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A Biographical Memoir by

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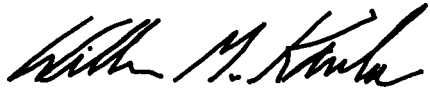

WILLIAM M. KAULA

May 19, 1926–April 1, 2000

BY DONALD L. TURCOTTE

BILL KAULA WAS THE father of space-based geodesy. As an academic scientist for some 37 years at the University of California, Los Angeles, Bill was unique: He graduated from West Point and did not have a Ph.D. His initial move into geodesy was to improve missile trajectories. He soon learned that tracking satellites could provide revolutionary information on how Earth works. He lived to see the determination of absolute positions on Earth to a millimeter accuracy using the military Global Positioning System array of satellites. Bill was also one of the fathers of comparative planetology: Understand the planets and you improve the understanding of Earth.

Bill Kaula was born in Sydney, Australia, on May 19, 1926, to Edna Mason, an Australian of British descent, and Edgar (Ed) Kaula, an American of Czech descent. Ed was a Texaco executive in the days when the United States exported petroleum products. Moves to New Zealand and Holland followed, but in 1935 Ed lost both his job and his wife due to alcoholism. Edna stayed in New York with their younger son David, while Ed and Bill returned to the Kaula home in Somerville, Massachusetts.

Bill found schoolwork easy, so he spent his adolescence in ways consistent with his introspective nature—chess, playing

the piano, and reading novels, philosophy, and so forth: a true nerd. As graduation from high school approached, Ed suggested that Bill apply to West Point, which Bill did, for lack of an articulated alternative. In his own words, "Turning 18 in the middle of a world war made West Point relatively attractive. Otherwise, I probably would have eventually become an English professor, like my brother."

As a plebe, Bill continued in his indolent introspection, which garnered a lot of demerits and a modest academic standing. At the start of yearling year, he had the good luck to be assigned Graham Kent as a roommate. Graham had trouble with his studies, so to help him Bill started studying the night before class for the first time in his life. Suddenly Bill's grades shot up. Bill kept studying even after Graham went off in 1947, and remained a starman for his last three years, despite being near the bottom of the class in athletics and military aptitude.

Bill considered going into the Air Force, but after nearly killing his instructor and himself goofing his first recovery from a tailspin, Bill decided he lacked the coordination, patience, and attention to detail to survive as a pilot. Hence he went into the Corps of Engineers. Meanwhile, he became engaged to a pretty French girl, Denise Bouche, which led after EOBC to an assignment in Hanau, Germany (the bachelor engineers gallantly volunteered to take the assignments in the Far East, where there was a shortage of family housing).

Two years in the Hanau Engineer Depot were rather desultory, but a year in the Fourth Combat Engineers was quite stimulating. Meanwhile, Bill was offered a year in graduate school. He decided that civil engineering was dull and that his record was not good enough to qualify for nuclear engineering, and so he chose a new option: geodesy. In his own words, "In 1951, as a regular officer in the Army

Corps of Engineers, I was offered a year of graduate school, with the program option of nuclear engineering, civil engineering, and geodesy. I elected the geodesy because it was vaguely a mixture of something easy—mathematics—and something that got you out-of-doors—surveying. Later I tried to renege but was compelled to go because no one else had asked for it. The resulting year at Ohio State was stimulating because I was the only student in the program; I did not have to attend lectures in my subject; I wrote my own syllabus; and I got to do a thesis leading to a published paper."

Bill often referred to the geodesy assignment as the biggest piece of dumb luck in his life. On arriving in Columbus in June 1952 Bill found that he was the first student in a new program with one faculty, an aged Finn, Weiko Heiskaneu, who said, "I thought you weren't coming until September. I'm going to Finland for the summer. Here, study this book." Hence the West-Point-taught self-reliance paid off. Bill studied the book (and other geodetic texts) diligently and signed up for summer courses. In the fall no other students showed up, and the Finn said he would not give lectures to only one student—so Bill wrote his own syllabus for weekly discussions, thus getting a more comprehensive view of the subject. He also cooked up a thesis topic that led to his seeing a lot of Ohio countryside.

The geodetic label resulted in his assignment as project officer for the topographic survey of the island of New Britain, just northeast of New Guinea. This proved to be his most satisfying military posting: a tri-racial, quadri-national command, 2,500 miles from his boss in Tokyo, lasting one year. Bill was very proud of the Pidgin English he learned during this assignment. This spell of independence spoiled him, because two years later when the word from OCE was "your next turn is with the Third Engineer Combat Battalion at

Fort Benning," he decided to seek other employment for which his talents were more satisfying to himself as well as useful to the nation, in those days of the "missile gap."

Bill quickly found his choices were limited to the Department of Defense: three offers, two Air Force, one Army. He chose the one with the most stimulating boss: John O'Keefe, head of geodetic research at the Army Map Service. In November 1957 Bill resigned from the military to support five dependents on a GS-12 salary ($7,520 a year, but an adequate house in nearby Bethesda, Maryland, cost only $17,000 then). On arrival at the map service he was surprised to be asked the question "What do you want to do?" To which his immediate response was "research on properties of Earth's gravity field" (then thought to affect inertial guidance significantly). He was further surprised to get the freedom to do it, with support.

A year later O'Keefe moved to the National Aeronautics and Space Administration (NASA), leaving the map service research supervision to Bill. In 1960 Bill moved to NASA to be project scientist for a geodetic satellite. The project, however, kept being postponed because of security objections, which left him free to do his own research. After mastering satellite orbit dynamics Bill turned his interests in two directions: implications of the gravity field for Earth's interior and applications of the dynamical techniques to the evolution of natural orbits. The void of talent in satellite geodesy made it easy for Bill to get papers published, and he regularly presented his results in the *Journal of Geophysical Research* and similar outlets—an average of about six papers per year for 40 years.

Bill's work interested a visiting consultant at NASA, Gordon MacDonald of the University of California, Los

Angeles. This led to a tenured faculty appointment at UCLA, an unusual event for someone without a Ph.D. In partial compensation for never having gotten a Ph.D. Bill wrote two books, *Theory of Satellite Geodesy* (1966) and *An Introduction to Planetary Physics* (1968).

In addition to teaching, Bill served UCLA twice as a department chair and twice as a member of the Council of Academic Personnel, a committee that advises on appointments and key promotions for the entire campus (about 600 cases per year). He frequently served NASA as a project participant (e.g., team leader for the altimeter on Apollos 15, 16, and 17) and proposal reviewer. He was twice a member of the National Research Council Space Science Board. His other principal association outside UCLA was with the American Geophysical Union, as section officer, journal editor, and advisory committee member.

During the mid-1970s Bill's scientific productivity was invigorated by a move into comparative planetology. He made many important contributions concerning the origin and evolution of the solar system. Another very important event in his life took place at about this time, the marriage to his second wife, Gene. They remained inseparable until Bill's untimely death. I remember one wonderful trip with the Kaulas in the late 1970s. We were attending a conference in Newcastle and for a lunch we drove across England to the Lake District. We had an unforgettable lunch at the Shallow Bay Hotel. We reminisced about the decadent sticky toffee pudding right up until a few weeks before Bill's death.

Bill had a very wry sense of humor and a rare ability to transmit scientific ideas. An example was his poem "The Seven Ages of a Planet" published in the journal *Icarus* (1975).

Our system is a stage,
And both the Sun and planets merely players.
They had their birth and'll have their fiery end.
A planet in its time plays many parts,
Its acts being seven ages. The first of these
Is condensation: dust grains drifting to
The nebula plane in chondrite clods. And then
The planetismals: breaking sometimes, but
Most growing, though the Sun's hot breath blows gas
Away. And then formation: sweeping up
The bodies in its way, in fierce infalls
To bring then full convective vigor, too hot
For crust to form, though iron may sink and seas
Outgas, by radioactive energy driven.
And then comes plate tectonics: cooling leads
To lithosphere, with many marginal breaks.
Convective thrusts a crust create in belts
Complex. But heating slows; the sixth age shifts
Into the final volcanism: no
More lithospheric spreading, only vents
For magma, Nix Olympica or mare
To surface, ending fractionation. Last scene
That ends this history is quiescence: time
Sans melt, sans plates, sans almost everything.

In the mid-1980s Bill took leave from UCLA to serve three years as head of the National Geodetic Survey in the National Oceanic and Atmospheric Administration. While on this tour he was diagnosed with hairy cell leukemia, but within five years was fortunate to be one of the first beneficiaries of the now standard cure. After 1991 his principal health problem was squamous cell cancer in the scalp.

The onset of leukemia was followed closely by three honors: the Whitten Medal of the American Geophysical Union; the Brouwer Medal of the American Astronomical Society; and in 1987 membership in the National Academy of Sciences.

A moving testimony to Bill's unique abilities and contributions was given by Stan Peale, chair of the Division of Dynamical Astronomy of the American Astronomical Society, at the division's thirty-second annual meeting on April 9, 2000.

As most of you know, our friend and colleague, Bill Kaula, died peacefully a week ago last night after a decade-long battle with cancer that was anything but peaceful. Bill was a member of the original organizing committee for the DDA in 1969, served as a DDA Committeeman from 1971 to 1973, as DDA Vice Chairman from 1974 to 1975 and as Chairman from 1975 to 1976. In recognition of his outstanding contributions to dynamical astronomy, Bill received the Brouwer Award in 1989. As one of the founders of the DDA, after a remarkably productive scientific career in dynamical astronomy, in the dynamics of planetary interiors, and broad aspects of solar system science, and after a lifetime of unselfish service to government agencies, to professional societies, to his university, and most of all to his innumerable friends, it is most appropriate that we dedicate this meeting to remembering Bill.

Bill developed some of the earliest expansions of the Earth's gravitational field using satellite geodesy, and he published a book describing the state of the art of geodesy at that time. After he moved to UCLA in the early sixties, he rapidly expanded his knowledge of planetary science, and he published papers on an incredibly broad range of subjects during his career. These include applications of his geodesy expertise to other terrestrial bodies, and interpreting the gravitational fields of these bodies in terms of interior properties. He also published on tidal evolution, chaotic dynamics, history and stability of planetismal distributions, the formation of terrestrial planets through accretion, the formation of the solar system, origin of the Moon, comparative planetology including compositional implications, thermal history of terrestrial bodies—especially Venus—and the quest for fast and accurate numerical integration schemes to follow solar system history and evolution. He must have devoured most of the literature in dynamical planetary science and in the physics of the solid solar system bodies, for one could ask him questions on almost any subject and he would understand the material in detail and know who had published what when. We celebrate his career.

Bill's fight with cancer would have driven most of us to all consuming self-pity and anger. Yet he remained always cheerful and optimistic. He

wore a hat to hide the wounds that would not heal, and proceeded with his life as if nothing were wrong. He remained scientifically active until the very end, having coauthored at least 6 papers last year, and he is a coauthor of a paper at this conference. Ever optimistic, only a month ago, while in the hospital for the last time, he was still intending to come to this meeting. His service to the University also continued until the very end as he was a member of the extremely demanding UCLA Committee on Academic Personnel when he died—fretting a few days before the end that he was not doing his share. We shall miss his energy, enthusiasm, and council. Let's make this a memorable meeting in memory of Bill Kaula—always interested and always our friend.

MY THANKS TO JOHN Wood and Gene Kaula who reviewed and contributed to my efforts in writing this memoir.

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