



2003 Technology Survey

In their first-ever technology forecast survey, IEEE Fellows cast a critical, yet hopeful, eye on the future of innovation, industry, and the profession

What's wrong? The list is long: tanking airlines, hemorrhaging telecoms, disgruntled engineering graduates, a dearth of alternative energy options, an ethically challenged corporate culture, a vision-free body politic. And what is next?

Against such a backdrop, how should intellectual and political capital be deployed to guide technological decision-making into the new millennium? To answer that question, IEEE Spectrum turned to an elite group of expert technologists - namely, the IEEE Fellows. Collectively, these highly accomplished and entrepreneurial men and women stand at the top of the engineering profession: they are the inventors of new technologies, the founders and managers of companies, and the educators of young engineers. And to judge by the results of our survey, their outlook is at once broad and critical, and yet idealistic and (cautiously) optimistic.

A total of 565 Fellows responded to our survey, which posed questions covering computers, telecommunications, power and energy, semiconductors, transportation, and education. Not by chance, these are also the Fellows' own areas of expertise: 29 percent come from telecommunications, 17 percent from semiconductors, 15 percent from computers, 13 percent from power and energy, and 1 percent from transportation. As for where they work, half of the respondents are in education, while about a quarter are in industry, and a tenth in government or nonprofits. And they are an enterprising bunch: though only 4 percent are self-employed, an impressive 58 percent described themselves as entrepreneurs.

The big picture: energy, terrorism, and the environment

How should technology be used to address social ills? When asked which of a set of broad social issues would require greater technological resources in the next five years, the Fellows rated energy development as society's top priority, well ahead of promoting technological literacy, bridging the digital divide, or protecting intellectual property. The over-dependence on fossil fuels motivated a number of Fellows' choices, and many called for more efficient use of existing resources. "We need to conserve, rather than pump more oil for 'recreation,'" wrote one respondent. Energy production, said another, "has to be combined with more efficient automobiles and the end of large SUVs. No one needs a GMC Yukon or a Cadillac Escalade."

The fight against terrorism and environmental protection also ranked high on the list of pressing problems, though not all respondents were convinced that technological solutions could or should take priority over social and political ones. "I place fighting terrorism high, but do not mean military offensive technology," wrote one respondent. "As engineers, we have the potential to provide a better standard of living for all people. When we eliminate poverty (by using better technology), we eliminate extremism. When we eliminate extremism, we have eradicated terrorism. This is the only long-term way."

Notably absent, in fact, was a sense of blind faith in technology. Indeed, respondents' comments tended to reflect a strong belief in technology as an integral, inseparable part of society. (The exception was a less-than-optimistic, and possibly tongue-in-cheek, suggestion that "since humans cannot come up with a rational foreign policy that protects this country from disasters like those of 9/11, maybe we can rely on machine intelligence to

guide us.") Several respondents urged their peers to think broadly and to drive the political process, "a more difficult task for engineers than tackling technological challenges," observed one respondent.

No consensus on recovery

Opinions were equivocal when it came to assessing the health of the tech industry. For example, about the same number of respondents predicted that the telecom and semiconductor industries would recover first as said they would be last. Statistically equal shares thought that energy, telecom, or semiconductors would be the first industry to recover, with slightly smaller shares voting for computers and transportation.

It's not surprising, then, that opinions diverged on what had caused these industries to fail in the first place. Some criticized the telecom industry for overbuilding and paying too high a price for speculative assets. Others felt that energy deregulation had caused more problems than it solved. "Deregulation of the energy industry, coupled with the alleged business ethics shortcomings of prominent players in this sector, will hamper strong recovery," is how one respondent put it. Nor was he alone in pointing out that any tech recovery will be greatly influenced by geopolitical events. "Recovery of the transportation industry will be very much aligned with the reduction of worldwide terrorism," said one respondent.

"Yes" to open-source computing

A remarkable two-thirds of the Fellows thought that open-source computing had a very important role to play in the computer industry. Many noted that competition is a healthy catalyst in the marketplace and took aim at the Seattle giant. "The biggest hindrance to the development of computing is Microsoft's monopolistic control of the software/operating system market and our government's reluctance to stop it," one respondent railed. Others, though, were more moderate: "It is not healthy to have one supplier, but I have to say that MS is doing a pretty good job, all things considered."

And while a few expressed some doubt that open source could cure all of software's ills, many seemed to agree with the respondent who wrote, "In an economically difficult environment, open-source computing offers an opportunity for talented individuals to contribute for the benefit of all."

The perfect information device

Asked what would be the most common way to access information 10 years from now, many of the Fellows rejected the survey's candidates - cellphones, laptops, desktop computers, television, personal digital assistants (PDAs), and tablet computers - in favor of "something we have yet to think up," as one respondent put it. Quite a few thought it would be some combination of the devices on the list, seeing the merger of PDAs and cellphones as a sure thing and the pairing of television and desktop as likely.

"There will be an 'information appliance' that combines phone and Internet access, possibly with voice recognition, into one wireless box," predicted one Fellow, while another waxed even more fanciful, foreseeing a "wearable computer like a wrist watch." Amidst such speculation, one certainty emerged: the information device of the future will be personal and portable,

making it possible to access any person or information, anytime, anywhere.

Demand for broadband

Traditionally, a product is considered successful when it has reached a 30 percent market penetration. When will that day come for broadband? Despite the shaky state of the telecom industry, the Fellows were confident that broadband access would be widely established in the developed world within the next 10 years. "Nowadays, one gets addicted to broadband in college, if not sooner. Just from generational change, a broadband pipe into one's home will soon be perceived as another utility," predicted one respondent. Another was less sanguine, though, pointing out that "penetration will depend on the type of product being offered."

The Fellows agreed that adoption of broadband would take far longer in Asia than in Europe and North America, although certain Asian countries would advance faster than others. As one respondent pointed out, Asia "consists of nations like Japan, where broadband access penetration will mature in less than 10 years, and also countries like Mongolia, where there is little communications infrastructure."

As for which applications will drive broadband demand in the coming years, the Fellows agreed that video—video on demand, videoconferencing, and so on—would be the chief driver. Though the survey didn't ask just what kind of video that might be, one respondent volunteered that "as with every other bandwidth and e-commerce advance, the dirty secret is that growth will be driven by 'adult entertainment.'" So will broadband be a medium for business or pleasure? With applications like video, music services, and gaming looming large, there seemed to be a consensus that, as one respondent put it, "entertainment, not work, drives broadband!"

That said, a number of respondents did put in a plug for broadband business applications. Several Fellows predicted that the day of the videophone may finally have arrived: "Audio-only telephony will go the way of the crank-started automobile engine," wrote a respondent, adding, "A side effect of videophones is that it will be a lot harder to cheat on one's spouse." And online education was mentioned by several respondents; "In five years, some 20 percent of college-level teaching might be online," said one Fellow.

Moore's Law and beyond

The Fellows showed remarkable confidence in the staying power of Moore's Law - the doubling of transistor density every 18 months - with over two-thirds saying it would hold true for at least another five years. Despite many predictions of the law's imminent demise, chip designers and manufacturers have overcome each technical hurdle, much to the surprise of, among others, Gordon Moore himself. "I remember sitting and discussing this with Gordon 12 years ago, and he felt the law was probably near its limits," recalled one Fellow.

Many respondents, though, seemed just as convinced that some emerging technology would topple Moore's Law. Among the suggested candidates were various forms of nanotechnology (carbon nanotubes, resonant tunneling diodes, molecular transistors), photonics, giant magnetoresistance-based memories, and three-dimensional IC stacking. "I think that smart developers are investing in biologically based computing, quantum computing, and other alternatives to the IC transistor," wrote one Fellow. "This area is ripe for a disruptive technology."

Until that happens, respondents were asked to envision likely uses for what some people in the semiconductor industry are forecasting by the end of the decade: billion-transistor ICs (up from today's 250 million). The vast majority felt that such big beefy ICs would best serve the computer and telecom industries,

while somewhat smaller shares felt they'd prove useful in the semiconductor and biotech businesses. In contrast, such chips were seen as offering no advantage in transportation and energy.

That said, a number of Fellows noted that all these industries have already benefited from the semiconductor revolution and would no doubt continue to exploit increased capacity. "There's no such thing as enough money, enough bandwidth, or enough computing power. Build it and they will come!" exhorted one. Seconding that opinion, another wrote, "I have to believe that the power of decision-making implicit in those gigaflop devices will become the ubiquitous heart of every system imaginable."

Such views, though, were balanced by those who felt that refining the design of applications was preferable to simply pushing for ever more horsepower under the hood. "We are caught in the fallacy that more transistors are better," one wrote. "Up to some limit, this is true, but in the end, the functionality and the applications are what matter, not the number of the transistors. Maybe smarter designs with fewer transistors are the answer."

"No" to energy deregulation

While energy development is considered a top priority for the Fellows, they were largely dismissive of energy deregulation. Asked what would contribute to successful electric energy production and distribution, 70 percent voted for alternative energy sources, while only 20 percent said deregulation. And only a quarter of respondents felt that a deregulated industry would advance the development of energy technology, with several suggesting that deregulation and innovation might be incompatible; one respondent wrote, "Energy deregulation seems to be correlated with energy development, but not energy technology development (ETD). ETD seems to be mainly stimulated by higher energy prices."

Why the harsh views on deregulation? Clearly, Enron cast a long shadow. As one respondent said, "Before Enron, I might have had a different answer. Deregulation of a major infrastructure item is no longer a clear positive, if it ever was."

When it came to selecting the most promising energy sources over the next decade, votes were distributed across a wide range. Topping the list was a surprising choice: hydrogen energy, which is still in the early phases of development, aside from some experimental hydrogen fuel-cell-powered cars and buses; still, it appears to have captured respondents' attention. Below that were nuclear energy, photovoltaics, and fossil fuels, with wind power and hydroelectric energy ranking lower.

Proponents of nuclear energy bemoaned the political climate: "If the spent fuel storage issue and general public perception could be changed, then nuclear would be very promising," one Fellow wrote. Proponents of wind, solar, and other alternatives were equally vocal: "U.S. dependence on oil, coal, and nuclear is not healthy for our great-grandchildren. With large investments of money, alternate energy resources can provide economical solutions," wrote one respondent.

Trains, planes, and automobiles

Opinions were fairly clear when it came to transportation. For example, a whopping 86 percent of respondents described the development of alternatives to gasoline for cars as "very important" - "perhaps the No. 1 energy issue facing the world today," one Fellow said. A number of respondents also voiced concern about U.S. dependence on foreign oil, and a political climate they saw as controlled by the petrochemical industry and hostile to environmental interests. "It is shameful that automobiles now are less fuel-efficient than they were 15 years ago. Neither the government nor the industry promotes efficient use of available energy," wrote one respondent.

As for what might replace the gas engine, hybrid electric

vehicles were the hands-down winner, for the pragmatic reasons that they require the least investment and might be subsidized because of their continued reliance on fossil fuels. Hydrogen fuel cells drew votes as a longer-term proposition, but garnered a cautionary note from one Fellow: “‘H’ stands for hydrogen but also for Hindenburg.”

Before alternative fuels can take off, though, a number of barriers need to be overcome. The Fellows largely agreed that industry resistance was a steeper barrier than the technologies themselves. But one respondent pointed out that not all car companies behave alike: “Honda and Toyota already have excellent offerings. U.S. players need to get on with it!” Some respondents suggested a range of government regulations - a levy on gas-guzzlers, tax breaks for hybrid electric vehicles, or higher fuel prices - that would enable “green” alternatives to compete more effectively with conventional autos.

Do planes and trains deserve government support? When it came to trains, which require a lower energy cost per passenger-mile than planes, the clear consensus was that subsidy was merited. Many respondents said they’d like to see a light rail system in the United States, and view government support of roadways as a major impediment to rail’s success. “If the U.S. government funded the railbed the same way as it does roads, then rail transport would be the cheapest and most efficient,” wrote one Fellow.

As for subsidizing air transport, respondents were split, with as many in favor as against. But a number of respondents pointed out that mass transit in general is a public good and that all forms of transportation require a lot of government support - not least an air transportation industry hobbled by the threat of terrorism.

Tomorrow’s engineers

How good an education do today’s engineering students receive? While only a tiny fraction of respondents thought universities were doing a “poor job” at educating students, opinions were split on whether they were doing an “excellent” or just “average” one. Nor was there a consensus on the top issue today in engineering education, opinions ranging from attracting more high-quality students to teaching students to think rather than memorize.

And, mirroring the debate in society at large, there was an even split between those advocating more fundamentals and those who counseled a broader, multidisciplinary approach. “Teach fundamentals. They never change, while technology does,” advised one respondent. “Broaden the curriculum to provide a more balanced understanding of social issues and articulation of technology solutions to such issues,” countered another. Still others said that engineers should learn more about business. “Teach them how their engineering knowledge relates to the operation of a company or government agency,” urged one Fellow.

Respondents also acknowledged the increasing depth of understanding required to practice any engineering discipline, and a keen awareness of the difficulty of balancing fundamentals with marketable skills. “The tendency in Europe is to specialize more at the cost of a less broad basis,” one respondent wrote. “This is a pity because first, engineering students are missing the broad overview of science, and second, the European industry does not need that deep specialization. Moreover, if an engineer has a broad educational basis, it is easy to specialize afterwards in a new domain.”

Are raises in order?

There seemed to be broad agreement among the Fellows that engineers in general are not well paid compared to other professionals. The parent of two mechanical engineers, both of whom had difficulty finding jobs out of college, wrote, “My third son, an accountant, is making more than the other two combined!” And is this pay disparity discouraging top students from entering engineering? On this, respondents were divided. Although one out of

two said this was the case, others agreed with one respondent’s view that “the best students aren’t in it only for the money.” Another respondent said, “Good students still study engineering, especially in newer areas like bioengineering. Students will come if job prospects are good and curricula are meaningful.”

There was also, though, a sense among the Fellows that engineering was perceived as too demanding, and that the profession’s poor image was no help. “I agree that high-caliber students aren’t choosing engineering, but this is not only because of money but due to a social value system and general aversion to hard sciences and math in the United States.” That respondent was one of several to point out that the issue primarily applied to U.S.-born students, and that qualified non-U.S. students continue to flock to U.S. engineering schools. “U.S. students definitely have the view that they can make more money with less effort in other professions. Foreign students are thankful for the opportunity to work hard.”

What’s next

Despite such moments of pessimism, the Fellows proved for the most part forward-looking and optimistic when it came to envisioning technology’s future. Asked to predict what would be the most important technological development of the next five years, they gave an enormous range of responses, from alternative energy, to high-speed wireless communication, to pervasive computing, to molecular computing. Many saw great promise in biotechnology: proteomics, designer drugs, genetic engineering, and more. Calling it “the integration of biology and engineering,” one predicted that “what we learn from nature will create the next leap-forward technologies.” That opinion was countered by another’s concern about “ethical considerations regarding biotechnology and biomedicine within our society.”

The Fellows seemed equally convinced that electrical engineering as a discipline would need to evolve and expand. One suggested that the profession “broaden its perspective of just what electrical and computer engineering involve. By themselves they have limited value. When linked with mechanics, biology, the natural sciences, and other disciplines to form a system, the value increases.” Another predicted that “chemical and biochemical technologies will join current electric/electronic and optical technologies for information processing and transmission.”

Other priorities respondents mentioned were proper allocation of the electromagnetic spectrum; development of an effective defense against electronic warfare; more sophisticated material-processing techniques; better methods for managing research; tort reform; space exploration; and balancing privacy and security. Also mentioned were sustainable development (“The cost of every product needs to include the cost of the earth’s resources used in its making”) and science education (“I believe it was Arthur C. Clarke, the science fiction writer, who said, ‘Any sufficiently advanced technology is indistinguishable from magic.’ I think we are facing this issue in regard to the level of our technology and the level of technological illiteracy in our society, and it strikes me as dangerous”).

Throughout the responses, the Fellows’ idealism was evident, as time and again respondents called for applying technology to the service of society, to promote a decent global standard of living and ensure the long-term habitability of the planet. “Technology for technology’s sake is useless,” concluded one Fellow. “If it can be harnessed for the welfare and development of mankind, its impact will be enormous, and that is exactly what we should aim for.”

To Probe Further

A PowerPoint file summarizing the results of the 2003 IEEE Fellows Tech Survey can be downloaded at <http://www.spectrum.ieee.org/WEBONLY/resource/jan03/2003IEEEfellsurv.ppt>

