ity and implication of this fundamental result. One of these others, Arthur Eddington, made no comment in private but publicly denounced Chandra's result, declaring, "I think there should be a law of nature to prevent a star from behaving in this absurd way." Later, Eddington argued that the Pauli exclusion principle could not be applied to relativistic systems. Léon Rosenfeld, Niels Bohr, Wolfgang Pauli and Paul A. M. Dirac upheld Chandra's result in private, but Eddington's cocksure faith in his own whims was unshaken, and the astronomical community largely accepted his authority. Thus arose the 50-year delay in Chandra's receiving the Nobel Prize in Physics in 1983.

Chandra received his PhD in December 1933, writing his thesis on rotating self-gravitating polytropes. But Eddington's authoritative wishful thinking on the mass limit of the white dwarf prevented Chandra from obtaining a proper position in England, while political bickering and favoritism blocked his chances in India. This situation led to his accepting an invitation from Otto Struve to join the faculty at the Yerkes Observatory of the University of Chicago.

In 1936 Chandra returned briefly to India to marry Lalitha Doraiswamy, with whom he had attended physics classes at Presidency College in Madras, and who was then working in the Bangalore laboratory of Chandra's uncle, Nobel laureate Chandrasekhara Venkata Raman.

Chandra and Lalitha arrived in Chicago at the end of 1936, and Chandra began his 58-year career at the University of Chicago, becoming Morton D. Hall Distinguished Service Professor in Astronomy and Astrophysics in 1952. They spent the first 27 years at the Yerkes Observatory and the last 31 years at the Chicago campus. Lalitha's broad interests and good judgment complemented Chandra's more severe outlook, and they got on well in the Chicago academic community.

Chandra developed his theoretical work on stellar interiors, including degenerate matter, into a treatise, *An Introduction to the Study of Stellar Structure* (University of Chicago Press, 1939), which still makes an excellent textbook on the basic properties of a star.

Chandra had also become interested in the gravitational frictional drag on a star passing through a tenuous cloud of stars as a key to understanding the ages of the globular clusters. He summarized this work in his 1943 book *Principles of Stellar Dynamics* (University of Chicago Press) and in his penetrating article on "Stochastic Problems in Physics and Astronomy," published in *Reviews of Modern Physics* in the same year. It is interesting to think of this work as the forerunner of plasma physics without the convenience of the Debye radius and without the inconvenience of a large-scale magnetic field.

Chandra continued his work on stellar interiors, with calculations on opacities and the basic theory of radiative transfer, doing fundamental work on the negative hydrogen ion as the principal cause of the opacity of hydrogen at stellar surface temperatures. His systematic formulation of the subject appeared in 1950 in his monumental *Radiative Transfer* (Oxford University Press). In the 1950s he investigated plasma physics and hydrodynamics and concentrated on the stability of a variety of magnetic fluid configurations. Much of his work in this area is to be found in *Hydrodynamic and Hydromagnetic Stability* (Clarendon Press, 1961), which has been a benchmark since its first appearance.

Chandra next directed his attention to the classical problem of the stability of rotating ellipsoidal figures. The results in the framework of Newtonian mechanics and gravitation were organized in the monograph *Ellipsoidal Figures of Equilibrium* (Yale University Press, 1968). This line of thought brought him to the gravitational theory of general relativity, with which he treated stellar pulsations, discovering the relativistic instability of radial oscillations of white dwarf stars, and the Chandrasekhar–Friedman–Schutz instability, which has ultimately developed into a mechanism for the gravitational wave emission of black holes. The dynamical properties of the rotating black hole were expounded by Chandra in *The Mathematical Theory of Black Holes* (Oxford University Press, 1983). His discoveries did not stop there. In his subsequent work with Valeria Ferrari on exact solutions of the equations of general relativity, the singularities that arise in interacting gravitational waves came to light. Chandra also developed the post-Newtonian approximation that has become the standard formal approach to calculating the gravitational waves from dynamical systems of massive particles and has served as the basis for the post-post-Newtonian formalism.

Chandra accomplished the difficult task of a formal general-relativistic treatment of the instability of radial stellar pulsations in recent work with Ferrari, and the final paper was essentially finished at the time of his death. The problem is of particular interest because without the emission of gravitational waves (that is, in Newtonian gravitation) the system is stable unless some other form of dissipation is introduced. In his last years Chandra became increasingly interested in Newton's *Principia*. He published his review of Newton's work in a monograph, *Newton's Principia for the Common Reader* (Oxford University Press), which appeared just two months before his death.

Chandra's book *Truth and Beauty* (University of Chicago Press), published in 1987, contains a number of essays, including his well-known Ryerson Lecture, "Shakespeare, Newton and Beethoven," which is only one of his explorations of the motivations, ambitions and aesthetic rewards of the artist and the scientist.

Chandra served as editor of the *Astrophysical Journal* from 1952 to 1971, transforming it from a more or less private journal of the University of Chicago into the national journal of the American Astronomical Society, still published by the University of Chicago Press.

Chandra maintained uncompromising standards of integrity and excellence for his own research, for his editing and for his students, associates and acquaintances. It did not always foster the smoothest personal relations, because there were occasional misunderstandings on both sides. But it was an integral part of Chandra's scientific prowess, and his friends and acquaintances respected him for it.

In spite of the difficulties that Eddington's mulish attacks had created for him, Chandra ranked Eddington next to Karl Schwarzschild as the greatest astronomer of his time when he presented an obituary address for Eddington in 1944.

Now Chandra's own death at the age of almost 85 marks the passing of an era in which physicists first reached inward to understand the atom and the fundamental particles and outward to embrace the stars. Chandra never wavered in his pursuit of the physics of the stellar object in its diverse forms.

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T. Keith Glennan

Thomas Keith Glennan, the first administrator of the National Aeronautics and Space Administration, passed away on 11 April, in Mitchellville, Maryland, after a stroke. During a career that spanned more than half a century, he achieved success as a leader of institutions in both the public and private sectors.

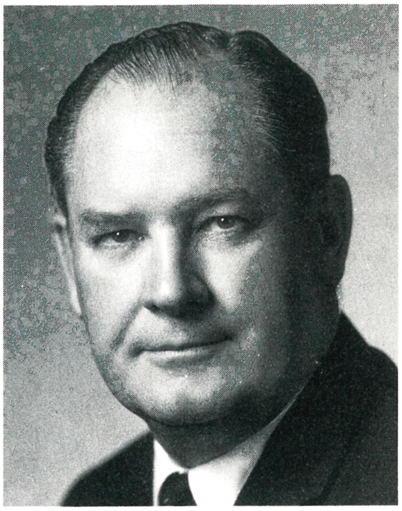
Glennan had been president of the

Case Institute of Technology, in Cleveland, Ohio, for more than a decade when he was appointed to head NASA on its formal establishment on 1 October 1958. He served at NASA throughout the remainder of the Eisenhower Administration; in 1961 he returned to Case.

Born in Enderlin, North Dakota, on 8 September 1905, Glennan earned a degree in electrical engineering from the Sheffield Scientific School of Yale University in 1927. Following graduation he worked as a sound engineer for the Electrical Research Products Co in a variety of places, including Europe. Glennan stayed with the company, a subsidiary of Western Electric Co, for almost a decade, becoming assistant general service superintendent. Subsequently he worked in the motion picture industry, serving in a management capacity at Paramount Pictures and then at Samuel Goldwyn Studios, and later was briefly on the staff of Vega Airplane Corp.

Glennan joined Columbia University's division of war research in 1942 and worked there for the rest of World War II, first as administrator and then as director of the US Navy's Underwater Sound Laboratory in New London, Connecticut. At the end of the war Glennan became an executive of Ansco Corp in Binghamton, New York, and then accepted the presidency of Case in 1947. During Glennan's administration, Case rose from being primarily a local institution to rank with the top engineering schools in the nation. From October 1950 to November 1952, also concurrent with his Case presidency, Glennan served as a member of the Atomic Energy Commission. When Glennan joined NASA in 1958, he became Case's president-on-leave.

As the first NASA administrator, Glennan presided over an organization that had absorbed the National Advisory Committee for Aeronautics in its entirety, which included 8000 employees, an annual budget of $100 million, three major research laboratories—Langley Aeronautical Laboratory, Ames Aeronautical Laboratory and Lewis Flight Propulsion Laboratory—and two small test facilities. Shortly after he joined NASA, Glennan incorporated into the agency several Federal organizations involved in space exploration projects to ensure a viable long-term scientific program of space exploration. He brought in part of the Naval Research Laboratory and moved it to the newly established Goddard Space Flight Center, in Greenbelt, Maryland. He also incorporated several disparate satellite programs, two lunar probes and the important research effort to develop a million-pound-thrust, single-chamber rocket engine from the US Air Force and the Department of Defense's Advanced Research Projects Agency. In December 1958 Glennan also acquired control of the Jet Propulsion Laboratory, a contractor facility in Pasadena, California, operated by Caltech. In 1960 Glennan obtained the transfer to NASA of the Army Ballistic Missile Agency, located at Huntsville, Alabama, and renamed it the Marshall Space Flight Center.



T. KEITH GLENNAN

By mid-1960 Glennan had secured for NASA primacy in the Federal government for the execution of all space activities except reconnaissance satellites, ballistic missiles and a few other space-related DOD projects, such as meteorological satellites, most of which were still in the study stage.

Upon leaving NASA in January 1961 Glennan returned to Case, where he continued to serve as president until 1966. During that period he helped to negotiate the merger of Case with Western Reserve University, creating Case Western Reserve University. After his retirement in 1966 Glennan spent two years as president of Associated Universities Inc, a Washington-based advocacy group for institutions of higher learning.

Remembering Keith Glennan, Robert C. Seamans Jr, NASA Deputy Administrator in the mid-1960s, commented, "He was the right man, in the right job, at the right time." His administration, Seamans added, positioned NASA so that it had the intellectual and physical resources necessary to carry out Project Apollo.

ROGER D. LAUNIUS
NASA Chief Historian
Washington, DC

Edward Nicollian

Edward H. Nicollian, Distinguished Professor of Electrical Engineering at the University of North Carolina at Charlotte, died of a heart attack on 17 December 1994. He was 67.

A pioneer in the semiconductor field, Ed Nicollian spent the years between 1957 and 1983 at AT&T Bell Laboratories. He then joined UNC Charlotte, initially with a joint appointment from the Microelectronics Center of North Carolina. In the 1960s, he pioneered, with Adolf Goetzberger, the determination of silicon–silicon dioxide interface traps using conductance measurements. The book *MOS Physics and Technology*, by Nicollian and J. R. Brews (John Wiley, 1982), remains a standard reference for researchers in the semiconductor industry.

Ed came to UNC Charlotte in 1983 and played a pivotal role in the establishment of the university's PhD program, which was finally established a year ago.

While at MCNC, Ed challenged me to join him in extending quantum devices such as the resonant tunneling device to silicon. Extremely complicated conductance structures were observed in tunneling through a thin layer of silicon with nanoscale particle sizes. Two important physical realities were found: As the particle size is reduced to dimensions comparable to localized defects, it becomes harder to distinguish between quantum confinements and tunneling through localized defects; and conductance of many particles measured in parallel gives rise to extra complications.

Among the giants in the world of metal oxide semiconductor capacitors and metal oxide semiconductor field effect transistors, several will be remembered as the ones most responsible for the rapid improvement of these devices: Grove, Deal, Kahng, Sah, Goetzberger—and Nicollian. Nicollian and Goetzberger extensively applied the measurements of the parallel conductance of metal insulator semiconductor capacitors resulting in the characterization of the $Si–SiO_2$ interface in terms of defect density of states in the band gap of silicon. With this better characterization of densities of interface states, various thermally grown oxides can be quantatively compared. Nicollian thus helped get the MOSFET universally accepted.

Those of us he left behind miss not only his insight into technical matters, but also his views and enthusiasm for life and his knowledge of civilization and military history.

RAPHAEL TSU
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