The varied careers of Kenneth L. Bowles

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It is not unusual for the careers of scientists and engineers to span a range of topics, driven by their insatiable curiosity about how things work, the fun they derive from problem solving, an aesthetic sense for "sweet solutions," and a joy in sharing their knowledge with others. Few careers have spanned as wide a breadth, or better reflected the technological explosion in the second half of the 20th century, than that of Kenneth L. Bowles, who died in California on August 15, 2018.

Bowles ("Ken" to everyone who knew him) began his career in experimental ionospheric physics and space science. In the course of pushing the bounds of early computers, he became passionate about moving computing off of large mainframes and onto small but powerful individual computers. In 1968 Ken became director of the computer center at University of California at San Diego (UCSD), and in 1974 began development of UCSD Pascal, the project for which he is best known. Ken went on to found a start-up that focused on developing the Ada computer language, and then in retirement became an accomplished wildflower photographer.

Observing the Top of the Atmosphere

Ken completed his doctorate at Cornell, in Ithaca, New York, under Henry G. Booker in 1955, using coherent backscatter radar to study the aurora borealis. He then joined the Central Radio Propagation Laboratory of the US National Bureau of Standards (NBS), in Boulder, Colorado. In the days before satellites, it was only possible to observe the bottom part of the ionosphere by using upward pointing radars called ionospheric sounders, which could trace out the density of free electrons up to the point of their highest concentration (the F-layer maximum at a height of around 400 kilometers).

What did the upper ionosphere look like? How far out did it go? Cornell's Bill Gordon (1) suggested that it might be possible to learn the answers by using a high-power, high-frequency radar and a very sensitive receiving system capable of observing the Rayleigh scattering from free electrons. Ken took up the challenge. Using a new 16-megawatt 41-megahertz pulse transmitter that NBS had acquired, Ken and his colleagues constructed a 120-meter × 120-meter field of dipole antennas in the Illinois countryside, and succeeded in showing that they could observe profiles of electron densities out to roughly 1,000 kilometers (2, 3).

Fig. 1. The large array of the Jicamarca Radar (*Left*). Ken Bowles (with wheelbarrow) and then graduate student M.G.M. (*Right*), and a close-up view of the field of crossed dipoles. Images courtesy of the Bowles family.

With the powerful new observing tool of "incoherent back scatter," Gordon went on to lead the development of the 305-meter-diameter Arecibo Ionospheric Observatory, while Ken became curious about whether it might be possible to observe ions orbiting in the earth's magnetic field using a radar on the geomagnetic equator. In cooperation with the Instituto Geofísico del Perú, Ken and his NBS colleagues led the development of the Jicamarca Radar Observatory in a dry wash valley just east of Lima (Fig. 1, *Left*). Building Jicamarca was a major engineering challenge that highlighted Ken's love of balancing theory with practical experimentalism. Importing equipment to Peru was slow and expensive, so Ken and his colleagues turned to local sources. For example, they found a local metal company that could extrude the aluminum tubing they needed for both the large diameter coax to carry power from the final transmitter tubes to the antenna and all of the dipole antenna elements (Fig. 1, *Right*).

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While it did not turn out to be possible to see modulation of the radar echoes from orbiting ions, Jicamarca supported a great deal of science on other important topics (4, 5). Now under Instituto leadership, the observatory continues to do science to this day. Throughout his years at Jicamarca, Ken revelled in the challenges of total immersion in solving technical and other problems and in the joy of producing "sweet" technical solutions and science. M.G.M. (coauthor of this retrospective) was one of Ken's doctoral students in radiophysics. He remembers fondly Ken's exclamations of "Ain't science grand!"—always accompanied by a quizzical grin—after finding a solution to a particularly challenging problem.

Looking Even Further Out

In 1965, Henry Booker moved from Cornell to UCSD to create a new department called Applied Electro-Physics. Ken was the first faculty member Henry hired. Having helped to resolve questions about the upper ionosphere, Ken's curiosity moved further out into space. What, he asked, does the turbulent structure of the newly discovered solar wind look like? Ken realized that when a radio star is observed at an appropriate frequency, variations in the density of the ionized solar wind cause scintillation, in much the way that stars twinkle when they are observed through the earth's turbulent atmosphere. If he could observe that scintillation pattern as it swept across the surface of the earth, Ken reasoned it would be possible to work backward to infer the structure of the solar wind (6).

A good idea, but how to do that quickly and at an affordable cost? The answer Ken chose was to build three phased array antennas spaced roughly 90 kilometers apart across the Southern California landscape, using inexpensive commercially available Yagi antennas operating at 74 megahertz, and simple custom-made low-cost fixtures to interconnect the hundreds of meters of coax cable required to direct the beams. New doctoral student Tim Hankins (now with the National Radio Astronomy Observatory in Charlottesville, Virginia) was recruited, along with a team of undergraduates led by Norman Down, to install the arrays.

Ken was a great teacher. He had a gift for focusing on the big picture and key ideas. As UCSD's Bill Coles observed, "I loved to go to Ken's lectures, not because I learned so much new stuff, but because I came out with the stuff I knew organized more clearly." Ken was an even more effective teacher in the laboratory and in the field, where he taught by doing. Doctoral students M.G.M. and Hankins both learned firsthand about the 15-hour days and joyful intensity with which Ken worked (fueled only by bits of lunchtime fruit) when he was focused on a new problem. In M.G.M.'s case this was a Venus radar experiment at Jicamarca, and in Hankins' case, trying to use one of the three almost-completed arrays from the solar wind experiment to perform inverse filtering of the signals from pulsars that had been dispersed by the interstellar medium.

What attributes made Ken's first career so successful? First, he was a gifted and inventive experimentalist who teamed successfully with outstanding theorists. His daughter Ann (A.E.B., coauthor of this piece) has described him as the *ying* to Henry Booker's theoretical *yang.* At Jicamarca he continued similar close collaborations with Donald Farley and Robert Cohen. He had a gift for thinking about the issues he addressed both as time series and in the frequency domain. Ken was able to rapidly identify and adopt new innovations, like the Cooley–Tukey algorithm to perform Fourier transforms, implementing it not just in computational applications but through hardware realizations. While both Jicamarca and the UCSD solar wind observatory were built to explore a specific question, Ken designed enough power and flexibility into both systems so that they were more than built-for-purpose experiments, and could be used to explore a range of additional scientific questions that had not been anticipated when the systems were built. Finally, in the case of the solar wind observatory, Ken provided the system with sufficient new computational power to support the analysis of what is now called "big data."

Bringing Computing Down to Earth

To do real-time signal processing of the Jicamarca radar returns, Ken had used early computers with acoustic delay line memories. To do the more challenging processing of signals from the solar wind studies, he acquired an SDS Sigma 7 small mainframe. At the time, UCSD was trying to channel all computationally intensive activities through its computer center. Ken's efforts to acquire the Sigma 7 had raised his visibility on campus and he was asked to take over the computer center. He rather abruptly left radio science to take on that leadership role, leaving the solar wind experiment in the capable hands of Bill Coles, Vick Rumsey, and their colleagues, who used it to perform a wide range of important science (7, 8). As Ken became more deeply involved with computing, he encouraged M.G.M. to work on bringing computing to disadvantaged communities in San Diego (9).

From early on, Ken understood that computers were more than big calculators: that they were a powerful class of new technology capable of performing a wide range of functions. He concluded that if their full potential was to be realized, it would be essential to free computing, especially instructional computing, from dependence on large mainframes. Ken left the computer center in 1974, and with the same drive, creativity, and infectious *joie de vivre* that he'd applied to radio science, he set out to do just that. The result was a project that became known as UCSD Pascal. Initially with doctoral student M.O. (coauthor of this piece) and a handful of undergraduates, including Richard Kaufmann, Roger Sumner, and John Van Zandt, the project built a programming environment that employed a "virtual p-machine" that could run on almost any small computer, and was suitable both for novice programmers and for experienced system developers. Optimizing and leveraging the compactness of the "p-code" for that virtual machine, and using clever design, the team created a complete development environment that included a file manager, text editors, and a debugger, plus machine language assemblers for a variety of small-system CPUs. It also included early realizations of several key features, such as the pull-down menus first created at Xerox PARC, that are ubiquitous in computer systems today. The system became widely popular, as the team distributed copies to many interested academic users across hundreds of campuses worldwide (10).

One contributor to that academic popularity was a computer-aided instruction framework and automated materials for an introductory Pascal programming course (11). Indeed, Ken's passion for delivering effective personalized computer science instruction at scale was the primary motivation for creating the UCSD Pascal initiative. He went from engineering large-scale scientific instruments to engineering a large-scale educational infrastructure that, for example, allowed both UCSD and University of California, Irvine (UC Irvine) to offer self-paced introductory programming courses to meet the booming student enrollment demands of the early 1980s.

Ken figured out that beginning programmers needed to see what their programs were doing, as opposed to what they intended them to do. To do that, the team added the Turtle Graphics subsystem that drove a graphical cursor or "turtle," modeled on the Logo programming environment conceived by Massachusetts Institute of Technology's Seymour Papert, which originally controlled robotic turtles (12).

Another critical ingredient of Ken's approach to educational scaling was his adoption of Fred Keller's Personalized System of Instruction, augmented with the experience of Ken's longtime friend and colleague, Alfred Bork at UC Irvine (13–15). This approach allowed students to proceed at their own pace, mastering the course materials module by module, with automated testing of both software engineering concepts and program development assignments, plus guidance along the way from undergraduate proctors.

In his 1984 A. M. Turing address, Pascal's creator Niklaus Wirth credited the UCSD project's breakthroughs as a critical factor in its widespread adoption for programming instruction (16). The Advanced Placement Computer Science course and examination were based on the Pascal language from 1984 to 1998. In 1979, as the number of copies of UCSD Pascal being distributed continued to grow, the university developed legal and tax concerns. The UCSD Pascal initiative was moved out of the university to a private company. Although Ken was no longer involved, the project continued to influence the development of personal computing well into the 1980s (17, 18).

Apple Pascal, an implementation of UCSD Pascal for the Apple II, was widely used for commercial applications at that time and several companies developed computer products based on hardware implementations of the UCSD p-machine, such as Western Digital's Pascal Microengine (Fig. 2, *Left*). IBM licensed UCSD Pascal as one of three operating systems for its new IBM Personal Computer. While of those three only Microsoft's MS-DOS is alive today, the influence of the UCSD project lives on in the careers of its alumni, who were inspired by Ken's curiosity, entrepreneurial drive, dedication to learning by doing, and an unusually strong commitment to undergraduate involvement in his projects.

Some of the attributes that contributed to the success of Ken's second career were the same as those that propelled the success of his first: a "just roll up your sleeves and do it" attitude and a focus on the big picture. Unlike many natural scientists in the 1970s, Ken was quick to grasp the enormous breadth and power of the computer science revolution. M.O. vividly recalls the contrast between Ken's vision and a view expressed by one senior UCSD faculty member who suggested that "a PhD in computer science" was no more appropriate than "a PhD in slide rules." In the late 1970s, M.G.M. recalls hearing similar views from an eminent engineering scientist.

Fig. 2. Two of Ken's passions were moving computing from large mainframes to small computers (such as the Pascal Microengine, *Left*) and photographing birds and wildflowers. He loved *Calochortus* lilies, such as the Tiburon mariposa lily (*Calochortus tiburonensis, Right*). Images courtesy of the Bowles family.

Ken was also a consummate collaborator. Within the project, Ken teamed effectively with dozens of bright young minds, mostly undergraduates, to address the inevitable engineering and managerial challenges of growing and propagating the UCSD Pascal system. Although his scientific training was in electrical engineering/applied physics, Ken's engineering instincts and guidance in these collaborations were spot-on. Outside the project, with computing companies and with peer academic groups within the University of California and elsewhere in the nation and the world, Ken was a dynamo, churning out project ideas. M.O. remembers frequent Sunday afternoon discussions of Ken's latest draft prospectus for a potential extension of the project in some complementary area.

Finally, Ken was an outstanding synthesizer. His UCSD project incorporated ideas from a wide range of domains and their respective experts and leaders, including such disparate characters as Alfred Bork, Steve Jobs, Seymour Papert, and Niklaus Wirth. As long-time colleague Stephen Franklin at UC Irvine observed, Ken had a genius for recognizing, seizing, and creating "golden moments" with hardware, software, education, and people.

With the departure of the UCSD Pascal project, Ken switched his programming language focus to Ada, a successor language that extended and strengthened Pascal's support for careful software engineering (19). After actively participating in the (D) ARPA-sponsored competition to develop and evaluate alternative approaches to the new language, Ken took early retirement from UCSD and started a software company, TeleSoftware, focused on Ada. Ada's use today is primarily in defense applications, but TeleSoftware's successor and descendent companies continued as leaders in the Ada market.

From "Sweet Solutions" to Aesthetic Images

A search for "sweet technical solutions" was a familiar refrain throughout Ken's careers, but retirement brought his pursuit of the aesthetic into a sharper focus. Ken had a lifelong interest in photography. To his wife's dismay, his early photographic subjects tended to be antennas, even while traveling in exotic places like the Azores. After retirement, however, Ken began photographing wildflowers in exquisite detail, with particular focus on species endemic to California. He contributed significantly to the *San Diego County Plant Atlas* as well as part of an award-winning exhibit at the San Diego Natural History Museum, *Earth, Wind & WILDFIRE*, which Ken helped to develop. A random selection of his photographs appears each time one visits the page sdplantatlas.org/.

Four factors strike us as especially important in shaping the success of Ken Bowles' several careers. First, Ken cared deeply about the welfare of the people he worked with, not just his professional colleagues and students, but all people. For example, a technician working on the transmitters at Jicamarca survived an electrocution accident because Ken had insisted that all of the staff go through CPR training. Second, Ken had an infectious curiosity and taste for problem solving that his students and coworkers quickly absorbed. He made problem solving, and the accompanying hard work, fun! Third, Ken had the gift to keep his eye on the big picture while he was diving in and working out the nitty-gritty details of a problem. His students and coworkers were consistently amazed by the overnight messages and emails that cast a problem they were addressing in a new light. Finally, Ken did not have a narrow-minded commitment to a single discipline. Like M.G.M.'s former Carnegie Mellon colleague Herb Simon (who had moved on to psychology and computer science, and no longer even had an appointment in economics when he won his Nobel Prize in that field), Ken followed the problems he found most compelling, irrespective of domain. The world would be more interesting, and perhaps even a better place, if more of us did that.

In 2003 the Jicamarca Radar Observatory in Peru staged an international conference to celebrate its 40th anniversary. Ken attended. Afterward he wrote, "I was delighted and amazed (but more than a little wistful) that routine observations are being done there now, aided by today's desktop scale computers, that are squeezing vastly more useful details about atmospheric science than we were ever able to do with the computers of the 1960s. But the industrial size electronics, and the huge antenna, are still operating essentially as we built them."

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