under Bateman. Played a key role, together with Klein, in the development of the 10-foot tunnel and the testing programs. Contributed both to practical aerodynamics and theoretical fluid mechanics including: effect of turbulence on lift; similarity in turbulent boundary layer and pipe flow; effect of propeller slipstream on aircraft performance; development of multi-engine high-altitude airplanes; jet propulsion; and guided missiles. Supervised all of the testing research carried out in the 10-foot wind tunnel, and had a significant influence on the early development of many of the important airplanes of the 1930s and '40s. Effectively directed GALCIT beginning in 1942, until he passed away in

1966. Saw the need for and proposed cooperative wind tunnel in 1938. Maintained productive relations with industry and government agencies; rebuilt GALCIT after the end of WWII.

Hsue-shen Tsien (Phd 1939). Assistant Professor of Aeronautics (1943–1946); Robert H. Goddard Professor (1949–1955). Director of the Guggenheim Jet Propulsion Center (1949–1955). Brilliant scientist who was von Kármán's protégé, colleague, and heir-apparent. Became the first Director of the Daniel and Florence Guggenheim Jet Propulsion Center established at Caltech in 1949. Seminal work in many areas, including aeronautics, applied mechanics, rocketry, and control. Discovered similarity laws of hypersonic flow; designed GALCIT's first supersonic tunnel. Was instrumental in advising the U.S. military during WWII. Left the U.S. in 1955 and subsequently played a key role in developing the Chinese missile and space programs.

Allen Puckett (PhD 1949). Built 2-1/2 -in by 2-1/2 -in supersonic tunnel during 1941–1942 and designed a larger tunnel (3-ft x 3-ft) in 1942 that was built at Ballistic Research Laboratories, Aberdeen Proving Ground, MD. Also designed smaller tunnels for JPL. Conducted supersonic airfoil studies and developed delta wing theory with H.J. Stewart. Taught compressible flow theory with Liepmann to Kelly Johnson and others at Lockheed at end of WWII. Went on to became CEO and Chairman of Hughes.

1950

Max L. Williams (MS 1947, AE 1948, PhD 1950). Professor of Aeronautics (1951–1966). Solid mechanics pioneer responsible for the first analytical publication of the square root singularity in fracture problems, which established the similarity of all (brittle) fracture problems in terms of a stress intensity factor which characterized the severity of stresses at the tips of cracks. Established one of the first dynamic fracture laboratories in this country. His involvement in the U.S. solid propellant rocket program led to far reaching changes in design practices regarding the structural integrity of solid propellant rocket motors in terms of mechanics principles. Became a major force behind instituting viscoelastic material characterization and extension to viscoelastic fracture mechanics. Had a major international influence on the evolving understanding of the time-dependent behavior of polymers. Founder of *The International Journal of Fracture*.

Yuan-Cheng Fung (PhD 1948). Professor of Aeronautics (1951–1965). His early interest in shell structures focused initially on stability issues of curved plates and shells of variable thickness. His interest in airplane stability and fluid-structures interaction precipitated by von Kármán vortices lead to an extended and long involvement in aeroelasticity. Significant work in formulating structural stability problems in statistical terms, especially in connection with supersonic aircraft. His interest in shell structures had a profound influence on his research when he observed in Harold Wayland's laboratories the ease with which blood cells moved through blood vessels of much smaller diameter; his answer being that the blood cell exhibits a low (~zero) internal pressure to allow the relative flexibility of its shell/membrane. This question led to a new career in biomechanics, which he then carried out successfully at the University of California in San Diego.

M. Williams and Yuan-Cheng Fung, 1970.

The Jet Propulsion Center and JPL establish a joint research program on combustion problems in propulsion system directed by Marble. Among its accomplishments during the next decade were the first analysis of ignition and combustion in mixing layers between combustible gas and hot combustion products (Adamson); demonstration of the mechanism by which flames are stabilized in the wakes of solid bodies; development of scaling laws which allowed sizing and spacing of flameholders in air-breathing propulsion engines (Zukoski and Broman); establishment of the mechanism of high-frequency combustion instability in gas turbine afterburners (Rogers and Barker). The final investigation of this program was a

Adrián Lew (MS '99, PhD '03)
Assistant Professor of Mechanical Engineering, Stanford University

Adrián Lew was born in Argentina, where he graduated as a Nuclear Engineer from the Balseiro Institute in 1998. He received his MSc and PhD degrees from GALCIT in 1999 and 2003, respectively. Since September 2003 he is an Assistant Professor of Mechanical Engineering at Stanford University. Adrian has been working on Computational Solid Mechanics, particularly focusing in problems involving shock-loaded materials, and looking at algorithmic, mathematical, material modeling and dynamic mesh adaption aspects.

Ken Liechti (MS '74, PhD '80)
Professor of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin

Ken Liechti received a BSc degree in Aeronautical Engineering with first class honors in 1973 from Glasgow University in Scotland. His graduate degrees are from the California Institute of Technology (MS 1974 and PhD 1980). He worked for General Dynamics' Fort Worth Division for two years and then joined the University of Texas at Austin in September 1982. He was promoted to Associate Professor in 1987 and Professor in 1992.

Liechti's major technical interests are in the mechanics of solids with an emphasis on fracture at interfaces between materials, fracture in adhesively bonded joints and the mechanical behavior of thin films. Research problems in these areas are approached via a combination of experiments and numerical analysis. The topics are usually motivated by practical problems such as the durability of adhesively bonded joints in automobile structures that are exposed to solvents, the durability of interfaces in microelectronic devices, debonding in rubber to metal joints and delamination in sandwich structures at high temperatures.

Hongbing Lu (PhD '77)
Associate Professor of Mechanical and Aerospace Engineering, Oklahoma State University

Hongbing Lu's research interests include experimental mechanics, viscoelasticity, fracture mechanics, and mechanics in web handling. Some of his current projects include accelerated life testing of structural polymers and measurements of local viscoelastic properties by nanoindentation. Lu is a member of the American Society of Mechanical Engineers (ASME), the American Institute of Aeronautics and Astronautics (AIAA), and the Society of Experimental Mechanics, for which he is currently Chair of the Division of Time Dependent Materials.

Paul B. MacCready (MS '48, PhD '52)
Chairman/Founder, AeroVironment Inc.

Paul MacCready began with flying sailplanes and powered aircraft after WWII. The sailplane flights pioneered high altitude wave soaring and in-cloud ventures (including winning three National Championships, and the 1956 International Championship in France). The powered plane flying fitted his early connection to weather modification research, a major dedication of his first company, Meteorology Research Inc., for fifteen years.

In 1971 he started AeroVironment Inc., mostly for environmental and energy goals. However, in 1976 he again began aeronautical developments and flying, becoming "the father of human-powered flight" in 1977 when his human powered Gossamer Condor captured the first Kremer Prize, and in 1979 when his Gossamer Albatross won the next Kremer Prize for crossing the English Channel (at $214,000, the largest prize in aviation history). The aviation division of AeroVironment was then started and soon the solar powered Solar Challenger carried its pilot 163 miles at 11,000 feet from Paris to eastern England. This initiated concepts that eventually saw the lightweight, giant 247 foot solar-powered Helios reach 96,863 feet altitude in 2001 (two miles higher than any plane had ever been able to maintain level flight). This was a step toward operational aircraft to remain in one location at 65,000 feet day and night for many days sustained by solar power, batteries, or fuel cells. The small, unoccupied planes of this aviation division (from 1/2 oz to 200 lbs) include large operational quantities of vehicles for the military.

AeroVironment Inc. was the primary developer, for GM/Hughes, of the Sunraycer, that won the first solar car race across Australia in 1987. The company then developed (for and with GM) the battery-powered Impact car in 1988-89, which became the EV-1. At present AeroVironment is developing both battery packs and fuel cell systems for powering a number of efficient planes, land and water vehicles.

MacCready continues work on vehicle and device developments that have immediate markets now and ones with potentials for unique futures. His work and talks and writings all fit the challenge of finding a balance between nature and future technology. He is dedicated to causing rapid change in institutions, technologies, education, and public understanding that can help meld humans, technology, and nature into a desirable, sustainable world.

Hans Mark
Professor of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin

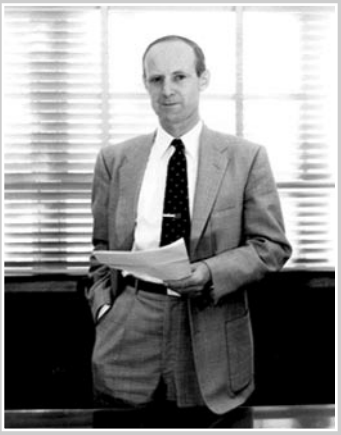
Hans Mark has been Professor of Aerospace Engineering and Engineering Mechanics at the

series of combustion instability experiments in solid propellant rockets by Brownlee, the data from which constitutes the most complete set of organized rocket firings.

Merrill Wind Tunnel. Closed-return tunnel used for teaching and research projects; 200 mph, 3-ft by 4-ft test section. Named after Albert Merrill, who helped with the design, the tunnel was installed in 1950 and is still operating.

1952

Tsien introduces the concepts of contemporary control theory into the control of propulsion systems. Among the consequences of these studies were the introductory investigations of servostabilization of combustion instability in monopropellant and bipropellant liquid rocket motors.


W. Pickering.

1953

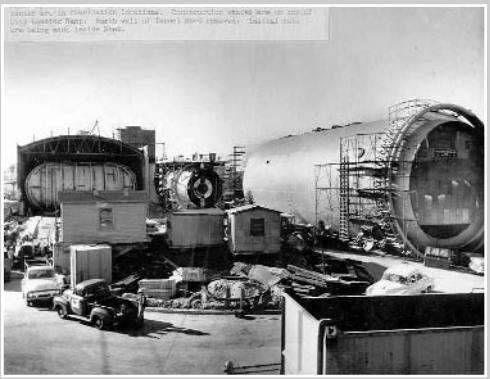
Lester Lees (1920–1986). Professor of Aeronautics and Environmental Engineering, 1953–1985. As director of the Hypersonics Laboratory from 1953–1970, he led investigations into key technological aspects of ballistic missiles and reentry body design including leading-edge shock-wave influence on boundary layers, hypersonic wakes, shock-wave/boundary interactions, rarified flow about blunt slender bodies, and physics of ablation. Director of Caltech's Environmental Quality Laboratory from 1970 until 1974.

1954

William Pickering (BS 1932, MS 33, PhD 36). Professor of Electrical Engineering, Emeritus, 1940-1980. Director of JPL, 1954–1976. In 1944, Pickering organized the electronics efforts at JPL to support guided missile research and development, becoming project manager for Corporal, the first operational missile JPL developed. From 1954 to 1976 he was director of JPL, and oversaw the development of Explorer I, Pioneer IV (the first successful U.S. circumlunar space probe), the Mariner flights to Venus and Mars in the early to mid-1960s, the Ranger photographic missions to the moon in 1964–65, and the Surveyor lunar landings of 1966–67.

1955

Donald Coles (MS 1948, PhD 1953). Professor of Aeronautics, 1955–1996, Emeritus. Known for his meticulous experimental studies and analysis of data, particularly in turbulent boundary layers. Discovered the "Law of the Wake" (1956); the complex transition between states in Taylor-Couette flow (1965); key participant in the influential 1968 Stanford Boundary Layer Conference; study of similarity structure of entrainment in turbulent spot (with Cantwell and Dimotakis); synthetic turbulent boundary layer (with Barker, Savas, Arakeri); wake structure of stalled airfoil (Wadcock) and cylinder (Cantwell) with the "flying hot wire" technique; writing monograph tentatively now titled *Topics in Turbulent Shear Flow*.


Co-op wind tunnel modifications, 1955.

Anatol Roshko (MS 1947, PhD 1952). Theodore von Kármán Professor of Aeronautics, 1955–1994, Emeritus. Acting Director, Graduate Aeronautical Laboratories, 1985–87. Experimental fluid mechanics. Shock-wave boundary-layer interaction. Boundary-layer effects in shock-tube design. Subsonic and supersonic separated flows: wake structure, base pressure, bluff-body modelling, vortex shedding, flow-induced vibration. New

insights into turbulent-shear-flow structure and mixing, with Garry Brown and Gene Broadwell. Co-author with Liepmann of *Elements of Gasdynamics*.

Julian Cole (MS 1946, PhD 1949). Professor of Aeronautics, 1951–1967, Professor of Applied Mathematics, 1967–1971. Contributions to transonic aerodynamic theory and singular perturbation methods.

1956

Edward E. Zukoski (1927–1997). (MS 1951, PhD 1954). Professor of Jet Propulsion and Mechanical Engineering, 1957–1995. Thesis work in the problem of combustion stability in ramjet engines and gas turbine afterburners. His work laid the foundations of the flame-holding mechanism. He and his students made major contributions to magneto-gasdynamics, aeroacoustics, problems of propellant control under micro-gravity conditions, and hydrogen/air mixing in supersonic combustion ramjet propulsion systems. Zukoski moved into building fire research in the 1960s, and with Kubota developed the first comprehensive description of convective fire plumes.

1957

Sputnik 1—October 4, 1957, launch of first artificial satellite of the Earth, Sputnik 1. This event began the space race by galvanizing interest and action on the part of the American public to support an active role in space research, technology, and exploration.

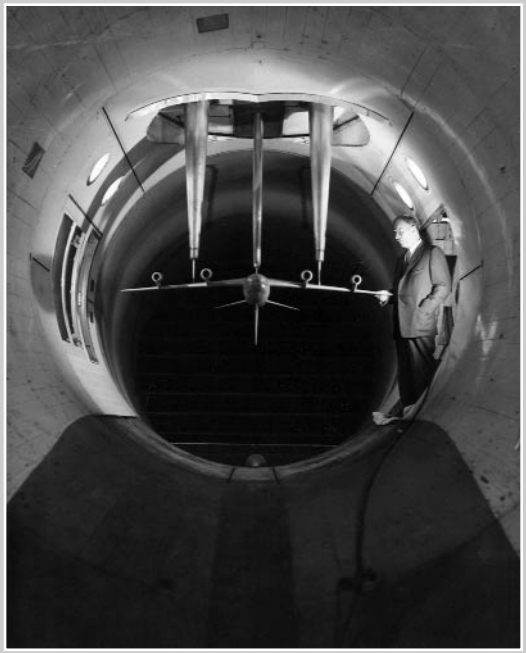
1959

Explorer I—the first U.S. earth satellite, was developed by the Jet Propulsion Laboratory and carried the U.S.-IGY (International Geophysical Year) experiment of James A. Van Allen that resulted in the discovery of the radiation belt around the Earth.

The 17-in shock tube was designed to operate at very low pressure in order to carry out shock-wave structure measurements with electron beams and mass spectrometry. The large size has been used to advantage at atmospheric pressure to study the focusing of weak shocks, shock-wave propagation through turbulence density fluctuations, and shock-wave induced instability. It is currently being used in converging shock studies.

1961

Toshi Kubota (1927–1999). (MS 1952, PhD 1957). Professor of Aeronautics (1959–1990). Kubota was a student of Lees. From 1957 to 1959 he was a research associate. He became a faculty member in 1959 and was promoted to full Professor



C. Millikan, 1960.

University of Texas (UT) since 1988. He also holds the John J. McKetta Centennial Energy Chair in Engineering. Since 1990, he has been associated with the University's Institute for Advanced Technology as a Senior Research Engineer. In that capacity he works on advanced weapons systems for the US Army.

Mark was named Chancellor of the University of Texas System on September 1, 1984 and served until September 1, 1992. The University of Texas System consists of fifteen separate institutions, nine academic campuses, four medical schools and two research-oriented hospitals.

Prior to joining UT in September 1984, Mark was the Deputy Administrator of NASA. During his term of service he oversaw the first fourteen space shuttle flights and helped to initiate the U.S. Space Station Program. Mark moved to Washington in April 1977 when he was appointed Undersecretary of the Air Force and director of the National Reconnaissance Office by President Jimmy Carter. In the latter post, he was responsible for managing the US satellite reconnaissance program. In April 1979, he was named Secretary of the Air Force, a post he held until February 1981. During his service as Secretary of the Air Force, Mark initiated the establishment of the US Air Force Space Command, which is now the US Space Command. In June 1998, Mark took a leave-of-absence from UT to return to the Pentagon to serve in the Department of Defense as the Director of Defense Research and Engineering. In that position, he was the chief technical advisor to the Secretary of Defense and the Undersecretary of Defense for Acquisition, Technology and Logistics. He returned to his post at UT in March 2001.

Mark served as the director of the NASA Ames Research Center (1969–1977). From 1955 to 1969, he was associated with the University of California at Berkeley. He served as a professor of nuclear engineering and department chairman at the University of California in Berkeley, and as a research scientist and division leader at the University's Lawrence Livermore National Laboratory.

Mark is the author or co-author of more than 200 scholarly articles and numerous books including *Experiments in Modern Physics*, *The Management of Research Institutions, Power and Security*, *The Space Station: A Personal Journey* and *Adventures in Celestial Mechanics*.

Mark was elected to the National Academy of Engineering in 1976. He is an Honorary Fellow of the American Institute of Aeronautics and Astronautics, The American Physical Society, and the American Association for the Advancement of Science. He has received numerous awards, including NASA's Distinguished Service Medal (in 1972 and again in 1977); the Distinguished Public Service Medal from the Department of Defense; and the US Air Force Exceptional Civilian Service Medal. Most recently in 2001, Mark was awarded the Gold Medal of the Department of Energy.

Jean-François Molinari (PhD '01)
Assistant Professor of Mechanical Engineering, Johns Hopkins University

Jean-François Molinari's current research projects include the modeling of the dynamic behavior of non-crystalline and crystalline metallic systems. Questions of failure at high velocity impact and optimization of composite design are being currently investigated. A strong emphasis is being put on microcracking and on the development of shear bands. Molinari is also analyzing the fragmentation patterns of ceramics upon impact. Another research area is the simulation of nanotribology. A multiscale approach is currently being developed to account for adhesive forces at the contact area. A final area of interest is nanocrystalline materials. Molinari uses an atomistic-enriched finite-element method to capture grain boundary sliding and diffusion in large nanogranular systems.

Roddam Narasimha (PhD '61)
Director of the National Institute of Advanced Studies, Chairman of the Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India

Roddam Narasimha received his PhD from GALCIT 1961 and joined the Indian Institute of Science in 1962. He was associated with the Department of Aerospace Engineering there until 1999 in various capacities, and with the Centre for Atmospheric Sciences, which he founded in 1982 and headed till 1989. From 1984 to 1993 he was Director of the National Aerospace Laboratories, also at Bangalore, where he established technology development programmes in composite materials and structures, parallel computing, civil aviation and other areas. He has been at Caltech at various times as a Sherman Fairchild Scholar and the Clark B. Millikan Professor, and has held visiting positions at several other universities. His chief research interest has been fluid dynamics, especially transitional, relaminarising or fully turbulent flows, shock waves, and the atmospheric boundary layer. He is a Foreign Associate of the US National Academy of Sciences and of Engineering, and a Fellow of the Royal Society. He was President of the Indian Academy of Sciences from 1992–94.

Ramarathnam Narasimhan (MS '83, PhD '86)
Professor of Mechanics, Department of Mechanical Engineering, Indian Institute of Science, Bangalore, India

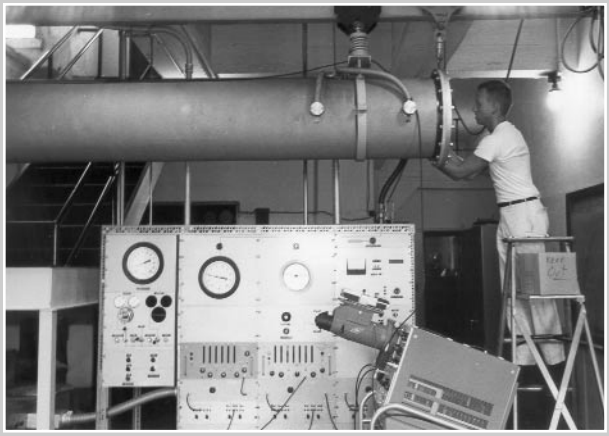
Ramarathnam Narasimhan received his B Tech from the Indian Institute of Technology, Madras, and his

in 1971. Kubota worked on fluid mechanics, with an emphasis on hypersonic flows, including wakes and shock layers. He also worked on supersonic turbulent shear flows and and supersonic boundary layer separation. He supervised a number of students that worked in the Hypersonics Laboratory.

GALCIT is renamed and G now stands for "Graduate" rather than "Guggenheim."

Yuri Gagarin (1934–1968). First person to orbit the Earth, April 12, 1961. The mission's maximum flight altitude was 327,000 meters. The maximum speed reached was 28,260 kilometers per hour. The flight lasted 108 minutes. Reentry was controlled by computer. Gagarin did not land inside of Vostok 1; he ejected from the spacecraft and landed by parachute.

Kármán Laboratory of Fluid Mechanics and Jet Propulsion dedicated. Funding provided principally by the Aerojet Corporation.



B. Sturtevant and shock tube.

1962

Firestone Flight Sciences Laboratory dedicated. Funding provided principally by the Firestone Corporation.

Gerald B. Whitham F.R.S. Charles Lee Powell Professor of Applied Mathematics, Emeritus, 1962–1998. Approximate methods in wave propagation stimulated experimental and numerical studies, particularly in shock dynamics, nonlinear steepening, wave focusing, and sonic boom propagation. Wrote influential text, *Linear and Nonlinear Waves*.

Brad Sturtevant (1933–2000). (MS 1956, PhD 1960). Hans W. Liepmann Professor of Aeronautics, 1962–2000. Worked on 17-in shock tube as a graduate student and faculty member. Taught and researched shock waves and nonsteady gas dynamics. His projects included experimental and theoretical investigations of the propagation of shock waves through nonuniform media, including shock-excited Rayleigh-Taylor instability; hydrodynamic sources of earthquakes and harmonic tremor; sonic boom, the effects of dissociation relaxation in hypervelocity flow; shock-wave physics of extracorporeal shock wave lithotripsy, including the focusing of weak shock waves; the fluid mechanics of explosive volcanic eruptions, including the explosive evolution of dissolved gas from rapidly depressurized liquids.

Peter Lissaman (MS 1954, PhD 1966). Assistant Professor of Aeronautics, 1962–1968. Research into applied aerodynamics and ground effect.

1963

Fred E. C. Culick, Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering and Professor of Jet Propulsion, 1963–present. Works principally on unsteady internal flows, or combustion instabilities. Contributions to understanding and controlling unwanted unsteady motions in liquid rockets, gas turbines, solid rockets, afterburners, and ramjets. Also works in propulsion systems. Built several models of the 1903 Wright *Flyer* in collaboration with AIAA; one is a full-scale model scheduled to be flown in the latter part of 2003.

C. Babcock, J. Singer, and J. Arbocz, 1969.

Charles Babcock (1935–1988). (MS 1958 PhD 1962). Professor of Aeronautics and Applied Mathematics, 1963–1988. Reconciled theory and experiments on buckling of cylindrical shells through the use of exceedingly closely toleranced shells (electroplating process) and control of the edge boundary conditions. Used imperfection theory to place the problem of shell stability and structural reliability on a different level. Applications to buckling of large liquid storage tanks under earthquake conditions and collapse of sea-bed deployed oil pipe lines. Knauss and Babcock studied the important problem of layer delamination in damaged composite panels under in-plane compression from a combined fracture mechanics and bucking point of view. Vice Provost of Caltech under R. Vogt until Babcock's untimely death in 1988.

1964

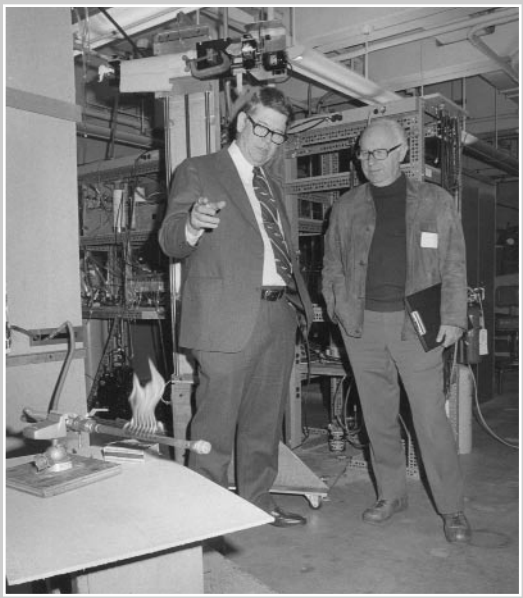
Applied Mathematics is established as a new graduate Option and splits off from GALCIT.

Philip G. Saffman Theodore von Kármán Professor of Applied Mathematics and Aeronautics, 1964–1999, Emeritus. Influential teacher and researcher on fluid mechanics. Emphasized role of vorticity and vortex dynamics in fluid mechanics. Studied vortex instability, reconnection, and dynamics of arrays of vortices. Author of *Vortex Dynamics*, based on his course of the same name.

Miklos Sajven Assistant Professor of Aeronautics, 1964–1970. Student of Lees, research into inlet aerodyamics. Went to Douglas Research Laboratory.

1965

Wolfgang G. Knauss (BS 1958, MS 1959, PhD 1963). Theodore von Kármán Professor of Aeronautics and Applied Mechanics, 1965–present. Motivated by the need to understand failure of solid propellant rocket fuels, provided the main experimental background for understanding the role of viscoelasticity in fracture propagation, and established the first comprehensive (linearly) viscoelastic fracture



E. Zukoski and D. Raskin, 1978.

MS (1983) and PhD (1986) degrees from the California Institute of Technology. His principal research interests are in nonlinear and dynamic fracture mechanics, computational solid mechanics, and the mechanics of indentation. He was awarded the Shanti Swarup Bhatnagar Prize in Engineering Sciences for the year 1999 by the Council of Scientific and Industrial Research, India. He was elected Fellow of the Indian Academy of Sciences in 1999, and Fellow of the Indian National Academy of Engineering, 2002. He is a member of the editorial boards of *Engineering Fracture Mechanics* and *International Journal of Fracture*.

Raul Radovitzky (PhD '98)
Assistant Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology

Raul Radovitzky has been an Assistant Professor of Aeronautics and Astronautics at MIT since 2001. He was born in Argentina and educated at the University of Buenos Aires, where he obtained his Civil Engineer degree in 1991. He received his MSc in Applied Mathematics from Brown University in 1995 and his PhD in Aeronautical Engineering from the California Institute of Technology in 1998.

He worked as a research engineer at the Center for Industrial Research of the Techint-Siderca Corporation in Argentina from 1990–93. From 1998–2001 he worked at the Caltech ASCI Center for the Dynamic Response of Materials, holding a Staff Scientist position at the Center for Advanced Computing Research. Radovitzky's research interests are in the area of computational modeling of the response of solid materials and of fluid-structure interaction problems. His research activities have included: the development of numerical models for the analysis of different manufacturing processes in the steel industry, the formulation of efficient finite-element interpolation schemes, the analysis of thermomechanical effects in welding processes, the Lagrangian formulations of viscous flows with applications to sloshing and wave-breaking, unstructured tetrahedral mesh generation algorithms, error estimation and adaptive remeshing schemes for nonlinear dynamic problems, analysis of electromagnetic riveting, dynamic fracture and fragmentation of glass rods, dry sliding wear of metals, formulation of efficient algorithms for the computation of the exponential and logarithmic mappings of square matrices, scalable Eulerian-fluid/Lagrangian-solid coupling algorithms, and shock-capturing schemes for the Lagrangian analysis of shocks in solids. More recently, he has been working in the development of algorithms for the high-performance simulation of the response of structures to blast waves as well as on local features of deformation in the high-rate response of polycrystalline materials.

Radovitzky is a member of the American Institute of Aeronautics and Astronautics, the International Association of Computational Mechanics, the American Academy of Mechanics, the Materials Research Society, and the U.S. Association of Computational Mechanics.

Krishnaswamy Ravi-Chandar (MS '77, PhD '82)
Professor of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin

K. Ravi-Chandar is a Professor of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin. Ravi-Chandar received an undergraduate degree in Aeronautical Engineering from the Madras Institute of Technology in India and MS and PhD degrees in Aeronautics from the California Institute of Technology. He began his academic career at the University of Houston in 1983 and moved to the University of Texas at Austin in September 2000. Ravi-Chandar's research interests lie in the general area of mechanical behavior of solids with a particular emphasis on high strain rate fracture behavior. He has presented a number of invited lectures at national and international meetings. Ravi-Chandar is an elected Fellow of the American Society of Mechanical Engineers, the American Academy of Mechanics, and the Society for Experimental Mechanics, He is an Honorary Fellow and Vice-President of the International Congress on Fracture. Currently he is the Editor-in-Chief of the *International Journal of Fracture* and an Associate Editor of the *Journal of Applied Mechanics*. He will receive the Murray Medal from the Society of Experimental Mechanics in June 2004. He serves on the Executive Board of the Society for Experimental Mechanics and the Applied Mechanics Division of the ASME.

Thomas J. Tyson (BS '54, PhD '67)
Retired CEO, GE Energy and Environmental Research Corporation (GE EER), a subsidiary of General Electric Company

Thomas Tyson retired in January, 2001 as CEO of GE EER a business unit within GE's Power Systems Division. He presently serves in a consulting capacity to the company. GE EER provides systems and related services for the control of air pollution emissions from power plants. Tyson founded EER in 1977. GE acquired the company in 1999.

Dr. Tyson is a 1954 graduate in mechanical engineering from the California Institute of Technology and received his PhD in aeronautics from the Institute in 1967. He received his MS in 1958 in nuclear engineering from UC Berkeley.

Prior to founding EER, Tyson served in engineering. Studied high-rate crack extension in brittle solids and resolved a longstanding dichotomy in dynamic fracture. Detailed high-speed photography demonstrated that the theoretically modeled fracture process was unrealistic and that multiple fractures at the crack tip controlled both the speed and the phenomenon of crack branching. Demonstrated the important influence of dilatational changes on the time dependence of the constitutive relationships for polymers in the nonlinear range. Pioneered work in nano-mechanics and reliability through the use of probe microscopy. Early diversions into geology and biomechanics (radial keratotomy, human intervetebral disk) investigations attest to the breadth of mechanics supported by the GALCIT spirit.

The 6-in shock tube built to study ionized gases at high shock Mach numbers (Roshko, Smith). Used also to study focusing of strong shock waves in cones (Storm, Setchell), refraction of shocks through density gradients (Haas), and numerous student projects.


H. W. Liepmann.

1967

Wilhelm Behrens (PhD 1966). Assistant Professor of Aeronautics, 1967–1973. Research into hypersonic flow including the structure and stability of hypersonic wakes, separated flow on lifting bodies, and viscous interactions. Presently technical Fellow and Manager of Fluid Thermal Physics Department, Northrop-Grumman (TRW).

1969

Francis Clauser (BS 1934, MS 1935, PhD 1937). Professor of Engineering, 1969–1980. Francis Clauser's early career included a job as research aerodynamicist at Douglas Aircraft after which he went on to teach at Johns Hopkins University. At Hopkins he founded and chaired the Department of Aeronautics. From there he went to the University of California, Santa Cruz, where he was a vice chancellor and professor of engineering. He returned to Caltech in 1969 to become the Chair of the Division of Engineering and Applied Science.

Gordon Harris Assistant Professor of Aeronautics, 1969–1972. Research into vehicle aerodynamics.

Apollo Program successful, first astronauts land on the Moon and return to Earth.

Harold Brown becomes Caltech's third President (1969–1977).

1970

At the request of the National Bureau of Standards, a study was undertaken by Marble, Rannie, and Zukoski to formulate a long-term program of analytical and experimental research aimed at a rational understanding of fire propagation in large building structures. This work led, in turn, to detailed experiments and computations by Zukoski and Kubota of fire spread in single rooms.


P. Dimotakis.

1972

Hans Wolfgang Liepmann becomes third Director of GALCIT (1972–1985).

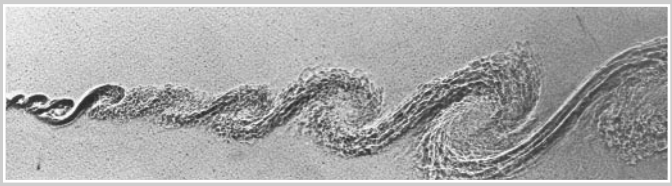
1973

Cyrogenic shock tube used to study first and second shock waves in liquid He(II). Fluid mechanics of liquid helium studied for the next decade by Liepmann and students, Cummings, Dimotakis, Laguna, Moody, Rupert, Turner, Torcyzinski, and Wise.

Candel and Marble establish that the passage of regions of non-uniform entropy through a choked nozzle produced a large acoustic source and made a significant contribution to the noise emitted by jets from propulsion devices.

1974

Brown and Roshko discover persistent two-dimensional coherent structures in high Reynolds number shear flow. Later studies show streamwise streaks, highly-intermittment entrainment, and the existence of a "mixing transition" at a critical Reynolds number.



Coherent structures in shear layer.

1975

Paul E. Dimotakis (BS 1968, MS 1969, PhD 1973). John K. Northrop Professor of Aeronautics and Professor of Applied Physics, 1975-present. His investigations include work on liquid helium superfluid mechanics, turbulence and turbulent mixing, chemically reacting flows and combustion, flow control, and aerooptics. Contributed developments in instrumentation and data acquisition, laser diagnostics, high-speed digital imaging technology, image correlation and particle-streak velocimetry.

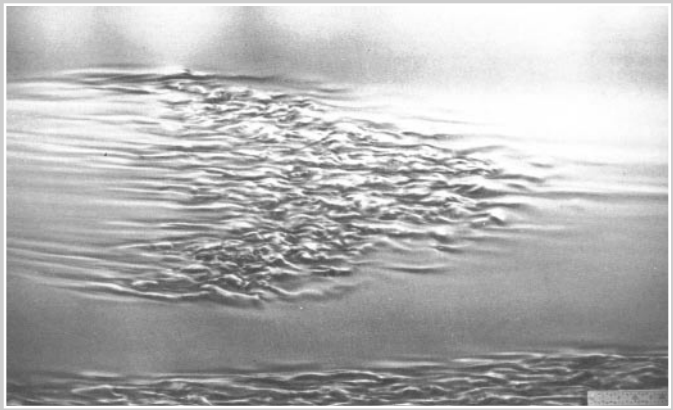
1976

Bruce Murray Professor of Planetary Science and Geology, 1960–2001, Emeritus. Director of the Jet Propulsion Laboratory, 1976–1982. Oversaw the Viking landings on Mars and the Voyager mission through Jupiter and Saturn encounters.

1977

Garry L. Brown Professor of Aeronautics, 1977–1982. Contributions to structure and mixing in turbulent shear flow; innovative design of experimental facilities. Became director of the Australian Aeronautical Research Laboratory.

The study of the distortion and stretching of flames in vortex structures was begun by Marble, Karagozian, and Candel.



Turbulent spot.

1978

Marvin Leonard Goldberger becomes the fourth President of Caltech (1978–1987).

Structure of sublayer and entrainment in turbulent spot determined by Cantwell, Coles, and Dimotakis.

1980

Super Sonic Shear Layer Facility established. Designed for the study of molecular mixing in high-speed flows from high subsonic to supersonic. Unique facility that

neering capacities with several defense and aerospace organizations with a focus on propulsion technology and high-speed aerodynamics. His career started at North American Aviation's Propulsion Center (later Rocketdyne) and included periods with Lawrence Livermore Laboratory and TRW's Space Technology Laboratories. Tyson was Vice President of Dynamic Science Corporation, a missile and propulsion technology spin-off from JPL from 1967 to 1972 at which time he became Vice President of Ultrsystems, Inc., which specialized in the turn-key delivery of small power plants.

He has served as a board member of the Industrial League of Orange County and the Orange County Business Council. He is a member of the Science and Technology Advisory Council to the South Coast Air Quality Management District. He is past chairman of the JANNAF (Joint Army, Navy, NASA, and Air Force) Theoretical Methods Committee of the Rocket Engine Performance Group that developed the standard methodologies for the prediction of rocket engine performance used by US industry and government. Tyson is past chairman of the Advisory Panel on Combustion Aerodynamics of the International Flame Research Foundation (IFRF) in the Netherlands.

Tyson maintains a close association with Caltech. He has served as president of the Alumni Association and of the Caltech Associates and is a member of the advisory board for Caltech's program of undergraduate research (SURF). In recent years he has served on the visiting committees for engineering at Stanford, UCLA, and Caltech.

Anthony M. Waas (MS '83, PhD '88)
Professor of Aerospace Engineering, University of Michigan

Anthony M. Waas received his BSc with first class honors from Imperial College, University of London, U.K., in 1982, the MS in 1983 and PhD in 1988 with a minor in Applied Mathematics from the California Institute of Technology, all in Aeronautics. He joined the faculty of the Department of Aerospace Engineering at the University of Michigan in 1988, where he was promoted to the rank of Associate Professor in 1994 and Professor in 2000. He is also the Director of the Composite Structures Laboratory. His current research interests include mechanics of composite structures and composite materials, nanocomposites, structural stability, optical methods for experimental stress analysis, biomechanics and hot structures. Waas has served as a member of the AIAA Structures Technical Committee (1991-1994, 1997-00, 02-present), the ASME Technical Committee on Instability of Solids and Structures (1995-03), the ASME Technical Committee on Experimental Mechanics (1996-00) and the ASME Structures and

Materials Committee (1998-02). He is the chair elect of the latter committee for the next two years. He is a recipient of the Royal Aeronautical Society Prize of Imperial College (1982), the William Balhaus Prize in Aeronautics at the California Institute of Technology (1988), a Rackham Faculty Fellowship (1990), University of Michigan Aerospace Department Teaching Award (1995), the Society of Automotive Engineers Ralph Teetor Award (1995), the American Academy of Mechanics Junior Award for Research (1997), University of Michigan Aerospace Department Research Award (1998) and the University of Michigan Aerospace Department Outstanding Accomplishment Award (2001). He is a Fellow of ASME and an Associate Fellow of AIAA. He is a member of the American Society of Composites and the American Academy of Mechanics. He has served as an Associate Editor of the *AIAA Journal* (1995-02) and on the Editorial Advisory Board of the *AIAA Journal of Aircraft* (1995-00). He is currently on the editorial board of the *Composites Part B-Engineering*. At the University of Michigan, he served on the Advisory Board in Control of Intercollegiate Athletics (1999-2002) and as the chairperson of the College of Engineering Rules Committee (1995-1998). He is currently on the College of Engineering Honors and Awards Committee. He served as the Aerospace Department Graduate Program Chair (1998-2002) and currently is the interim Associate Chairperson of the Department. He is author or co-author of more than 80 refereed journal paperis and numerous conference papers and presentations.

Max Williams (MS '47, Eng Ae '48, PhD '50)
Dean Emeritus of the School of Engineering, University of Pittsburgh

Williams retired from the University of Pittsburgh in September 1990 as Distinguished Service Professor of Engineering Emeritus. He had come to Pittsburgh in 1973 from the University of Utah where he had been Dean of the College of Engineering and Distinguished Professor of Engineering. Prior to those eight years in Salt Lake City he had been at the California Institute of Technology as Professor of Aeronautics since receiving his doctorate there in 1950. His undergraduate work was completed at the Carnegie Institute of Technology in 1942 just prior to his entering the US Air Force.

His main professional research and extensive industrial consulting activities have been concentrated in the field of general materials behavior and structural mechanics and design. He has published extensively, with a specific interest in both cohesive and adhesive fracture. This experience is reflected in his being the founder and Editor-in-Chief of *The International Journal of Fracture* from which he retired in 1997.

relies on the fast chemical kinetics between hydrogen and fluorine to mark fluid that is mixed at a molecular level.

F. Culick and Wright Flyer model, 1979.

1981

Launch of *Columbia*, first space shuttle.

1982

Lew Allen, Jr. Director of Jet Propulsion Laboratory, 1982–1991.

Ares J. Rosakis Professor of Aeronautics and Mechanical Engineering, 1982–present. Studies of non-brittle phenomena in dynamic fracture as experienced primarily with metals. Developed the "Coherent Gradient Sensing" (CGS) method for optically determining deformation gradients under arbitrarily rapid loading conditions. Applications in determining the curvature of silicon wafers used in microelectronic industry. Dynamic interfacial fracture behavior between different materials, discovered intersonic crack propagation, of direct interest in the interpretation of geological slipping phenomena associated with earthquakes. Experimental development (with G. Ravichandran) of high speed thermography to follow the evolution of energy conversion at the tips of rapidly moving cracks and in the evolution of shear bands.

1985

Anthony Leonard (BS 1959). Theodore von Kármán Professor of Aeronautics, 1985–present. Numerical simulation of fluid motion. Direct simulation of the Navier-Stokes equations and studies of turbulance and mixing. Vortex element and vortex particle methods for separated flows. Discovered role of "Leonard Stresses" in Large-Eddy Simulations. Simulation of flow-structure interactions near wake regions of oscillating bodies.

Among the problems posed by the hypersonic ramjet propulsion system was the injection and rapid mixing of the hydrogen fuel with air at Mach numbers of the order six. Marble proposed a mechanism by which the mixing of low density hydrogen with air could be greatly enhanced by carefully controlled weak shock waves. Over a period of five years the shock-enhanced injection system was developed by Marble, Zukoski, and their students, and was successfully demonstrated by Waitz at the NASA Langley Research Center.

H. Hornung, ABC *Nightline*, 1987.

1987

Hans G. Hornung C. L. "Kelly" Johnson Professor of Aeronautics, 1987–present. Director, Graduate Aeronautical Laboratories, 1987–2003 After serving as director of the DFVLR in Gottingen from 1980–87, Hornung became the third Director of GALCIT. With a special interest in hypervelocity and nonequilibrium flow, he initiated construction of the T5 shock tunnel and a series of investigations into chemical reaction rate effects on shock standoff, boundary layer stability and transition, transverse jet interactions, facility characterization and advanced diagnostics, and vorticity production behind curved shocks.

Thomas E. Everhart becomes sixth President of Caltech (1987–97).

1989

The T5 facility at GALCIT is a free piston shock tunnel, and is named T5 because it is the fifth in a series of shock tunnels built by or under the supervision of R. J. Stalker, H. G. Hornung, and colleagues (the previous four are in Australia). The facility is capable of producing flows of air or nitrogen up to specific reservoir enthalpy of 25 MJ/kg, reservoir pressure of 100 MPa, and reservoir temperature 10000 K. It achieves this by using a free piston to adiabatically compress the driver gas of the shock tun-


M. Brouillette and shock tube.

nel to very high pressure, as high as 130 MPa. These conditions are needed to simulate the real gas effects of chemical dissociation and reaction that occur in flows about vehicles flying at sub-orbital speeds through the atmosphere. The test section can accommodate models up to 8 inches in diameter and the useful test time is 1–2 ms. Construction started in 1989 and the first test was in 1990.

1990

Guruswami Ravichandran Professor of Aeronautics and Mechanical Engineering, 1990–present. Experimentalist whose work has covered dynamic response characteristics of materials; thermodynamics of the energy conversion process in large deformation and rate dependent plasticity phenomena. In deviating from the standard test routines associated with uniaxial compression behavior, his interest has centered on generating multiaxial stress states dynamically using high-strain rates, with applications to impact and penetration problems in metals, ceramics, and heterogeneous materials. Investigation of large deformation elastostriction behavior that can potentially be used as actuators. Time dependent behavior of amorphous metals and metallic glasses.

1991

Edward C. Stone David Morrisroe Professor of Physics, Director of the Jet Propulsion Laboratory, 1991–2001.

Dale Pullin Professor of Aeronautics, 1991–present. Computational and theoretical fluid mechanics, vortex dynamics, structure of fine scales of turbulence, theory and simulation of turbulent mixing, compressible flow and shock dynamics, turbulence, large-eddy simulation of turbulent flows.

1992

Morteza Gharib (PhD 1981). Hans W. Liepmann Professor of Aeronautics and Bioengineering, 1992–present. Research interests have included advanced sensors and diagnostic systems such as digital particle image velocimetry, thermometry, 3-D particle velocimetry and micro-optical systems. His fluid mechanics research interests include vortex flows, unsteady aerodynamics, two-phase flows, and flow-induced vibration. Biomechanics work includes cardiovascular mechanics and fluid dynamics, eye optics and fluid mechanics. Co-founder of the Bioengineering Option at Caltech.

1993

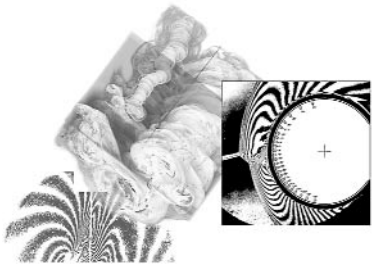
Joseph E. Shepherd (PhD 1981). Professor of Aeronautics, 1993–present. Developed Explosion Dynamics laboratory and studies combustion, fuel properties, and fluid dynamics relevant to explosion initiation and propagation. Applications include: novel propulsion systems (pulse detonation engines); evaluation of explosion hazards in industrial processes, transportation systems, and nuclear facilities; and investigation of accidental explosions. Experimental studies are being carried out on ignition and propagation of flames, transition from flames to detonation, propagation of detonations and shock waves, response of structures to explosions, application of detailed chemical chemistry to combustion modeling, and the simulation of high explosive detonation.

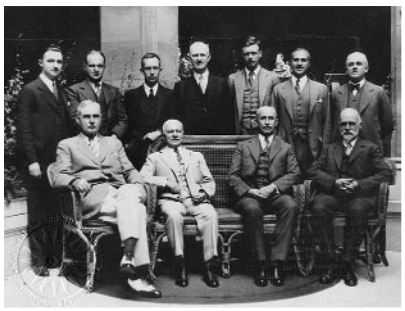
1995

Michael Ortiz Professor of Aeronautics and Mechanical Engineering, 1995–present Computational methods in mechanics. Scalable adaptive finite element software. Quasi-continuum software for advanced mixed atomistic-continuum simulations. Multiscale models of material failure, particularly the behavior of individual atoms and their electrons. Other focal areas of activity concern: the development of informed continuum models for plasticity and fatigue crack growth; the development of appropriate cohesive zone models for cracks and interfaces under fatigue and corrosion conditions; and the incorporation of continuum mass transport methods in the quasicontinuum method. Advanced numerical methods for the computation of shells and flexible structures.

Williams has lectured nationally and internationally, as for example a Sigma Xi National Lecturer and as a Visiting Professor and National Science Foundation Fellow at the Imperial College (London), in addition to his many professional presentations. He is a Professional Engineer and has served on many governmental technical advisory committees such as the National Institute of Dental Research, the National Science Foundation, the National Aeronautics and Space Agency, and the National Materials Advisory Board where he was Chairman of its Council on Materials, Structures and Design. For the Office of Science and Technology Policy he chaired the Structural Mechanics Committee for the Interagency Task Group on Cooperative Automotive Research, and Williams has been an Associate Member of the Defense Science Board. For approximately twenty years he served as a consultant in structures and materials for the Department of Defense; he also served for several years as a technical advisor to the Department of State.

Williams completed a four-year term as a member of the US Air Force Scientific Advisory Board in 1990, and during 1985–87 held a two-year appointment to the General Lew Allen Research Chair at the US Air Force Institute of Technology, Wright-Patterson Air Force Base in Dayton as Distinguished Visiting Professor of Aeronautics. The subsequent year, 1987–88, he became Science Advisor to the Commander of the Acquisition Logistics Center at Wright-Patterson AFB before returning to his teaching and research duties at the University of Pittsburgh. During the 1993–94 period, he was a von Humboldt Visiting Research Professor at the Fraunhofer Institut fur Werkstoffmechanik in Freiburg, Germany. In 1995 he was designated a Distinguished Alumnus of the California Institute of Technology. Since 1995 he has been an Adjunct Professor of Aeronautics at the University of Texas at Austin. Williams was elected a member of the National Academy of Engineering in 2003.





The Guggenheim Fund Trustees: (left to right standing) Secretary J. W. Miller, F. Trubee Davison, Elihu Root, Jr., Hutchinson Cone, Charles Lindbergh, Harry Guggenheim, the Fund President, Robert Milllikan (left to right seated) John D. Ryan, Daniel Guggenheim, the fund's creator, Orville Wright, William Durand.

GALCIT *and the*

Daniel Guggenheim Fund for the Promotion of Aeronautics, Daniel and Florence Guggenheim Foundation

The Graduate Aeronautical Laboratories at the California Institute of Technology, or GALCIT, started as the Daniel Guggenheim Graduate School of Aeronautics. The involvement of the Guggenheim Fund began with a donation of $300,000 in October of 1926. An annual endowment of $15,000 was also given for a number of years. In 1949, the Jet Propulsion Center was founded with a contribution from the Daniel and Florence Guggenheim Foundation.

The tremendous impact of the initial investment by the Guggenheim Fund on the original seven universities was described in 1978 by Hans Liepmann (GALCIT Director from 1973–1985) as follows: "If you count all the contributions to education from the Guggenheim Fund it amounted to something on the order of $2 million—less than 10% of the cost of a single 747 airliner today. Even after we multiply it by 10 to allow for inflation, it is an unbelievably small amount if we consider that it was the beginning of U.S. supremacy in aeronautics research, particularly for commercial and military aviation."

As for the impact of GALCIT, Liepmann says: "Under Kármán's leadership, the school rapidly became an important source of new ideas and directions in aeronautics. When the war of 1939–1945 broke out, GALCIT was practically the only school in the nation equipped to tackle the problems arising from the explosive development of aircraft and missiles to transonic and supersonic speeds and finally into space flight. A list of the approximately 1,300 GALCIT alumni (about 10% of all Caltech alumni) reads like a Who's Who of aeronautics; and they have spilled over into other engineering endeavors in which advanced fluid and solid mechanics are important. The offspring of GALCIT, the Jet Propulsion Laboratory, has become a leader in interplanetary exploration. The Guggenheims have every reason to be proud of their child."

1997

David Baltimore becomes the seventh President of Caltech (1997–present).

Demolition of 10-foot tunnel and rehabilitation of basement and subbasement of Guggenheim.

1998

Ludwieg Tube. This facility allows Mach 2.3 flow in an 8-in x 8-in in test section with a test time of 80 milliseconds The flow is produced by unsteady expansion following the bursting of a diaphragm separating the test section from the dump tank. A novel suction scheme removes the boundary just upstream of the throat. The concept was first proposed in 1955 by Hubert Ludwieg. Construction started in 1998; the first test was in 2001.

Lucas Wind Tunnel inaugural.

2001

Charles Elachi (MS 1969, PhD 1971). Professor of Electrical Engineering and Planetary Science, Director of Jet Propulsion Laboratory, 2001–present.

Lees-Kubota Lecture Hall dedicated on January 8, 2001. Located in the Guggenheim Building on the site of the old Aero Library, this was made possible by donations of former students, particularly Denny R. S. Ko.

2002

Adaptive Wind Tunnel commissioned on October 3, 2002. It was built as a replacement for the 10-foot tunnel. The Lucas AWT uses adaptive wall technology in the test section to reduce and even eliminate the need for data corrections required in straight-wall tunnel tests. While the tunnel is operating, pressure measurements are taken along the floor and ceiling of the test section; combined with the current displacement profiles, a one-step predictive algorithm determines the required wall contour for the current model configuration and adapts the walls to match. The system effectively "tricks" the air into thinking it is in an infinite flowfield, rather than confined by the walls of the tunnel. This idea was developed by Sears in the 1970s.

2003

75th Anniversary of the Graduate Aeronautical Laboratories.

GALCIT Distinguished Alumni

Recipients of the Caltech Distinguished Alumni Award

The Distinguished Alumni Award is the highest honor the Institute bestows upon an alumnus/a. It is in recognition of extraordinary achievement in business, community, and professional life, and may be acknowledging a particular achievement of noteworthy value, a series of such achievements, or a career of noteworthy accomplishment.

The award was initiated as part of Caltech's 75th Anniversary celebration in 1966. Nominations are made by a joint faculty-alumni committee and confirmed by the Board of Trustees; the awards are presented at a ceremony during Caltech's annual Alumni Seminar Day.

Here we present the Distiguished Alumni who have been closely associated with GALCIT. We salute each and every one.

A note on the listing: The year in parentheses just after the name is the year the Distinguished Alumni Award was received. The title below the name reflects the position the person held *at the time the award was given*. (d) indicates the person has passed away.

William F. Ballhaus (1978)
President, Beckman Instruments, Inc.
PhD 1947 Ae

Frank Borman (1966)
Colonel, United States Air Force
MS 1957 Ae

Arthur E. Bryson, Jr. (1991)
Pigott Professor of Engineering, Department of Aeronautics and Astronautics, Stanford University
MS 1949 Ae, PhD 1951 Ae

Francis H. Clauser (1966)
Academic Vice Chancellor, University of California, Santa Cruz
BS 1934 Ph, MS 1935 ME,
PhD 1937 Ae

Joseph V. Charyk (1966)
President, Communications Satellite Corporation
MS 1943 Ae, PhD 1946 Ae

Julian D. Cole (d) (1971)
Professor and Chairman, Department of Mechanics, University of California, Los Angeles
MS 1946 Ae, Eng 1946 Ae, PhD 1949 Ae

Richard D. DeLauer (d) (1985)
President, Orion Group Ltd.
Eng 1950 Ae, PhD 1953 Ae

Satish Dhawan (1969)
Director, Indian Institute of Science
Eng 1949 Ae, PhD 1951 Ae

Louis G. Dunn (d) (1974)
Retired
BS 1936 Ae, MS 1937 ME, MS 1938 Ae,
PhD 1940 Ae

Yuan-Cheng Fung (1994)
Professor of Bioengineering and Applied Mechanics, Emeritus, University of California, San Diego
PhD 1948 Ae

Anthony J. Iorillo (1990)
President, Space and Communications Group, Hughes Aircraft Company
BS 1959 ME, MS 1960 Ae

Jack L. Kerrebrock (1997)
Richard Cockburn Maclaurin Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology
PhD 1956 ME

Chia-Chiao Lin (1992)
Institute Professor, Emeritus, Massachusetts Institute of Technology
PhD 1944 Ae

Paul B. MacCready, Jr. (1978)
President, AeroVironment, Inc.
MS 1948 Ph, PhD 1952 Ae

Benoit B. Mandelbrot (1988)
IBM Fellow, T. J. Watson Research Center, Abraham Robinson Professor of Mathematical Sciences, Yale University
MS 1948 Ae, Eng 1949 Ae

Duane T. McRuer (1983)
President and Technical Director, Systems Technology, Inc., Hawthorne, California
BS 1945 ME, MS 1948 ME

Ruben F. Mettler (1966)
President, TRW, Inc.
BS 1944 EE, MS 1947 EE, PhD 1949 EE

John W. Miles (1997)
Professor of Applied Mechanics and Geophysics, University of California, San Diego
BS 1942 Eng, MS 1943 Ae, MS 1943 EE, AeE 1944 Ae, PhD 1944 Ae

Roddam Narasimha (1986)
Director, National Aeronautical Laboratory, Indian Institute of Science
PhD 1961 Ae

Stanley C. Pace (1987)
Chairman and Chief Executive Officer, General Dynamics Corporation
MS 1949 Ae

Allen E. Puckett (1970)
Executive Vice President and Assistant General Manager, Hughes Aircraft Company
PhD 1949 Ae

L. Eugene Root (d) (1966)
President, Lockheed Missiles and Space Company
MS 1933 ME, MS 1934 Ae

William R. Sears (d) (1988)
Professor, Aerospace and Mechanical Engineering, University of Arizona
PhD 1938 Ae

Ozires Silva (1992)
Minister of Infrastructure, Brazil
MS 1966 Ae

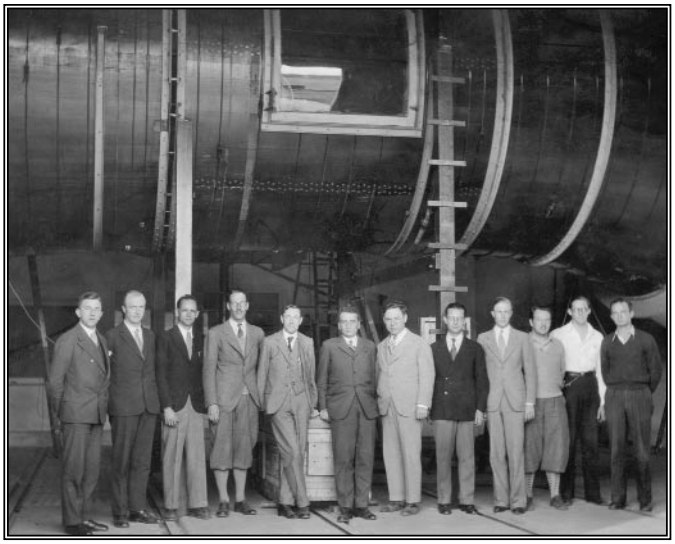
George E. Solomon (1983)
Vice President and General Manager, Electronics and Defense, TRW, Inc.
MS 1950 Ae, PhD 1953 Ae

Hsue-Shen Tsien (1979)
Chairman, Institute of Mechanics, National Academy of Science, Beijing, China
PhD 1939

Donald L. Turcotte (1999)
Professor of Geological Sciences, Cornell University
BS 1954 ME, PhD 1958 Ae, PhD 1939 Ae

Max L. Williams, Jr. (1995)
Dean, Emeritus, School of Engineering, University of Pittsburgh
MS 1947 Ae, Eng 1948 Ae, PhD 1950 Ae

Thornton A. Wilson (d) (1968)
Executive Vice President, Boeing Company
MS 1948 Ae



1930

1961

1999