Werner Goldsmith, 1924–2003

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WERNER GOLDSMITH: Life and Work (1924–2003)

Stanley A. Berger,[1] Albert I. King,[2] and Jack L. Lewis[3]
[1]*Department of Mechanical Engineering, University of California, Berkeley, California 94720-1740; email: saberger@me.berkeley.edu*
[2]*Department of Biomedical Engineering, Wayne State University, Detroit, Michigan 48202; email: king@rrb.eng.wayne.edu*
[3]*Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, Minnesota 55455; email: lewis001@tc.umn.edu*

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■ **Abstract** Werner Goldsmith, one of the foremost authorities on the mechanics of impact and the biomechanics of head and neck injuries, died peacefully at home in Oakland, California, on August 23, 2003, at age 79 after a short, courageous battle with leukemia, ending a long and very distinguished career in mechanics, dynamics, and biomechanics, and an almost six-decades-long association with the University of California, Berkeley. He was one of the pioneering, eminent solid and fluid mechanicians who made an early transition to biomechanics, and in rising to equal distinction in their new fields, added great credibility to biomechanics as a discipline in its own right. He was also a distinguished and influential figure in bioengineering education at his own institution, and, more broadly, in the United States and abroad. An emeritus professor for over a decade, he continued to be active in research and teaching until the very last days of his life.

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LIFE AND CAREER

Werner Goldsmith was born in Düsseldorf, Germany, on May 23, 1924, the only child of Siegfried and Margarethe Goldschmidt (née Grunwald). He attended lower schools in Düsseldorf. He was allowed, at his parents' insistence, to enroll at a gymnasium after the National Socialists assumed power, even though the family was

Figure 1 The young Werner Goldsmith in Germany shortly before he was sent to the United States by his parents.

Jewish, because his father had served, and in fact had been badly wounded, in World War I. As the only Jew, he was subjected to much abuse and prejudice, which he dealt with by concentrating and excelling in his studies (Figure 1). When he was 14 years old his parents arranged with a cousin in the United States to provide appropriate papers that allowed him to emigrate from Germany and come to the United States. He was on one of the last "kinder transports" to leave Germany. His parents were not able to escape from Europe, and they later died in the Nazi death camp at Auschwitz, leaving second cousins as his closest relatives. On arriving in the United States, he went to live in the New York City area with a family that was taking in Jewish child refugees from Europe. He finished high school in Mount Vernon, graduating in two years, just before the United States entered the war. He attended the University of Texas, and graduated in 1944, after three years, with a B.S. in

Mechanical Engineering. During his undergraduate years, he augmented his scholarships and loans with assorted jobs, including working as a typist for the university library, where he honed his legendary lightening-fast typing skills. He remained in Austin for an additional year working as a tutor in Applied Mathematics while earning a Masters Degree in Mechanical Engineering in 1945 in the area of heat transfer, specifically, studying the freezing point of sugar/salt solutions. For two years following his M.S. degree, he held appointments or positions at the University of Pittsburgh as Instructor in Mathematics, at the Westinghouse Electric Corporation as an engineer, and at the University of Pennsylvania as a Lecturer in Engineering.

Goldsmith began a 56-year-long association with the University of California, Berkeley, starting with his enrollment in 1947 as a doctoral student in Mechanical Engineering (ME), carrying out research in heat transfer. Simultaneously, he was appointed as Lecturer in ME. He completed the Ph.D. in ME in a brief two years and was immediately appointed to the full-time faculty, with the title Assistant Professor of ME. At this time, he switched his research and teaching interests from the area of thermal systems to mechanics and dynamics. He progressed through the academic ranks rapidly, with promotion to Associate Professor in 1955, and Professor five years later.

Goldsmith was a devoted and able teacher, passionate and dedicated to the profession. His courses were tough, his standards and expectations of students high, but he was always fair and always sensitive to student needs and difficulties. He generously gave of his energy and time, even in his later years when he had to deal with major, painful, health problems. Students seemed instinctively to know this lay beneath Goldsmith's sometimes stern countenance, and so, for example, years later former students would thank him for all they had learned from him. He taught courses in bioengineering and biomechanics, and continued to mentor students in research well beyond his official retirement. He was especially effective working one-on-one with graduate students, guiding numerous of them in their research, in total the thesis advisor for 33 Ph.D. and 45 Masters students, many of whom went on to become leaders in academia, industry, and government in the United States and abroad (Figure 2). He was well known for looking after students doing research with him, at both the undergraduate and graduate levels. He expected much of his research students, holding them to a very high standard of excellence, but he reciprocated by being fiercely loyal and dedicated to them. His concern for his students did not end when they left the university. He continued to support and mentor his former students throughout their careers. This attention to and concern for young investigators was not limited to his own students. For example, the second author of this article fondly remembers, when over three decades ago, Goldsmith, visiting Wayne State University as part of his NIH-commissioned survey of biomechanical research activities in the United States and abroad, spent as much time with him, then a junior assistant professor at the university, as he did with other more senior faculty. Goldsmith listened attentively and took copious notes, even though the research had nothing to do with head injury.

Figure 2 Goldsmith explaining a point to a graduate student after a class.

SCHOLARLY CONTRIBUTIONS

Throughout his long career, Goldsmith authored or coauthored more than 200 papers, the last of which, on shaken baby syndrome, appeared after his death (1). His papers are universally as impressive in their readability as they are in their content. In the precomputer age, his well-honed typing skills minimized errors, and, as always, his expert editorial eye and his command of English, his second language, of which he was justifiably proud, led to publications that were as pleasing to the eye as to the intellect.

It was noted above that Goldsmith, early in his professional career, switched to dynamical problems in solid mechanics. In particular, upon receiving his professorial appointment at Berkeley he initiated, in 1950, an ambitious experimental and theoretical program on impact, which at the time assumed major technological importance owing to problems and challenges arising out of WWII. His focus was on the behavior of colliding objects and the waves generated by collisions. This interest continued to the end of his life, his contributions so highly regarded that he was for half a century universally recognized as a foremost authority on the mechanics of impact. In 1960, his book *Impact*, subtitled *The Theory and Physical Behavior of Colliding Solids* (2), was published by Edward Arnold, London. This treatise, the first organized collection of work in the field and the first text to scientifically systematize the mechanics of collision, had a very significant influence when it was published and attracted many investigators to this area of research. It remains one of the most important works available on impact; in recognition of this, it was reissued in 2001 in the Dover Publications series of classic texts in engineering (3). Goldsmith's research in this area was diverse and prolific, including, among other topics, investigations in penetration mechanics, dynamical properties of materials, and wave propagation in bodies of various geometries. His work on wave propagation and impact had applications to military problems, and led to his service as a consultant to the U.S. Naval Weapons Center at China Lake, California, from 1951 until his death. His work at China Lake included investigations of the trajectories of missiles, explosive materials, and other aspects of ballistics. Living and working in a part of the country noted for its antiwar sentiments, Goldsmith was untroubled by this affiliation, regarding it as a modest repayment to the nation that gave him sanctuary from the fascism that killed his parents and countless other millions. His interest in impact problems continued for the duration of his life, as evidenced by his recent monumental 300-page review article, "Non-Ideal Projectile Impact on Targets," which takes most of two issue numbers of the *International Journal of Impact Engineering* published in 1999 (4). This same journal, in 1994, in honor of Goldsmith's seventieth birthday, published an entire voluminous (c. 250 pp.) issue dedicated to his work (5). The issue includes a brief biography and letters from friends, colleagues, and former students from around the world, many expressing deep gratitude for his loyal friendship, support, and mentoring throughout the years. Many of the papers are by Goldsmith's research collaborators, colleagues, and former students, or are accounts and surveys of areas particularly associated with his name.

In the 1960s, Goldsmith was both an internationally recognized expert in impact of solids and an emerging pioneer in biomechanics. His work in impact was performed in the context of the applied mechanics community, and he was recognized as one of the prominent members of that community, frequently presenting invited papers at national and international meetings. Although thoroughly grounded in applied mechanics theory, he was primarily an experimentalist. His interest in impact at this time was focused on dynamic material properties and wave propagation in elastic solids. There was considerable activity in the mechanics community in theoretical developments in elastic wave propagation, but less in the experimental side. This was the beginning of the computer era, so there were few computational solutions for wave propagation in solid bodies of irregular shape; his work was partially intended to provide data for developing these theories. Goldsmith was one of a small community exploring elastic wave propagation experimentally, particularly waves in cylindrical rods (6–8). He established a laboratory for such studies, utilizing high-pressure air guns with associated instrumentation (Figure 3). He became particularly interested in developing transducers for measuring stress waves in solids of irregular shapes, such as cones and blocks (9–11). These included strain gages and piezoelectric crystals embedded in three-dimensional models (9, 12). In this type of work, he was always trying to extract sound experimental data and then fit this with the best available theories, or developing them himself (13–17). During this time, he became interested in geophysical applications of impact and studied wave propagation phenomena in rock and concrete

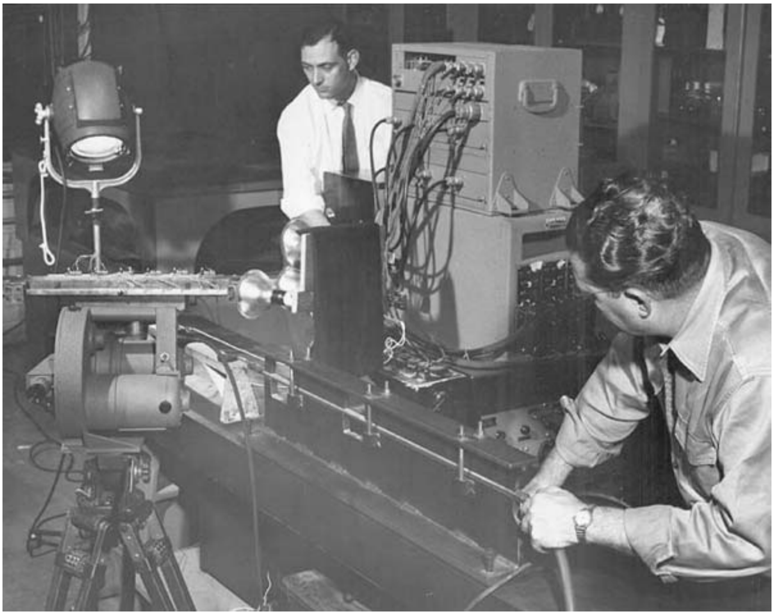

Figure 3 Goldsmith in his Wave Propagation and Impact Laboratory in Etcheverry Hall on the Berkeley campus preparing for an impact experiment, of the kind that he performed countless times. The photograph shows the long barrel of a small diameter gas gun, a high-speed camera, lighting for the photography, and oscilloscopes to read the signals from various transducers.

(11, 18–21), using many of the same techniques perfected for metals and polymers.

Along with his interest in elastic wave propagation, Goldsmith was also particularly interested in dynamic material properties, wherein dynamic meant a strain rate range applicable to impact. He developed several experimental and theoretical models for studying dynamic plasticity, and linked these with his interests in penetration phenomenon (14, 22, 23). But his interests went beyond this to more general dynamic properties, leading him to the Hopkinson pressure bar, which combined his interests in dynamic properties and elastic wave propagation (6, 8, 24). The Hopkinson pressure bar technique had been developed several years earlier, and was now being used by several investigators to measure material properties at rates higher than could be achieved by rapid loads applied by test machines or simple drop weight tests. The method utilized elastic stress waves generated in a long cylindrical rod. The specimen to be tested was placed between two metal rods, one a load applicator and one a load recorder. Strain gages were placed at strategic locations on the rods and strain-time data recorded as a stress pulse propagated in the rod and through the specimen. Data was interpreted using one-dimensional wave theory. This was a very effective method and was used by a community of experimental mechanicians. Goldsmith was a leading member of this group.

Although much or most of the work described above was not specifically addressed to biological problems, it was a precursor to the bioengineering, more specifically biomechanics, research for which Goldsmith subsequently became equally renowned.

In the mid-1960s, amid his intense activity in impact mechanics as a respected member of the applied mechanics research community, Goldsmith became interested in impact-related problems in biomechanics. Although the techniques he would use in biomechanics would be very similar to those he had been using in his nonbiomechanics work, this was quite a departure from his prior work. It required learning extensive anatomy and biology and forming collaborations with medical researchers. At this time, there was a small, but growing, cadre of researchers beginning to apply traditional engineering methods to biomedical problems. These were somewhat divided into two groups, the first using fairly simple mechanical models to address current medical problems, particularly related to musculoskeletal injury and cardiovascular disease, and the second applying more sophisticated mechanics to similar issues, but often to more basic biological phenomenon. Members of the first group tended to be physicians and anatomists, with good understanding of the medical issues. The second tended to be recognized leaders of the applied mechanics community, who formed collaborations with medical researchers. Goldsmith was a member of the latter.

Goldsmith's particular interest in biomechanics was head and neck injuries, and he was to become one of the modern pioneers in conducting careful scholarly research in this area, an interest that continued to the very last days of his life. Experimental work on head injury models began in his laboratory in 1967 and continued, quite literally, until the final weeks of his life. He applied a wide array of methods to the problem of head injury, treating the problem much more as a mechanics problem compared to earlier approaches.

An early sign of his rapidly growing reputation in this field was the invitation by the National Institute of Neurological Diseases and Stroke of the National Institutes of Health for Goldsmith to chair the Head Injury Model Construction Committee, the purpose of which was to conduct a study that would eventually lead to an understanding of the response of the head to impact. It was as a consequence of that study analyzing the state of head injury research in the United States that there began a lifelong productive collaboration on head injury research between Goldsmith and Ayub K. Ommaya, MD, a distinguished NIH neurosurgeon. For years, their work set the standard for research into the mechanics of head injury.

After his survey of the field regarding head injury, Goldsmith initiated his own research on head injury by building a physical model of the brain. Goldsmith's approach to head injury followed his earlier impact work. It was in the late 1960s and finite element programs were not available. He used physical and mathematical models to study human response to impact. His physical model was a fluid-filled sphere because it was possible to develop a set of equations representing response of the fluid in the sphere owing to an impact on the shell. The mathematical model was an extension of an earlier model developed by Engin (25), who used an impulsive input force with an infinitesimal duration. The impact duration was extended to a finite duration by Kenner & Goldsmith (12), using a convolution integral, and the model was able to predict accurately the fluid pressures and shell strains measured from the physical model (26). Goldsmith viewed the problem as one of impact, with the impact causing both local contact or penetration damage, and stress waves generated owing to the impact (12, 26–28). These waves could interact to cause elevated stress levels in cranium and brain tissue distant from the impact site. He set up several analogue models in which internal stresses could be measured directly, allowing the development of approximate three-dimensional models of the injury phenomenon. Subsequent work went on to greater complexity and realism, including rigid body motion and the effect of head-neck interaction (29–36). By accomplishing the validation of their models, Goldsmith led the biomechanics community into the arena of mathematical modeling of head impact, just as he recommended when he initiated the NIH head injury project. Work of this type continues by others, but Goldsmith's approach laid the groundwork for many.

Research in fundamental aspects of head and neck injury was interwoven with a variety of practical problems, such as the design and evaluation of various human protective devices, including headgear, and, more generally, investigations of energy-absorbing materials. He developed helmet models with Khalil, who used the spherical shell model as the surrogate head and added an aluminum shell on the outside of it for a helmet (27, 37). He did additional work on different types of helmets, including construction helmets (38) and baseball caps (39), as well as studying oblique impact on helmets (28). Appropriate design of protective gear, to which Goldsmith made such significant contributions, is still an ongoing important area of research.

Goldsmith then extended his studies to the head and neck system, again developing physical and mathematical models. Several Ph.D. students were involved in this investigation over a period of approximately 10 years (29–33, 40–50). This was eventually extended to include the torso (34–36, 51). Such studies were invaluable in understanding the causes and nature of injury in vehicular collisions and what measures could be taken to avoid them. Goldsmith then became interested in the effect of the vasculature on brain response (52–54), probably because of his interest in the shaken baby syndrome. Much of the work was done by Monson, his last Ph.D. student. This work also led to a collaborative effort with the second author of this article to do the modeling while Monson measured the material properties of cerebral blood vessels (55). This collaborative effort, now between King and Monson, continues.

In addition to his own work on head injury, Goldsmith left a legacy that is likely to endure for many decades to come. He played a major role in the Head Injury Conference of 1966 in Chicago, which was sponsored by NIH. There was a strong contingent of bioengineers at the conference and Goldsmith made two crucial recommendations, as recorded in the Proceedings of the conference (56). The first was that engineers ought to be able to describe the impact event using mathematical models, and the second was the need for more materials property data for the brain so that the models could more accurately predict the response. Both of these recommendations were taken to heart by the bioengineering community and there resulted a plethora of papers on computer models and brain properties by researchers from around the globe; research that continues even to this day.

Goldsmith was one of a handful of established applied mechanicians who turned to biomechanics in the 1960s (e.g., Y.C. Fung, F. Ling). The fact that these were established researchers gave this young field a great deal of early credibility and was very influential in bringing younger researchers and students into the field. Goldsmith was not only following his own interests and research, but playing an active role in developing the field. His participation in the head injury research needs study was one way he did this; another was his role in starting the *Journal of Biomechanics*. This journal was started in the late 1960s and was for many years the primary journal for biomechanics in the world, serving as the principal outlet for mechanics applications to medicine and biology. Goldsmith was a member of the original Editorial Board, and was instrumental in getting the journal started.

At the turn of the century, Goldsmith took on the herculean task of writing an encyclopedically comprehensive survey of studies of the biomechanics of head injury spanning the previous six decades. Part 1 of this, 160 pages long with 20 pages of references, appeared in 2001 under the title "The State of Head Injury Biomechanics: Past, Present, and Future: Part 1," and was published in *Critical Reviews in Biomedical Engineering* (57). Part 2 was incomplete at the time of his passing but is now being finished by Ken Monson, the last of the 33 Ph.D. students he mentored. (This second part, under the joint authorship of Goldsmith and Monson, will appear in the same journal, most likely in 2005.) These two monumental works not only demonstrate the breadth and depth of Goldsmith's knowledge of the head injury field, but also the skillfulness to report the findings in the literature critically but with complete objectivity. None was better qualified to carry out such a discerning review of the subject, and the final result represents Goldsmith at his best.

As is evident from his publication record up to the end of his life, Goldsmith maintained an active interest in biomechanics and applications of his vast store of knowledge in impact mechanics to biology and medicine. Approximately a quarter of his publications were related to this subject. We can only speculate why he chose to enter this field at the height of his prominence in impact mechanics. Goldsmith had an abiding social conscience and a sense that he should contribute toward making things better for others. He wished not simply to be focused on his personal gains, but to be part of a larger community working for the greater good. We can only guess whether this was a reaction to the horrors of his experiences as a youth, or the product of other events. In any case, there was a deeply-rooted humanity within him that seemed not to be totally satisfied by mechanics alone.

CONTRIBUTIONS TO BIOENGINEERING EDUCATION AND THE PROFESSION

As noted, in the mid-1960s, Goldsmith's interests began to encompass the fields of bioengineering and biomechanics. During the late 1960's Goldsmith was asked by the NIH to report on biomechanical research activities at American and European institutions. He visited 15 institutions and interviewed 116 researchers in a three-month period, taking detailed notes of the on-going work. His investigations were reported in a series of four papers that appeared in the *Journal of Biomechanics*, in Volumes 2 and 3, 1969–70 (58–61). These, and his other papers on head injury during the late 1960s, which melded his considerable knowledge of dynamical solid mechanics with newly learned physiology and anatomy, once again, like his book on impact, acted as a stimulus, drawing many researchers into an important emerging field.

In the early 1970s, Goldsmith played an important role in forming the Joint UCB/UCSF Bioengineering Graduate Group, which, years after his retirement, led to the establishment at Berkeley of the Department of Bioengineering. This might be an appropriate point to digress to describe for the historical record the evolution of bioengineering on the Berkeley campus. The evolution and the nature of a bioengineering program will depend on numerous factors, including (*a*) the host college and (*b*) whether the campus has a medical school, and if so, the proximity of the medical school to the campus, among other considerations. The scenario at Berkeley, a large prestigious public university with very strong engineering, biological, and life science departments, without its own medical school, but at a relatively small distance from a health sciences sister campus (University of California, San Francisco, UCSF), might provide some useful insights into the organization of bioengineering programs.

The significant date to begin the narrative is 1965, before which Berkeley had no formal academic program in bioengineering. Notwithstanding this, in 1965, 20 or so engineering faculty members had one or more research projects at the interface between technology and biology or medicine. Professors Irv Fatt (then of the ME Department and an Associate Dean of Engineering) and Charles Susskind, of the Electrical Engineering Department, organized these faculty members into a bioengineering graduate training program. Fortuitously, just at this time, Professor Larry Stark, then at the University of Illinois, Chicago Circle, later to be at Berkeley, was traveling around the country to identify campuses to which NIH might give start-up funds to initiate academic bioengineering programs. Stark immediately recognized Berkeley, with an already sizeable effort underway, as a very suitable site to direct NIH funds. The National Institute of General Medical Sciences soon thereafter awarded Berkeley a Training Grant to financially support the nascent bioengineering graduate training program.

Fatt and Susskind, along with Professor Howard Mel of the Biophysics Department, designed a curriculum for an undergraduate program in bioengineering, which Fatt implemented under the aegis of the undergraduate engineering science program. Engineering science at Berkeley was, as at many other institutions, an elite program. This mandated quality standard has characterized the bioengineering program throughout most of its history and undoubtedly helped to nourish its growth and success.

By 1970, the undergraduate and graduate bioengineering programs each had approximately 100 students. A decade later, undergraduate bioengineering science had grown to nearly 200 students and had become one of the two most competitive programs on the Berkeley campus as measured by freshman admission metrics (highest GPA and SAT scores).

In the late 1970s began a set of meetings and actions that led to a more formal organizational structure for bioengineering. The then Dean of the Medical School at UCSF, soon-to-be Chancellor, Julius Krevans, met with Goldsmith and the lead author of this article. Krevans had come to UCSF from Johns Hopkins hoping to develop a strong relationship between the UCSF medical school and the Berkeley engineering school, akin to what he had seen at Hopkins. He encouraged the two of us from Berkeley to work with Stan Glantz of the Department of Medicine at UCSF to get this off the ground, and promised support for such an effort. In response to this meeting, the Berkeley Dean of Engineering established a joint Berkeley/UCSF committee, chaired by Ted Lewis of the Berkeley Electrical Engineering and Computer Sciences (EECS) Department, and including Glantz. Seizing the initiative, Lewis and Glantz came up with a plan for a joint program. Lewis' idea was to have Berkeley M.S. and Ph.D. engineering students working in clinical settings at UCSF, under joint mentorship of UCSF and Berkeley faculty. Glantz was to enlist approximately 20 or so UCSF faculty members with appropriate projects, which Lewis would present to incoming bioengineering graduate students. By advertising this option in the catalog, an entirely new type of graduate student began to be attracted to Berkeley, and notwithstanding the complications of melding two autonomous UC campuses with different academic cultures, ever increasing numbers of Berkeley and UCSF faculty members began to affiliate with this effort. That program was in its fifth or sixth year when the Graduate Group finally was formed. Krevans, by then UCSF Chancellor, encouraged the formation of a Group because he wished UCSF to receive some credit for the students, who were all registered Berkeley students—even though they were doing research at UCSF. A formal Joint UCB/UCSF Bioengineering Graduate Group would also be more attractive to graduate students while dealing more effectively with the academic complications of having faculty with formal affiliations on different campuses.

Because a Ph.D. in Bioengineering degree did not exist, formal approval of the degree had to be obtained from the University of California Regents, after approval by all the relevant campus and system-wide faculty committees. This took a full two years! When finally approved in 1982, what had been a handful of people had grown to nearly a hundred, with the initial majority of Berkeley faculty members now outnumbered by their UCSF colleagues.

No account of the development of bioengineering at Berkeley up to this point, or as follows below, could be complete, nor would the success it relates have occurred, were it not for a series of continuing NIH Training Grants awarded to the campus. The first was in place as early as 1967, with Irv Fatt, the P.I., identified by the NIH as the "Director of the Bioengineering Training Program at Berkeley." A decade later this was merged with the training grants of Biophysics, Physiology, and Nutritional Science to form the campus's Systems and Integrative Biology Training Grant, with the bioengineering component headed by Ted Lewis and allotted approximately a dozen traineeships. It was funded by NIH until 1991.

Although many details were still to be worked out after the formal approval of the Joint Group, ultimately, graduate students accepted to the program upon registration at either campus were considered to be registered at the other, could take courses for credit at either campus, could enroll in medical school classes, faculty could cross campuses to teach, and UCSF faculty could teach and have access to Berkeley undergraduate and graduate students.

With approval of graduate bioengineering degrees, a quota for admissions, a sizeable faculty contingent, and the changing career interests of top-quality graduate students, the Graduate Group was poised for rapid growth. Four to five of the campus NIH traineeships were allocated to the Group. (A few years later this number was supplemented when the Group received its own small Training Grant. Both Programs continued until 1991 when the Group received a larger NIH Training Grant, which became the exclusive NIH funding source.) The growth of the Joint Group occurred simultaneously with the growth of the undergraduate bioengineering program, still a part of engineering science. Chronologically, we are now in the mid-1990s, and Berkeley administrators at the campus and the college level have become fully cognizant of these now very large undergraduate and graduate programs filled with some of the most qualified students on campus, with hundreds as capable being turned away, all of this accomplished with meager resources. An untenable situation, the remedy for which all seemed to agree was the formation of a bioengineering department, as was happening at various other universities for not dissimilar reasons. Numerous faculty committees were set up to examine all the relevant issues, draw up programs of study, etc. In 1998, a Joint Berkeley-UCSF Department, a rare hybrid for the University of California system, was established, with the Berkeley component to be instituted immediately, the UCSF segment to follow. The undergraduate bioengineering science program became the undergraduate program in the new Department of Bioengineering, whereas the Joint Graduate Group was to remain intact but to also function as the departmental graduate program. A capstone to all this effort was a grant to Berkeley in 1999 of a $15 million Whitaker Foundation Leadership Development Award to cover the capital cost of the bioengineering component of a new major biosciences and bioengineering building.

The above history highlights the importance of a few visionary, creative, industrious, and committed individuals. Goldsmith entered the picture just slightly later than the earliest people named above, but Goldsmith's stature, illustrious history in the academic and professional worlds, and basic good instincts were important in the evolution of bioengineering on the Berkeley campus, and elsewhere as well.

His experience and steady hand were always available as requested or needed. In recognition of the influential contributions he made to the creation of the department, he was appointed Professor Emeritus in the Department of Bioengineering in January 2003, earning for Goldsmith the distinction of becoming emeritus in a department that did not exist when he retired from the university!

To help address the need for instructional material for courses in bioengineering, Goldsmith and colleagues wrote one of the early comprehensive texts in the field, *Introduction to Bioengineering* (edited by S.A. Berger, W. Goldsmith, E.R. Lewis) published by Oxford University Press in 1996 (62). The text was based on a long-running team-taught course of the same title that, although he had not introduced it, Goldsmith was coordinator and mentor of for many years, and which he led off teaching each year with a tour de force three-week survey of much of undergraduate mechanics and dynamics! This was also the first specifically identified bioengineering course taught at Berkeley.

SERVICE AND HONORS

We have noted Goldsmith's contributions to such practical problems as the design and evaluation of various protective headgear, e.g., protective hats worn by baseball players when at bat. Goldsmith's extensive research and knowledge in impact and the biomechanics of head and neck injuries led to his being widely asked to consult on automobile safety and accidents, helmet design for sports and hazardous work, head trauma, etc. He was called upon often to testify as an expert witness in court cases, some of them well known, involving automobile collisions, falls, beatings, etc. One of the most prominent of these, and one his strong social conscience made him take special pride in, was his testimony in the Rodney King trial, testifying about King's head injuries for the prosecution. Later, his experience in the legal arena led to his study of pediatric head and neck injuries, in particular the forensics associated with the violent shaking of an infant or child, commonly referred to as shaken baby syndrome. He led a group of scholars who argued that prosecutors and doctors who alleged death by shaken baby syndrome were often not well-versed in basic biomechanics, and consequently, frequently made false accusations of child abuse. Once again, he began to be called as an expert witness in important court cases in this area.

Goldsmith's renown in impact and biomechanics led to invitations for him to act as consultant to a wide a range of agencies and organizations, including the U.S. Army, Air Force, and Navy; the National Institutes of Health; Consumer Products Safety Commission; Federal Trade Commission; Lawrence Radiation Laboratory; and the National Research Council.

Goldsmith was a man of prodigious energy and perseverance. That, coupled with his creativity, ingenuity, and originality, led to over 300 journal papers and technical reports. He was as courageous in his research as he was in the way he lived his life, and would venture into uncharted, ill-defined areas where others, more wary, chose not to go. In doing so, he encouraged the development of new fields. He received many honors and accolades. He was elected in 1989 to the National Academy of Engineering, with affiliations both to ME and bioengineering in the Academy, and cited for his "outstanding research on impact phenomena in solids, including projectile penetration, rock mechanics and head and neck injury." In 1997, he was elevated to the rank of Honorary Member of the American Society of Mechanical Engineering (ASME), the highest honor bestowed by the ASME. The citation for this honor read, "For his outstanding status as an internationally acclaimed and widely published authority on collision of solid objects, involving analytical, experimental and numerical investigations, with special emphasis on head and neck injury, and protection, striker penetration, rock mechanics and dynamic material properties and as an educator, public servant and legal consultant." Other awards and honors, to list but a few, include a Guggenheim Fellowship, a Lady Davis Fellowship at the Technion, two Fulbright Fellowships, election as a Fellow of the American Academy of Mechanics, having an entire issue of the *International Journal of Impact Engineering* dedicated to him in honor of his seventieth birthday, being chosen by the Berkeley Engineering Alumni Society as a Distinguished Engineering Alumnus in 2001, and receiving the title Doctor Honoris Causa of the University of Patras in 2002. The occasion of the presentation of the honorary doctorate from Patras, which he received in the presence of his wife, daughters, and two grandchildren, was his last awards ceremony and his last visit to Europe.

Goldsmith's involvement with the Fulbright Program, noted above, merits a fuller account. He was a Fulbright Research Scholar in Greece in 1974–1975 and then again in 1981–1982, a Visiting Fulbright Fellow to Turkey and Israel in 1975, and a Visiting Fulbright Fellow to Israel, Italy, France, and Germany in 1982. Goldsmith knew firsthand the tragedies that discord within and between nations caused. This, coupled with the personal and professional satisfaction he derived from these Fulbright experiences abroad, made him a lifelong supporter and enthusiast of the program, at both the local and national level. He and his wife, Penny, would periodically attend social gatherings in the Berkeley area of former Fulbright scholars, receptions in San Francisco hosted by the Institute of International Education for foreign Fulbright students and scholars just arrived in California, and entertain these foreign visitors at dinners. A highpoint of this association was Goldsmith's Management Chairmanship of the third International Fulbright Alumni Association Convention in Berkeley in September 1980.

As a distinguished scholar first in mechanics and then biomechanics, Goldsmith's services were frequently sought by professional societies, organizations, and journals. He served the ASME in a number of positions and served as a member of a number of Scientific Committees for International Union of Theoretical and Applied Mechanics (IUTAM) Symposia and for an International Congress of Applied Mechanics (1989). He served long terms on the editorial or advisory boards of a number of prestigious journals (*Journal of Biomechanics*, 1967–1987; *Journal of Impact Engineering*, 1983–2003; *International Journal of Mechanical Sciences*, 1971–1983). In the modern world of paper-writing, grantsmanship, conference attendance, etc., service as an editor or reviewer of manuscripts is seen by some as foolhardy, so it is worth quoting comments of Norman Jones, Editor-in-Chief of the *International Journal of Impact Engineering* in his foreword to the 1994 special issue of the journal honoring Goldsmith (5) cited in Scholarly Contributions (above). After noting Goldsmith's long service on the editorial board and his many scholarly contributions to the journal, Jones writes, "Werner is always prompt, fair and very helpful to me as Editor, and, more particularly, to the authors, who receive much encouragement and helpful advice from him. He never writes a review which will shatter the confidence of a young author, even when a manuscript is not acceptable. This advice is much appreciated by authors and by me when communicating with authors." At the end of Life and Career, above, much was said about Goldsmith's work and support of his own students. Less known and heralded was his encouragement to the next generation of scholars in his field.

The University of California system has not awarded honorary degrees for decades, so the highest Berkeley honor is the Berkeley Citation, awarded to only a few individuals of distinction each year. Goldsmith was very proud to receive this in 1995 for outstanding contributions to his field and service to the university. What added immeasurably to his delight on the occasion of the award was that Chang-Lin Tien, Berkeley Chancellor and Goldsmith's M.E. colleague and good friend for five decades, presided over the ceremony.

In 1989, Goldsmith was the keynote speaker at the 50th Anniversary Symposium of the Bioengineering Center of Wayne State University. He enjoyed the visit immensely because many of his former graduate students in the Detroit area came to the Symposium and took him out to lunch as a sort of reunion. At the 1995 ASME Applied Mechanics and Materials Summer Conference at the University of California, Los Angeles, a three-day (June 28–30) symposium was held to honor Goldsmith. The Symposium, "Impact, Waves and Fracture," had 11 sessions, 36 papers, and was attended by approximately 100 of the leading experts in impact mechanics from around the world. The symposium proceedings fill 443 pages and appeared as Applied Mechanics Division (AMD) Symposium Volume, Vol. 205 (63). A high point was the Symposium Award Dinner, which included a roasting of Werner. He took copious notes and then delivered, in inimical Goldsmith manner, a brilliant rebuttal to each "roaster" in turn, the rebuttal generally delighting the large audience of his colleagues, friends, family, and former students more than the original remarks! A typical example of Werner getting the final word, this proved once again that, appearances notwithstanding, Werner had a lighter side and had no peer in poking fun at himself when the occasion called for it.

CONCLUDING REMARKS

Werner had many interests and abilities beyond the technical. Throughout his life he loved to travel, he visited most parts of the world, and used each of his sabbatical leaves to live in a foreign country, including two in Greece, where he developed some fluency in the language. He subscribed to the "one city, one day" travel philosophy and was never without a camera. In addition to his adopted English and native German, he spoke French fluently. He loved sports and the outdoors, passions he combined in his zest and love for skiing. He was known to drive through blizzards to get to the snow, and would often do day-trips to Tahoe from Berkeley. Werner loved collections. He collected antique maps, stamps with maps on them, first day covers, coins, African masks, and other trinkets from around the world. Another of his passions was food. He was especially fond of good desserts. He had a potentially life threatening allergy to tomatoes, which anyone accompanying him to dinner was well aware of by his intensive grilling of the wait staff as to the possibility of any tomato residue in what he was ordering. He also loved family meals, which could last for hours, and from which no one would leave the table hungry. He was an inveterate photographer and had a collection of several thousand photos, many of famous engineers taken at the myriad professional meetings that he had attended. Tragically, in 1991 a devastating fire in the Oakland Hills destroyed the Goldsmith home and all their possessions, including Werner's lifetime treasured collections of maps and stamps and irreplaceable photographs, including the few tear-stained remnants of his now-lost European life and family. But, being the survivor that he was, he wasted no time rebuilding his life. The family moved into his elder daughter's one bedroom Berkeley apartment, and the next day Werner was on the phone, starting the process of rebuilding. Soon a new foundation was being laid and a new home rising on the ashes of the old. As soon as it was done Werner resumed taking photographs, buying maps, and rebuilding his precious collections.

Werner was a lover of classical music and prized his season tickets to the San Francisco Symphony. The four years he had taken piano lessons in Düsseldorf were interrupted by his departure from Germany, to be resumed, after a break lasting decades, when he retired. He had a strong sense of justice, and was outspoken and vigorous in his defense of victims of injustice. He enjoyed playing cards: For years he was a member of the group that met regularly at lunchtime at the Berkeley Faculty Club to play hearts and was a Life Master in the American Contract Bridge League.

Werner was passionate about the study of history. This passion found a productive outlet when, in the early 1990s, he was asked by the chair of ME at Berkeley to compile a history of the department. He was the ideal choice for such an assignment: an emeritus professor with a less-demanding schedule and with wide-ranging academic and professional acumen, a leader in the discipline, and one of the longest serving faculty members in the department ever, with personal experience of a significant fraction of the department's history. Goldsmith worked at this task with his usual indefatigable determination and thoroughness. With great effort he amassed an enormous amount of material and documentation, including numerous old photographs and prints, some going back almost to the founding of the department in 1870. The culmination of his work was so exceptional that the department published the history as a hardbound book, under its own imprint, under the title *Mechanical Engineering at Berkeley, The First 125 Years* (64). It will long remain a touchstone for such historical accounts.

Werner is survived by his wife, Penelope A. Goldsmith; son, Stephen (Olena) Goldsmith; daughters, Andrea (Arturo Salz) Goldsmith and Remy Margarethe Goldsmith; and grandchildren, Michelle S. Goldsmith, Dimitry Pobyyvovk, Daniel Salz, and Nicole Salz. His family, especially his wife Penny, brought him much love and happiness throughout his life, but especially in his later years, when he started to slow down a bit. He totally doted on his grandchildren and whatever academic, Germanic, reserve he had completely melted in their presence.

A Final Note

In 1991, through the good offices of another distinguished German Jewish native son and refugee from Düsseldorf, Professor Fritz Ursell of Manchester University, Goldsmith was invited to visit the city, where he was warmly welcomed by the Head of the Cultural Affairs Department of Düsseldorf. Goldsmith was able for the first time in decades to visit the gravestones of his beloved and respected grandfather and another relative, and to arrange to have the names of his parents, killed at Auschwitz and with no formal burial site, inscribed on one of the headstones. He and Penny were officially invited to visit Düsseldorf for a week in 1996. In a video for the *Holocaust Oral History Project* in 1992, Goldsmith had described the efforts of the City of Düsseldorf to deal with Nazi crimes, including "memorial visits" it organized and financed, such as his in 1991 and 1996, as a sort of restitution or reparation, for which he was grateful. Encounters and friendships arising from these visits meant a great deal to him and gave him hope for the future. His rational self told him that younger generations in Germany could not be held responsible for what happened six decades earlier. Nevertheless, he found himself on such occasions of remembrance time and again overcome by his emotions—anger mixed with grief—and cognizant that his own survival was the product of the selfless help of a few people, and, ultimately, as in the lives of so many of us, of the whims of fate.

Surviving the loss of parents and family and displacement from the land of his birth, Werner Goldsmith forged, with the support of a loving family and dear friends, a long, full life, enriched by countless scholarly and professional achievements, and crowned with the highest honors of his calling. To his numerous friends, colleagues, and associates—relationships made and nourished over a lifetime—he bequeaths many fond memories. He is missed dearly, and will be long and affectionately remembered.

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