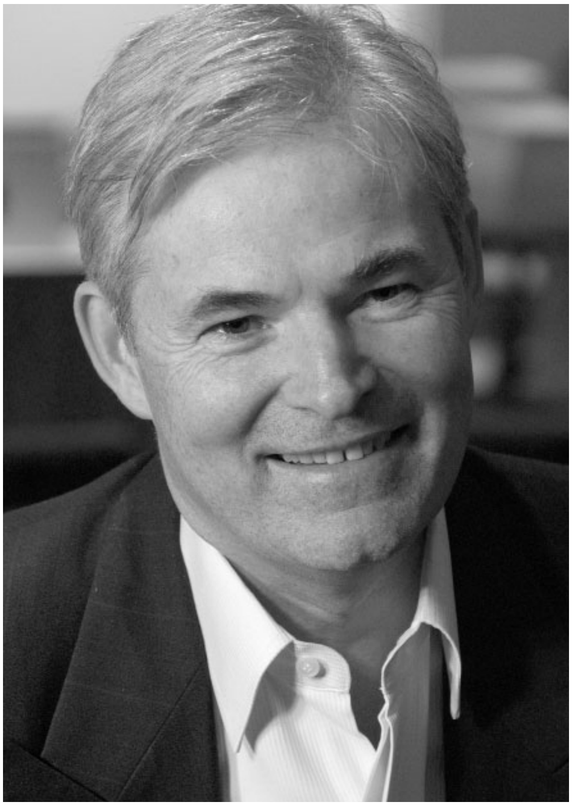
Engineering Applied to Societal Problems: A New Outlook

An Interview with A. Richard Newton, Dean of the College of Engineering, University of California, Berkeley



Richard Newton inspired Berkeley's engineering faculty to come together and envision a way to maximize their collective impact on society. Ken Wagner, *IEEE Design & Test*'s interviews editor, spoke with Newton about the resulting Center for Information Technology Research in the Interest of Society. Newton's view is that the 21st century will be the "century of the engineer."

D&T: Tell us what interested you in engineering and how you began your original work in Australia.

Newton: It was probably predestined. I was 20 when I learned that, just after I was born, my grandmother had consulted with an astrologer, who had written down predictions for my future. My grandmother gave those to me when I was 21. She was approaching 96 and losing her memory, and she said, "Before I forget, I want to give you this. I had this done just after you were born." Among other things, the predictions said "when Arthur [Newton's first name] grows up, he will make studies along the most scientific lines …" and "… he will be interested in trains, planes, and electrical gadgets." So I think my fate was cast in stone from the very beginning.

During my youth, my father owned a record store where he also repaired radios and similar items. The shop, called Newton's Home Electric, was a mom-and-pop business, and his brother also worked there. Clearly, I had some exposure there to my dad's interests. He probably would have been an engineer himself, except that World War II interrupted his studies. When my father returned from the war, his life—like that of many returning soldiers—was quite disrupted and he wasn't able to complete his studies. As a result, he ended up working with his brother in this family record business.

Having been exposed to the shop environment, during my teenage years I naturally fiddled with electrical gadgets, and I enjoyed that. Obviously, I was interested in science, and my father in particular encouraged me to focus on the sciences through high school. When it came time to go to university, I was planning to study physics at Melbourne University, but I learned just before being admitted that if I studied engineering instead, I could always transfer later to physics or to the sciences. If, however, I studied physics, I would be missing a prerequisite that would prevent me from transferring back to engineering.

To keep my options open, I decided that I might as well start with engineering, not knowing exactly what I

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was getting into. In considering the various engineering disciplines, I picked the one that was in some sense the least hands-on, which was electrical. So I ended up in electronic engineering not by choice, but actually by a process of elimination.

D&T: After you earned your BEng and MEngSci degrees in Melbourne, you were attracted to the University of California at Berkeley by Don Pederson. [Prof. Pederson is an EDA pioneer well known for leading the development of the Spice circuit simulator, still widely used today.] It must have been an exciting time. To digress for a moment: Did you ever consider going back to Australia?

Newton: Yes. After I graduated from UC Berkeley with my PhD, I accepted a position on the faculty at Berkeley. But not long after I became an assistant professor at Berkeley, a senior lecturer position opened up at the University of Melbourne. A friend there contacted me and told me about it, and I actually applied, thinking that I would like to go back at some point. I put Don Pederson's name down as a reference without asking him ahead of time, not really thinking about the consequences. But because he was intent on my staying at Berkeley, he wrote me a letter of reference for the position in Melbourne, then came to me and said, "Rich, I understand that you've applied for this position at Melbourne. I can understand why you might want to do that, but I think you're making a big mistake." Then he said, "And just to make the point clearer, here's the letter of reference that I wrote for you."

He gave me a copy of the letter of reference and when I read it, boy, I can tell you, I didn't recognize the person he was describing! He wrote what we would call a "walks on water" letter. I was overwhelmed by it. It was a good tactic, too, because what he said—and what he considered my potential to be—was enough to dissuade me from taking the Melbourne position.

D&T: So you became involved in the nascent EDA industry while at Berkeley with Spice and other tools, and with the creation of several generations of EDA companies. It's clear that you've had a strong interest in EDA and its impact on semiconductor development. What struck me, looking through your CV and a lot of the testimonials, however, was how broad your interests are: They're not just semiconductor or just EDA. Maybe you can tell us a little about this interest, and what you're after, generally, in terms of leaving a legacy.

Newton: I never really think in terms of leaving a legacy. I'm one of those people who just tend to follow their nose, and not really have a grand plan. I don't think strategically about my own life—probably not as much as I should have, in retrospect. What tends to happen is that I become involved in a dialogue around a topic, and usually problems or challenges within that topic are presented. Then I become intrigued by the problems or challenges and begin thinking about how to approach those problems—broadly as well as deeply.

It could be just about anything, frankly, that attracts my attention. Most of my challenge is pruning away the problems and issues that wouldn't necessarily be the best use of my time at a given point. What I become involved with depends on the community that I'm immersed in. Because I've been immersed in the EDA community for so long, starting with my work with Don Pederson, my involvements have focused broadly around EDA, chip design and related issues.

Typically, what motivates me is a belief—sometimes right, sometimes wrong—that when I look at the way someone (or the community) is approaching a problem, I think I can do it better. If I believe I have an insight that either others have not yet come to see but eventually will, in my opinion, or if I see some better way of solving a problem than the approach others have developed in the past, then I typically sign up one or more students and work with them to try to address those issues. A lot of what has motivated me over the years has been the challenges of methodology, the challenges of, "Are we solving the right problem?" as much as, "How do we solve the problem?"

D&T: With respect to the Center for Information Technology Research in the Interest of Society (CITRIS), do you see this as the application of many of the EDA, semiconductor, and systems design skills to social problems?

Newton: Well, not really! Again, it comes from being immersed in a community. In this particular case, when I became department chair at Berkeley five years ago, it was during the middle of the dot-com boom. I was concerned that our electrical engineering and computer science faculty might become increasingly restless about why they were at Berkeley rather than down the road in Silicon Valley making their fortunes, particularly given all the press that accompanied those opportunities. Clearly, our faculty and students had the potential to do that too, and some did make a move. So I initiated an activity for my faculty on Friday afternoons called the Sherry Hour, where whoever wanted to come would get together as a group and talk about nondepartmental business—talk about inspiring thoughts, and about why we were at Berkeley and not in Silicon Valley.

Typically, about 14 to 20 of the approximately 85 faculty members in EECS joined me during those afternoons, but it was a different combination almost every week. We began talking about, for instance, why we were at Berkeley. Out of that discussion came the notion that, as faculty, we're at Berkeley because we think that's the right place for us to be to maximize our impact on the world.

For other people, the right place to be is in business; for still others, the right place is in government service. But for us, it's at Berkeley. The question then arises, How do you maximize your impact? Some of our discussions over the weeks addressed that issue. The feeling was that over the past 25 or 30 years, electrical engineering and computer science had been focused on essentially proving to the world (especially the physicists!) that it was a legitimate discipline—a "science." To that end, most of our research and development [R&D] in EECS had been inwardly focused; using the computer science and engineering to build better computers and networks, for example. EDA is an example of that, where we use the most sophisticated computers we can develop to design even more sophisticated computers. So it's sort of an inwardly focused activity. Whether we dealt with routers, computers, or networks, the R&D was very much focused on the industry itself.

The Sherry Hour faculty felt back then—five years ago now—that in this next wave of information technology [IT] research and development, a much more effective way to maximize one's impact was going to be to pay more attention to its application, especially in fields not directly related to the technology itself. That is, the basic research that we should be undertaking—which is still what universities should be doing, of course; focusing on the fundamentals—would be motivated by a use or by an application: by some kind of Grand Challenge problem. We came to call this use-inspired basic research after the work of Donald Stokes in his book [*Pasteur's Quadrant*]. So then the next question to answer was, "What uses should we consider in terms of how we inspire our basic research?" We had further discussions about that as a group, and in fact I also involved our EECS department's industrial advisory board in that dialogue as well. That external board of advisors has the benefit of including many national and international luminaries from the field of electrical engineering and computer sciences.

What emerged from that dialogue was our conviction that, yes, multidisciplinary research in the application of IT was in fact critical to the future, and it was where the impact would be felt most profoundly in terms of basic research. But what was even more profound for me was the recommendation from the group that we believed Berkeley should think about taking on those problems that the rest of the world was not really considering at the time—these were the Grand Challenge societal problems, problems that relate to improving the quality of life for people.

So we decided to examine quality-of-life problems insofar as IT applications were concerned. It seemed like the right thing to do, and a core group of my faculty were definitely motivated to do that. I regarded that consensus as a mandate from the faculty and looked into it myself in more depth. Then, when the governor of California decided to create four new California Institutes for Science and Innovation at UC campuses, we decided to propose that particular topic as the one of most interest to us as a college and as a campus, and we partnered with our collaborating campuses: UC Santa Cruz, Davis, and Merced. We also found a great deal of interest in this approach from some of our key industrial IT research partners, and CITRIS today is as much about developing a model for effective university-industry collaboration as just about anything else. So that's how the Center for Information Technology Research in the Interest of Society—CITRIS—arose as a concept and as a vision, through discussion and dialogue with many people over period of a year and a half.

D&T: I assume you see CITRIS creating a diverse set of solutions to societal problems. It means a lot of creativity, this kind of work. Is it half inspiration and half perspiration, or how does that work?

Newton: I think that's the important thing to keep in mind. A lot of people talk about multidisciplinary research today, and of course many of us believe that it's crucial for universities to pursue that direction in terms of their research agenda. The real question is, "How do you go about it in ways that are effective?" If you're working in a biotechnology center, or a computer science department, or in a university's nanoengineering or material sciences division, you start with a particular technology base. And given that I'm, say, a material scientist, what can I do that's interdisciplinary? Frankly, that's not the best way to go about pursuing new areas of interdisciplinary research. The most effective way to approach this is in fact something that we learned well, I think, through the Mead-Conway generation in electronic systems design and design automation as we've tracked Moore's law.

The best approach we know to encourage the most effective interdisciplinary research is to start with an idea or problem that you want to address—a Grand Challenge problem we sometimes refer to as a "moon shot"—and then think about what basic science or technology is missing that would enable you to address that particular problem most effectively. Start with a Grand Challenge problem. For example, one problem we've worked on recently at Berkeley is the problem of Dengue Fever, which is a viral scourge that kills many millions of people every year around the world and reduces the productivity of people in tropical regions dramatically, impacting the national economies of those regions significantly. The Grand Challenge here was to find a way to detect the presence of the Dengue Fever virus in a blood sample quickly, accurately, and very inexpensively, and communicate that result to an integrated tracking system. The group of CITRIS researchers that came together to work on this problem have developed a technical solution that involves a microelectromechanical system (MEMS) chip that can analyze the blood to detect the presence of the virus or its by-products and a wireless sensor that can transmit the results of that analysis to a collection point. It involves the software necessary to make all of that work. It involves people from public health knowing what the key issues are in terms of making this practical and applicable in developing regions. It involves people from the business school at Berkeley looking at the cost factors critical to making this application scale. It involves industrial partners like National Semiconductor, who built the chip, and various other partners that have been helping us with this. Ultimately, what happens is there's a sort of bottoms-up effort that emerges as a consequence of considering the "use."

And that's what CITRIS is about. In many ways, CITRIS is not about picking Grand Challenge problems, like the detection and elimination of Dengue Fever. It is much more an experiment in how to organize a large-scale research program to implement a multidisciplinary research culture that includes effective research collaboration with industry and government partners as well.

D&T: It sounds fascinating, and we'll be sure to give a reference to CITRIS so people can take a further look [http://www.citris.berkeley.edu/]. I want to turn our attention now to a couple of more-focused questions for your thoughts. One is the role of Silicon Valley in a more internationalized world and, perhaps, in a post-Internet, telecom-bubble world. Does a keen, creative researcher still benefit by coming to Silicon Valley? How do you see things developing in terms of centers of competence or creativity?

Newton: Many national and regional governments have tried to replicate Silicon Valley, in general as well as in specific disciplines that are different from Silicon Valley and its particular ecosystem. Some have been partially successful; I also think there are other parts of the world now with centers of competence somewhat comparable to what Silicon Valley has to offer. Some of the claims concerning those areas are overblown, and time will tell how effectively they develop. There's no doubt in my mind that the Silicon Valley ecosystem remains unique, remains extremely important to the development of technology and new ideas—not just in silicon, but in many new ideas and many new areas. It's not any one component of that ecosystem—the venture capitalists, or the readily accessible infrastructure for getting things done when you need to get them done, or the lawyers—it's not any one of those, but one component that has been, and remains absolutely critical in my mind is the incredible educational and research resource that's available in the Bay Area. By that I mean, of course, Berkeley, Stanford, and UC San Francisco, just to name three key elements of that resource, along with many of the Bay Area's other research and higher education institutions. I think this entire ecosystem attracts the very best and the brightest, in terms of intellectual leadership from both a commercial point of view as well as an academic point of view. Of course, the students and the young people who come to Silicon Valley either for the entrepreneurial opportunities or the educational opportunities are the key here—that factor will continue to drive innovation and leadership.

The challenge, from a global point of view, was well expressed recently by Vinod Khosla of Kleiner, Perkins, Caulfield and Byers. Vinod, perhaps the most successful venture capitalist of our time, was asked the question: "What is the future of Silicon Valley?" He was also quite optimistic and pointed out that Silicon Valley will continue to lead in many ways because of the ecosystem that exists there, among numerous other factors.

The challenge that exists from a global point of view is not in trying to *compare* one part of the world with another—which we often tend to do; we often ask, "How will Silicon Valley compare with Bangalore, India, or with

Shanghai, China?" Instead, the challenge is in creating a place in the world that views *the entire world* as a part of its *own* ecosystem. I think that's an opportunity that Silicon Valley, particularly because of our great research universities, has a unique opportunity to take on. So rather than "us versus them," rather than "brain drain or reverse brain drain," we need to be talking about brain *circulation*. We need to be talking about embracing the world and other parts of the world as part of our own ecosystem, as part of the toolkit that we have available to us to do whatever it is we choose to do, based here in Silicon Valley. People in Silicon Valley understand how to go about this at least as well as, if not better, than anybody else. And that's what makes me optimistic.

D&T: Two more questions, then we'll let you go. The first is in the fabless area, because the fabless model has driven an immense amount of creation in the semiconductor industry. With the increasing cost and the increasing risk of development, do you see a sea change of some kind in terms of established companies being the only ones that can grow and be innovative, or do you still see the role of fabless startups as one that's important to nurture?

Newton: We've been up against these sorts of brick walls in the past, and we've always found a way to tunnel through them and suddenly appear on the other side (with a lot of hard work, of course!), and we wonder why we ever were so concerned in the first place. Whether it's the thickness of gate oxide or the number of people required to design a chip, we've seen these potential brick walls and "the sky is falling" scenarios, and have overcome them. Nonetheless, there do appear to be a number of major challenges confronting us today, the most important confronting the fabless model is the cost of building a chip; most important there being the overall nonrecurring engineering costs associated with designing and implementing a chip that works correctly. These factors certainly are changing—and will continue to change—the dynamic of how we should be approaching the design problem. I'm one of these people who believe that there are going to be fundamental breakthroughs in areas, which we have yet to see and yet to imagine, that will let us continue to drive the industry forward as we have in the past.

For example, if someone were to invent a field-programmable chip architecture that could deliver near the density of a custom or semicustom chip, and therefore produced nearly the performance and power consumption of such a chip, that would completely change the way we think about our industry. It certainly would enable us to do many, many more designs and deliver them cost-effectively in small volumes, for example. Now would they be considered "fabless semiconductor designs"? Not in the sense that we view them today, but they would still be fabless semiconductor designs, and they would still be innovative on that particular circuit fabric, and I think such a capability would build some great companies.

At the other end of the spectrum, the notion of putting more programmable elements of other forms on silicon and leveraging a single, task-oriented programmable chip into many other related applications is an idea whose time has come and is taking off today. The notion of having one—or, much more likely, many—processes on a chip that can be programmed in software and coupled together in interesting ways will continue to grow in importance. Of course, potentially customized and special-purpose hardware for analog RF and other coprocessing style uses is another addition to such programmable platforms that has emerged as critically important.

This trend will, therefore, fuel a return to the importance and relevance of the embedded software industry in the EDA domain, but in ways that are clearly very different than we saw a decade or two ago. I think we'll see the breakdown of the historical barrier between hardware and software in some very unique ways, so it won't be a case of porting the software to a processor, but in fact there will be more of an integrated approach. I don't like the term 'hardware-software codesign' because I think it reinforces the notion of separate-but-together hardware and software design.

In my mind, a common approach to design in the future is more likely to be a sort of a common seat where the designer sits down and looks at the technology through the eyes of a programmer, and the hardware will in some sense be "side-effected" as a consequence of the particular design and its needs, either as a customized chip in certain cases, or as logic that would run on some field-programmable circuit in others. I don't know what the specific answer is going to be, but I'm quite confident that the industry will transform itself as it has in the past and continue in some very productive ways.

D&T: Finally, what is your advice for tomorrow's engineering student? Is engineering still a great place to be? How should such a student organize their career?

Newton: No doubt; engineering is a really important direction to take. Greg Papadopoulos, the CTO at Sun Microsystems, recently said that if the 20th century was the century of big science—physics, chemistry, understanding the atom and the investments that we made in the nuclear sciences—then the 21st century has to be the century of the engineer. His reason is that many of the challenges we face as a planet are ones that require the application of basic science and technology to the Grand Challenge problems of quality of life and sustainability that really only engineering is equipped to deliver. There's no doubt in my mind that engineering will have a critical role to play at the nexus of the scientific, medical, societal, and ecological universes for this current century.

That said, I think engineers that we educate today and in the years to come must be educated in a different way than they were when I was a student engineer more than a quarter of a century ago. The historical focus on a strong technical education that teaches the fundamental tools of science, of engineering analysis and design, is probably more important today than ever before. But we must also challenge our engineers to think more broadly, to think about aspects of the technology they're developing that, historically, they haven't been asked to think too much about. These aspects include the implications of our work to public policy, to the law, to business, and in ethics, for example. All of these concerns are increasingly important aspects of an engineering student's education, at least at levels that allow our engineers to engage constructively in a dialogue about how the technologies they're inventing are applied and the consequences of that use.

So I think the historical legacies of engineering are important even today and that the field will continue to evolve. If I were starting out today, would I become an EDA engineer? Probably not. Today, the field that probably excites me the most, and it's just beginning right now, is a field called synthetic biology. And synthetic biology is very much an engineering discipline, in which we view the cell much like we viewed a circuit schematic diagram and a breadboard 25 years ago. We're just beginning to develop the fundamental components that will let us take the basic breadboard of a cell and engineer it to pretty much do anything we want it to do. That's very exciting, somewhat frightening in its potential, and an example of where engineers must have the tools they need to understand the potential consequences of their actions.

D&T: Thank you very much, Dean Newton. Your time, I know, is tough to find, and we really appreciate the interview.