

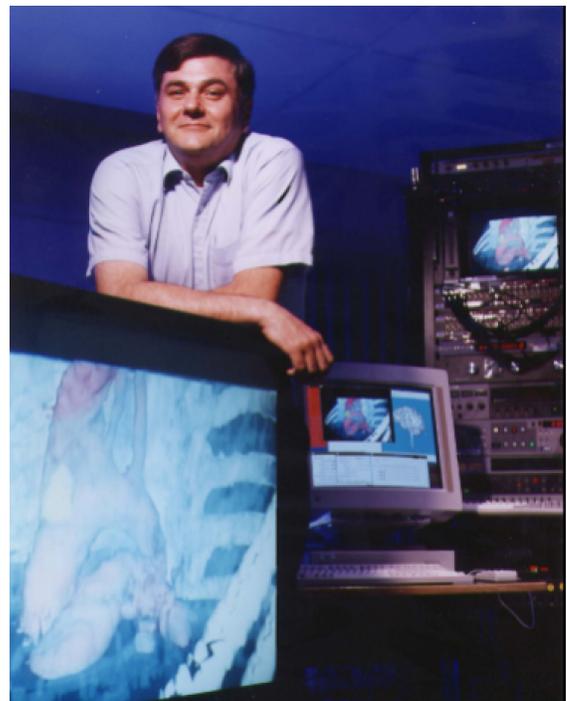
Remembering Bill Lorensen: The Man, the Myth, and Marching Cubes

■ **BILL LORENSEN DIED** on December 12, 2019. Given the outpouring of grief from his coworkers, friends, and family, it is clear that he will be greatly missed. Anyone who had the happy opportunity to work with Bill can tell you that he had an understated influence which continues to provide lessons to all of us. In this tribute, we will try to capture some of these lessons by relating personal stories that exemplify what we learned from Bill over the many years we knew him.

When we think of great influencers in fields like computer science, graphics, and visualization, we tend to focus on technical excellence. Bill had this in spades: he was involved in the creation of core software systems, algorithms, and workflows. Along with Harvey Cline, he created the most widely cited visualization algorithm—Marching Cubes—which is used in a huge number of applications ranging from gaming to weather visualization to medical imaging. Bill remained—until just a few months before his death—a key contributor to the VTK visualization system. He was a senior contributor to both the ITK Insight Toolkit segmentation and registration toolkit, and the 3-D Slicer medical computing application. He had his hand in the creation of the software quality process tools based on agile and test-driven development (which have since evolved into the CMake,

CTest, CDash, and CPack software process tools). Bill was one of five authors who wrote the *Object-Oriented Modeling and Design* book, an explosive bestseller at the advent of object oriented software design and implementation techniques.

Many more of Bill's accomplishments were achieved less visibly behind the hallowed halls of GE Research where Bill spent the bulk of his career. For example, the LYMB system was



Bill posing for the GE Calendar.

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written using Smalltalk-style object oriented principles, written in the C-programming language with a powerful message-passing interface and a precursor to VTK. He also made many software contributions to systems as diverse as *GE'S Advantage Workstation for Diagnostic Imaging* and a golf putting visualization application which was shown on-air (NBC) to predict putting trajectories, which Bill joked was his best-known piece of work. Here is a very brief summary of his legacy.

- Marching Cubes algorithm: As of 16 January, 2020: ACM Digital Library reports 6881 citations; Google scholar reports over 14 000; Researchgate.net reports over 7500. See the associated *History of Marching Cubes* in this edition of CG&A.
- The 1992 paper on triangle decimation by Schroeder, Lorensen, and Zarge also ranks among the top ten cited SIGGRAPH papers of all time.
- One of five authors on the seminal book *Object-Oriented Modeling and Design*.
- 31 U.S. Patents.
- Recognized as GE Coolidge Fellow in 1991, the Company's highest scientific honor.
- Bill received the IEEE VGTC Career Award in 2004. His interests included the creation of high-quality software engineering processes for code development and maintenance in image processing, visualization, and computer graphics applications.
- He was a principal architect of the Visualization Toolkit (VTK), the Insight Toolkit (ITK), and 3-D Slicer, all open source projects, with vital communities, that continue to change the world.
- SIGGRAPH and VIS Pioneer: Bill was a fixture at ACM SIGGRAPH and at IEEE VIS for decades, eventually serving as the awards chairman for the VIS conferences. The continuing impact of his ideas has been profound and his personal commitment helped to shape the dialog for graphics and visualization research for over 40 years.

While these accomplishments by themselves are representative of a highly successful career, Bill's genius extended past the technical arena. Indeed, he had an extraordinary combination of technical and emotional intelligence, which is rare



Bill and Terri Lorensen, 1996.

in any person. On a personal level, Bill was keenly interested in the careers of each person he met, whether it was a student, postdoc, professor, program officer, or institutional head. There are many stories of Bill engaging directly with students whom he inspired and encouraged to do great things. He also rubbed shoulders with ambitious and high-achieving individuals and had a way of keeping them humble using a combination of humor, gentle barbs, and postmeeting socialization with plenty of beer, wine, and witty repartee, all backed by the force of his technical reputation. In large group settings Bill really shone: he had the ability to navigate difficult technical challenges and associated countervailing requirements while at the same time listening to and respecting the views of each member of the group. At one moment, Bill would be humbly open to new ideas,



Bill in action: wine and community.

then he might use his sharp wit to make a key point and steer the process, and finally he would express enthusiasm for proposed solutions and gratitude to those that contributed to them. As coworkers, we felt ourselves to be in the presence of a man with an open heart and powerful intellect who used both—and leveraged the talents of others—to create great things in the world.

To illustrate these and many other of Bill's qualities, here are some personal remembrances of four of us who had the distinct honor of working with Bill for one or more decades.

CHRIS JOHNSON

In 1992, I published both my first IEEE VIS paper¹ on work visualizing heart bioelectric field simulations and a paper at the 1992 Visualization in Biomedical Computing Workshop.² Given the biomedical application, Bill was keen to know more about my work. From that moment, Bill became a mentor and friend. From its founding, he took a great interest in SCI (Scientific Computing and Imaging) and interacted with SCI Institute faculty, staff, and students over the past three decades, serving as a long-time member and then Chair of the External Advisory Board of our NIH Center for Integrative Biomedical Computing (www.sci.utah.edu/cibc-about/eab.html). With his insights, motivation, and experience, he helped guide us through multiple successful Center renewals.

I always enjoyed Bill's presentations. He was a great speaker, and had the ability to help us all look at our field in new ways. One of Bill's slides that I still have is from a talk he gave in 2003, in

which he tracked the cost of creating a surface triangle on the computer hardware of the day.

In 1984 it cost \$100/triangle on a \$200 000 Vax computer, yielding 2000 triangles/second. In 2003, it cost \$.002/triangle on a \$1000 Intel P2.4 GHz computer producing 500 000 triangles/second.

Bill's point was that the traditional measure of graphics algorithm speed of triangles/second had become obsolete. It was a typical example of his ability to provide new ways of thinking about algorithms.

In 2003, Bill suggested that SCI become part of an ambitious DARPA project called the Virtual Soldier, led by Brian Athey from the University of Michigan. They assembled a great team of researchers from Stanford University, UCSD, University of Washington, University of Michigan, University of Utah, and Oak Ridge National Laboratory, among others. After we received the award from DARPA, Brian hosted a party at his home after an all-day meeting. At the meeting there was a significant discussion about the need for ontologies for simulation models, which was a new idea for most people. Bill thought there were too much talk about ontologies and not enough discussion about the simulation models themselves. At the party, Bill started the *ontology drinking game*—every time someone said “ontology” all the participants had to take a drink. Needless to say, much beer was consumed at that party.

In 2005, I nominated Bill to become a Fellow of the American Institute of Medical and Biological Engineers. As part of the nomination, I needed a copy of Bill's CV.³ While I knew about many of his papers and books, I did not know about most of his 30 patents, including patents for “Method and Apparatus for Vehicle Management,” “Method and Apparatus for Generating Cable Occupancy Volumes,” and a “User Interface for a Golf Green and a Golf Putt Modeling System.” For an amusing story about the golf system, see the link on marchingcubes.org.⁴

In 2006, Bill organized a panel at VIS on Visualization Careers. The panelists included Bill Lorenson (Industrial Research), Will Schroeder (Entrepreneur), Terry Yoo (Government Scientist), myself (Academic Center), and Tamara Munzner (Academic Research). Prior to the panel, Bill sent us an email saying that “We each have 10

min to excite, enthral, entertain, and motivate the audience.”

Bill’s position statement, which is interesting to read in its entirety,⁵ focused on relationships, which was typical. It ended like this:

The most rewarding part of my career has been the personal relationships that I have made within the Company and in the external community. These relationships, more than anything else, made me a successful researcher and a valuable employee.

He said that when he was asked in a GE interview about his best advice for an early-career researcher at the company, he replied:

Establish yourself technically both within and outside the Company. Find others who share your interests and work with them regardless of where they sit in the organization. Become active in professional organizations like the IEEE or ASME. Attend society meetings, work on committees, review papers. The external exposure is great for you and the Company.

After 29 years at GE, Bill retired in 2007. At the NIH National Alliance for Medical Image Computing (NA-MIC) Center External Advisory Board (EAB) Meeting, NA-MIC PI Ron Kikinis hosted a retirement party for Bill at Murphy’s Pub in Salt Lake City. It was such a success that at the following year’s NA-MIC EAB Meeting we had the first Anniversary of Bill’s Retirement Party at Murphy’s Pub. The tradition continued each year until the end of the NA-MIC grant in 2015; Bill was able to attend all but one, the year he injured his foot while snow blowing and could not travel. That year, his anniversary retirement party just was not the same.

TINA KAPUR

I remember well the first time I interacted with Bill. I was new to General Electric Healthcare, and he was a distinguished scientist there. In a room full of men with C*O titles, I was not even sure if Bill remembered that we had met once before when I was a student, yet he greeted and introduced me to the others as the new genius on the team that they all must surely know about already. That was just the first of my many encounters with Bill’s strategic generosity and sponsorship, and I am glad that I was able to

keep working with him through one excuse or another for the last 15 years. During this time, he often dealt with difficult topics by invoking his hero, the baseball great, Yogi Berra. I learned from the Bear via Bill such important lessons as, “If you come to a fork in the road, take it.” When I heard of Bill’s passing I could hear him say “Always go to other people’s funerals, otherwise they will not come to yours.”

WILL SCHROEDER

The first time I met Bill it was through his code. I was a recent hire at GE Power Systems in the Gas Turbine division. After falling in love with numerical computing in my junior and senior years at the University of Maryland, I was working at GE as a simulation analyst, helping engineers design, diagnose, and improve turbine blade designs. Early on it became clear to me that visualization was the critical interface between computer and human and so was an exciting field in which to work. However the tools at that time were awful. I was able to get my hands on a doctored version of MOVIE.BYU (modified by Bill) and a series of raster and vector plotting editing, painting, and display tools which ran on emerging hardware like the RasterTek. Seeing that code written by Bill, implemented in C, was a revelation: it was clear that there was a genius behind the work, and my enthusiasm for computing increased that much more.

Soon after this I met Bill, and we began a relationship that lasted more than 35 years. This journey took me to work side-by-side with Bill, first at GE Research, and then within several open source communities like VTK and ITK. What was astounding about Bill’s working style was that he would always first welcome newcomers like me, encourage them, and through gentle wit and suggestion point us in the right direction. Then, when the work began to gel, he would start using it, or dogfooding it as we used to say, to prove it out and point the way toward future improvements and additions. There was no sitting still with Bill: he continuously moved forward to make the world a better place. The best part of it is that he took many of us along for the ride. This sense of purpose, fun, and adventure was a rare gift and I am convinced that his approach led to the formation of many successful



The Computer Graphics and Systems Program at GE Research, circa 1990. Will Schroeder and Ken Martin (coauthors of the VTK textbook) are seated in the front; Dr. Peter Meenan was the team leader on far right.

open source and other technical communities. Since his influence on their creation was subtle, Bill will not receive much credit for it, but if you look closely you can see his fingerprints all over them.

Lest you think that Bill was a career-driven overachiever, he had a whimsical side that was manifested through his joy of computing. For example, he and some GE coworkers spent many months designing and implementing an AI-based horse-racing system (this was back in the day before the current AI frenzy). This system required manual entry from published racing forms (before the information was downloadable), and used a backward-chaining inference engine to pick winners. Needless to say, Bill did not strike it rich, although he did generate a wealth of fun doing it.

TERRY YOO

In 1995, Bill and I attended a planning panel along with a distinguished team of radiologists, anatomists, engineers, and other experts to plot the future course for the Visible Human Project,

the comprehensive study in human anatomy sponsored by the NIH's National Library of Medicine. While most of the panel advocated for an intensive study of the data being generated by the project, Bill was a member of a minority advocating for the development of software tools to segment and classify biomedical images. He foresaw the torrent of data that was about to come, and he realized that an investment in software to analyze and manage that data would be a wise one. By 1998, NLM had adopted that position and funded a project to develop a library of medical image analysis algorithms. Bill was an essential player in that project, helping guide the Insight Toolkit ITK to its maturity. By 2004, the rest of NIH had followed suit, creating the National Centers for Biomedical Computing. Again, Bill was a critical member of the team that helped to deliver the National Alliance for Medical Image Computing NA-MIC, a project led by Ron Kikinis at Harvard's Brigham and Women's Hospital Surgical Planning Laboratory.

Ever generous with his time, Bill Lorensen was one of the foremost advocates for open source

software development and was both recognized and respected internationally for his expertise and judgement. He was one of the principal developers of VTK, an open-source software system and API for advancing computer graphics in science and medicine. He and his colleagues broke new ground in this effort at a time when Stellar/Stardent/AVS, Khoros, and IBM Data Explorer were strongly proprietary software tools. His textbook, written along with coauthors Will Schroeder and Ken Martin, remains one of the most widely used graphics texts in graduate computer science education. VTK is widely used as an educational and research tool for scientific visualization among universities, national laboratories, and private companies, and has thousands of users worldwide. Few computer graphics professionals can claim such a wide and unselfish impact.

The future was important to Bill. People all over the world sought his advice. For years, he was a member of the Advisory Board for the Scientific Computing and Imaging Institute at the University of Utah. When the Swiss National Science Foundation created Co-Me (Computer Aided and Image Guided Medical Interventions) a National Centre of Competence in Research under Gabor Szekely at ETH-Zurich, Bill was there as an advisor, helping to guide research and engineering programs. Even after retirement, he continued to stay involved as a member of the Advisory Board for the National Alliance for Medical Image Computing. As part of a national panel on Visualization Research Challenges, Bill announced grave concerns over the lack of domain experts engaging with academic researchers in scientific communication and visualization.

The image in my mind is of Bill gleefully writing and celebrating his working code. He would put in hours out of love to see things work. I remember him programming GE's Advantage Windows workstation, adding Parzen windows, a nonparametric classifier in statistical pattern recognition while Guido Gerig read details of the technique from the textbook by Duda and Hart. Even long after retirement, he could be found lurking on the Slicer dashboard under the nom-de-plume: Unpaid intern in Bill's Basement at noware dot com.

Bill could brighten a room with his laughter. He could entertain a group with his stories, no



With beer in hand, Bill cutting it up with former GE Research boss Vince Scavullo at Saratoga Race Course while testing the heuristics of their horse racing system.

matter how many times we would hear them. Often, his ability to engage people was infectious; he could bring out the best in people. Engineers and computer scientists can be very introverted, but I never encountered one who did not respond to Bill's gregariousness by growing, unfolding, and becoming comfortable around him. In all the laboratories where he worked, the teams he joined, and the panels and meetings where he appeared, he left countless people in his wake whom he taught how to be better human beings. He was comfortable with technology, with people, and with himself, a blessing of gifts that made him a wonder and joy to get to know.

Bill taught me an enormous amount about life, and about how to rise through circles of technology and business, while never sacrificing curiosity and vision. He taught me not only by advising and mentoring me, but also through example, by demonstrating through his actions how a person of integrity and character can make the world a better place. He challenged me and he changed me, and I am a much better person for having known him.

MEMORY LANE

As we wrote this tribute, we were faced with an overwhelming selection of stories and anecdotes. Space limitations prevent us from including even a small percentage of them. Since we could not include as much material as we would have liked, we have gathered additional content at the wiki marchingcubes.org.⁴ This wiki was



Bill Lorensen and Dick Bair (both at Watervliet Arsenal) looking at a Lundy Electronics vector refresh graphics display system. The graphics shows the results of a finite element nodal analysis.

created and authored by Bill for over a decade; now we have added some stories and content from many others who wish to pay tribute to this great individual. Here are some of our favorites:

- How I lost the Nobel Prize
- The Goof Ball Story
- The Bubbling Rock
- Career Advice

Bill was a great man and a great friend. We miss him, and we know that the graphics and visualization community has suffered a great loss. Fortunately, he left a legacy that will continue to guide and shape us all for many years to come. To honor him, we suggest that the next time you are in the company of your technical peers, lift a glass of beer, and together toast him in memory.

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