JOSEPH MILLER
1937–2007

Elected in 1991

“For contributions to advanced high-power lasers and optical systems.”

BY PETER STAUDHAMMER

JOE MILLER was born on April 3, 1937, in San Francisco, California, to parents of modest means. His father was a carpenter, later to become a general construction contractor. Eventually, the family moved to Los Angeles, where Joe grew up together with his three siblings. The family prized education and provided both nurture and a balance of love and competition that gave flavor to Joe’s personality and success.

Joe attended Van Nuys High School, where he became interested in math, science, and engineering. In 1954 he entered the University of California at Los Angeles (UCLA) as a freshman engineering student. For the first two years, his record at UCLA was unremarkable. From his transcript one would conclude that Joe might just be average. Not so! Near the end of his second year, Joe applied for a job on a state-supported air pollution project, under the leadership of Professor Sam Yuster. Though there were many applicants and Joe’s academic record did not stand out, he came through as brilliant in his interviews. So he was asked to join the project team. Sam Yuster was a good principal investigator, but he was an absolute genius at knowing how to teach about life and how to motivate—and motivated Joe became. His academics improved to practically straight A’s for the rest of his stay at UCLA; he wrote papers, he made innovations, and he became a first-rate engineering leader.
(A parenthetical note here that I know Joe would want me to include. At the time, Professor Yuster had been at UCLA for just a few years, and he headed relatively modest projects. Yet within that short time span, he produced three graduate students who would later be elected to membership in the National Academy of Engineering. Sadly, Professor Yuster passed away from brain cancer in 1958, a few years before the NAE was chartered. Still three engineers, including Joe Miller, all know that they owe their success to the care that Professor Yuster gave them.)

With the passing of Professor Yuster and the lack of sustained state funding, the principal graduate students started to seek different specializations. Joe received his B.S. in engineering (at the time UCLA had no departments and awarded only general engineering degrees—a practice that now is being revived with the many multidisciplinary centers at a lot of U.S. campuses). Joe elected to pursue nuclear engineering, which at the time seemed very promising. He received his M.S. degree in engineering, with nuclear specialization.

Meanwhile, we discovered a match for Joe, a young lady, Judy Peckler, who worked as an administrative assistant in the dean’s office, which conveniently happened to be located on the same floor and hallway as the research lab where Joe worked. It seemed that introducing them to each other would be a good idea. To my surprise, the relationship flowered, and Judy and Joe were married in 1959.

Following a short enlistment in the U.S. Army, Joe returned to UCLA to get a Ph.D. in general engineering, with a nuclear option, which he was awarded in 1961. Armed with a Ph.D. in the nuclear field, Joe joined Atomics International and worked for eight years on liquid metal reactors, an advanced class of power reactors cooled with liquid alkali metals. Unfortunately, these reactors became a victim of federal budget pressures and environmental litigation. Joe still had his job at Atomics International, but he started to look for one with more immediate potential. As it happened, a job was waiting for him at TRW, Inc. He joined TRW in 1964.

The Apollo Mission to land a man on the Moon and safely
bring him back was started in 1961. The mission required a variable-thrust, deep-throttling, high-performing rocket engine to achieve a soft landing. The propellants chosen were nitrogen tetroxide (N2O4) and a 50/50 mixture of hydrazine (N2H4) and unsymmetrical dimethyl hydrazine (N2H2(CH3)2). This is a hypergolic propellant combination that ignites within less than a tenth of a millisecond following contact of the propellants and immediately releases gaseous reaction products at the interface, preventing further mixing.

An ingenious concept for achieving a variable-thrust engine was invented by G. W. Elverum at the National Aeronautics and Space Administration’s (NASA) Jet Propulsion Laboratory a few years earlier. It employed a variable-area injector and a pair of variable-area cavitating venturis, all mechanically slaved together and actuated by an electromechanical actuator. This control architecture separated the injection area control (which controlled combustion efficiency) from propellant flow control (which controlled flow rate and propellant residuals). TRW proposed to develop the Elverum engine.

Recognizing the difficulty of developing a 10:1, deep-throttling engine, NASA awarded a primary development contract in 1962 to Rocketdyne and a backup to TRW in 1963. By 1964 it became clear that the variable-area injector–venturi combination had a better chance of succeeding, and TRW was awarded the sole contract to complete the development.

Joe Miller joined TRW Propulsion in 1964 and seamlessly became part of the LMDE development team. He had an excellent knowledge of engineering, he had learned a lot about combustion and fluid mechanics at UCLA, and he was an excellent project and personnel manager. He started out as staff to the chief engineer and in a short time was promoted to assistant chief engineer and eventually took the place of the chief engineer for the Apollo lunar descent engine. Joe was clearly too late to have much influence on the research phase, but his skills as a planner, a manager, and a new, inquisitive voice to question project decisions were invaluable. He was clearly one of a handful of leaders of the development project.
The development phase of the program lasted for five years, until 1968, when all significant specification requirements had been achieved. It was a most difficult development. We had to address a long list of issues that had never been dealt with up to that time: feed system and combustion stability over a 10:1 flow regime, very high combustion efficiency, compatibility with an uncooled combustion chamber, and many more. Still in five years the development was finished, just in time for qualification.

Originally the LMDE was to have two full-duration, unmanned, Earth orbital flights. One was canceled due to schedule and budget pressures. The other, though intended to fire for 500+ seconds, only received a three-second test at less than 10 percent thrust. Nevertheless, based on ground test data, the engine was pronounced by NASA as fully flight worthy. (Although Joe Miller and the rest of the TRW team objected, it turned out to be a good decision, saving both time and money.)

The next flight was Apollo 11, the first vehicle to soft land on the Moon, with Neil Armstrong and Buzz Aldrin. The flight to and from the Moon was uneventful, with the LMDE completing its job of soft landing. The only excitement occurred at the very end of the landing. Neil Armstrong did not like the boulder field that turned out to be his primary landing site, so he took an additional 15 seconds to select a different terrain. He nearly ran out of propellant.

The successful soft landing echoed around the world. All of us were proud of our achievement, which we thought had been done for the United States. The entire Apollo team celebrated, though politicians soon stepped to the forefront. The two-hour television broadcast from the Moon landing was seen by an estimated 500 million people around the world, up to that time the largest single TV audience. Also, July 20, 1969, was arguably the last day the United States was truly proud of itself.

The next flight, Apollo 12, was hit by lightening on liftoff from Cape Canaveral. All data channels, the normal communication to the ground, both to the controllers and the technical people,
went blank for about 30 seconds, but the TV monitors showed propulsion and attitude control still holding. Communication was restored, and the mission ultimately turned out to be a success, including the flawless performance of the LMDE.

We all know about Apollo 13. During transit to the Moon, an oxygen tank in the service module exploded, leading to a loss of most of the oxygen and modifying the vehicle’s thermal characteristics, resulting in a precipitous drop in cabin temperature. Also, all propulsion was disabled, except for the LMDE, which was then used to put the vehicle into an Earth-return trajectory. It was a six-day ordeal for the three astronauts, who huddled in the lunar ascent vehicle, with temperatures hovering near freezing. Still, with the help of the descent engine, the Apollo command service module was put into a correct orbit to return to Earth. The orbit correction required a burn behind the Moon, which was successfully accomplished under computer control, with no communication to Earth.

The rest of the missions, Apollo 14, 15, 16, and 17, went smoothly, without a hitch. In all the LMDE soft landed 12 astronauts on the lunar surface and rescued the three-man crew of Apollo 13. An absolutely necessary part of the Apollo missions was the variable-thrust LMDE. It completed its part of the missions and more on Apollo 13 without a flaw. At the time Joe was TRW’s systems engineer for LMDE and was present in Houston in the technical resource room, where he gave advice on technical matters.

Joe also performed flawlessly as a leader within TRW. The total project staff peaked at 700 persons, with 250 engineers. This required a very broad approach to leadership. Joe established a structure to assign requirements and to get rapid feedback; he chaired planning meetings; he held frequent working meetings for the solution of specific technical issues; and he reported faithfully problems and accomplishments alike.

Following completion of the lunar program, Joe was promoted to laboratory director, with about 300 engineers and scientists with responsibility for propulsion, fluid mechanics, solid state physics, and applications of electro-physics and
chemical laser development. In effect, he was now in charge of fundamental research for the entire Space and Electronics Group (S&EG). Other groups within S&EG were focused on major projects, whereas Joe was to lead advanced research. Joe focused on two areas, most important to the future of S&EG: chemical lasers and solid state devices. Both were highly successful. Chemical lasers, based on fluorine, had been invented at the Aerospace Corporation a few years earlier in 1969. Joe’s principal contribution was to build a competent staff, structure, and plan and to manage and secure funding for the development of useful products. Due to the high cost of fuel and the expense of development, the application of chemical lasers was restricted to the military, where the possibility for speed-of-light delivery of very intense energy concentrations led to military interest in high-energy weapons system applications. A laser produces coherent light that can be concentrated and focused to a vastly higher intensity than an incoherent beam. For instance, a 10-micron diffraction-limited coherent beam can be focused to an intensity factor of 10^8 higher than an incoherent beam. However, to achieve that amplification, a series of very difficult physics and engineering issues needed to be resolved. These issues are every bit as difficult to resolve as the ones Joe found in the LMDE—and this time Joe directed and contributed to the research that included:

- Creating a gain medium with an inverted population, where beam amplification is sufficient to add energy to the beam but not so high as to allow spontaneous emission to grow
- Removing the de-excited product very quickly, so that it does not reabsorb laser energy from the beam
- Building an optical resonator that causes lasing energy to build up. Usually this is an unstable resonator with one concave and one convex reflector that, with proper choice of focal lengths, causes the beam to “walk out.”
- Building water-cooled mirrors and coatings to take the laser heat load
Developing chemical pumps to maintain low-exhaust pressures
Developing a model and balancing all flows, including energy flow, such that all requirements are balanced optimally and continually. Verify the model against test data.

Most of the above requirements needed to be resolved to support the analysis and design the laser. In most cases, basic physics data did not exist and had to be measured. Still, Joe’s team made the fundamental measurements, designed the whole laser system, and balanced and optimized.

At this point, it is worthwhile to include a short tutorial on chemical lasers, as authored by Joe, some 15 years ago:

“A chemical laser uses its own inherent reaction energy and needs no electrical augmentation. Reactants, including a fluorine-bearing oxidizer and fuel, are injected along with suitable diluents into a combustion chamber. The fluorine oxidizer is in excess of stoichiometric requirements. Combustion pressures range from 10 to 100 psi at temperatures in excess of 1500 K. This is sufficient to dissociate the excess molecular fluorine and to produce atomic fluorine. The atomic fluorine-bearing gas is then expanded through an array of supersonic nozzles to low pressure, low temperature, and very high velocity. Hydrogen, H2, or deuterium, D2, is injected between the fuel and the fluorine nozzles. Within the cavity, a second combustion stage occurs (this time between hydrogen or deuterium and fluorine) and in which a non-equilibrium, inverted population of hydrogen fluoride or deuterium fluoride is produced, from which in turn a laser beam can be derived.”

Under Joe’s leadership a number of chemical and other lasers have been developed at TRW, including pulsed HF and DF lasers, excimer lasers (exited dimer lasers that lase on KrF* or XeF* and, since they exist only in the excited state, they dissociate simultaneously with energy decay), free electron lasers, and solid state lasers. All hold promise for various applications.
Joe Miller was clearly a pioneer in high-power lasers and advanced optical systems. His contributions ranged from personal invention to innovative design and leadership of successful major engineering efforts. He was responsible for achieving a number of national milestones in combustion-driven chemical lasers: the first such laser in 1970, the first high-power operation (BDL) in 1973, a higher power laser (NACL) in 1975, beam propagation and dynamic target tests, the first high-power repetitively pulsed chemical laser in 1980, a megawatt-class laser (MIRACL) in 1980, operations at the National High Energy Laser Test Facility at White Sands, and the lightweight, high-beam-quality, high-power, cylindrical, megawatt-class, chemical laser (ALPHA) in 1989. Since 1994, he was a leading contributor to the development of non-linear optical phenomena, applied to high-power optical projection systems, space-based imaging and continued research in high-energy lasers.

As a manager and leader, he built nationally recognized organizations that have pioneered in both rocket propulsion and high-power lasers. Since 1981 he was responsible at TRW for applied physics research. Under his leadership several, classified national space payloads were and are continuing to be developed.

As Joe stated in 2007, “These areas tend to involve a wide range of physics, chemistry, and engineering disciplines. I also have a relatively broad technical knowledge involving nuclear reactors, combustion, optics and optical phenomena, test and laboratory facilities, and have background in the management of innovation and the development of complex technologies and products.” Joe indeed did have the fundamental knowledge. He held six patents and authored 25 technical publications (in addition to numerous classified papers). He generally shunned awards, preferring to win contracts in the classified field. It needs to be added that he was also an outstanding motivator and much of his success stemmed from that.

Dr. Miller retired from TRW in 1993. All his life he believed in the virtue of service to society—to give back to society of the
gifts he received from the prior generation. True to his nature, in 1997 he joined UCLA as an adjunct professor. He designed a course he titled “The Art of Engineering Endeavors,” which covered the essence of engineering design, along with moral, ethical, and environmental aspects of engineering design and management. He emphasized that engineering was a social endeavor and that great engineering accomplishments were the direct results of collaboration—thus was Joe’s dedication.

Joe was also a great family man and a philanthropic contributor to his community. From his youth on, he was an accomplished violinist, for the last few years playing with the Pacific Palisades Symphony Orchestra as the concert master. Love also prevailed, as he remained married to his first love, Judy, whom he had met at UCLA. Joe and Judy raised three children, Elizabeth, Mona, and David, who in turn are raising five grandchildren. Elizabeth is a successful architect, Mona is a doctor of veterinary medicine, and David is an attorney. All three live in the San Francisco Bay area, while Judy lives in Tarzana, California. In addition, Joe is survived by his mother, Ida Major, and three siblings.

In June 2007 Joe called and enlisted me to sponsor him on an ALS (Lou Gehrig’s disease) bike-a-thon. About two weeks later, on July 5, 2007, he took his bike on the road to get in shape for a 100-mile ride. Tragically, he was struck by an automobile and was killed instantly.

Joe certainly lived a good, full life—a life of visionary leadership and service to society. He made very significant contributions to national programs and laid the research foundations for commercial applications, and he deserves our admiration. Perhaps it was Professor Yuster who had a major impact on him, but Joe, in turn, had an equal impact on others around him. Many of us who knew him well will remember him as a gentle giant—as an engineer, a leader, a musician, and a dear friend.

May God be with you, Joe. You gave us a lot!