2000 Woodruff Distinguished Lecture
TRANSCRIPT

The Societal Responsibility of Engineers

(And Its Implications for Engineering Education)

Given by Wm. A. Wulf
President
National Academy of Engineering

At the
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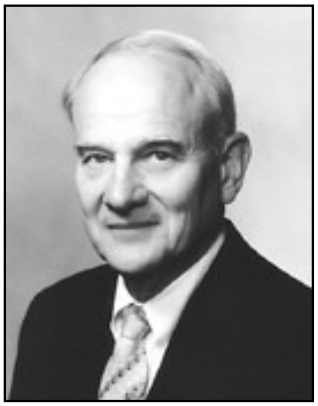

Dr. Wulf is on leave from the University of Virginia to serve as President of the National Academy of Engineering (NAE). Together with the National Academy of Sciences, the NAE operates under a Congressional Charter to provide advice to the government on issues of science and technology. Much of this advice is provided through the National Research Council, the operating arm of the two Academics; Dr. Wulf serves as Vice Chair of the NRC.

At Virginia, Dr. Wulf is a University Professor and holds the AT&T Chair in Engineering and Applied Science; among his activities at the university are a complete revision of the undergraduate Computer Science curriculum; research on computer architecture and computer security; and an effort to assist humanities scholars exploit information technology.

Prior to joining Virginia, Dr. Wulf founded Tartan Laboratories and served as its Chairman and Chief Executive Officer. Before returning to academe, Dr. Wulf grew the company to about a hundred employees. Tartan developed and marketed optimizing compilers - programs that translate high-level languages such as FORTRAN or C into highly efficient computer codes. The technical basis for Tartan was research by Dr. Wulf while he was a Professor of Computer Science at Carnegie-Mellon University.

While at Carnegie-Mellon and Tartan, Dr. Wulf was active in the "high tech" community in Pittsburgh. He helped found the Pittsburgh High Technology Council and served as Vice President and Director from its creation. In 1983 he was awarded the Enterprise "Man of the Year" Award.

Dr. Wulf has been a consultant to numerous computing and telecommunications companies. Dr. Wulf is a member of the National Academy of Engineering and a Fellow of the American Academy of Arts and Sciences. He is also a Fellow of three professional societies: the ACM, the IEEE, and the AAAS. He is the author of over 80 papers and technical reports, has written three books, holds two U. S. Patents, and has supervised over 25 Ph.D.'s in Computer Science.

Dr. Wulf received his bachelor's degree in engineering physics in 1961 and his M. S. in electrical engineering in 1963, both from the University of Illinois. He received his Ph.D. in computer science from the University of Virginia in 1968. He was born in Chicago, Illinois in 1939.

Introduction

[Editor's Note: This transcript is an edited version of Dr. Wulf's lecture. To view the original lecture here on our web page, click on the George Woodruff Medallion from our home page.]

Thank you very much, Ward, for that kind introduction. Ward said I am at the Academy of Engineering right now. I will explain to you something about what that means in a minute, but one thing it means is that I spend full time in Washington, D.C. In preparing this lecture I realized that I had been infected with one characteristic of the Beltway. For all of my career I've lectured using overheads. In Washington, you don't lecture with overheads. You make speeches just standing in front of people. So I'm going to try to not put you to sleep by just talking to you.

The title of the talk that I've prepared for today is *Are We Fumbling The Future?* I will explain the context of that phrase in just a minute, but it comes from the subtitle of a book about Xerox Palo Alto Research Center, PARC. In the 1970s PARC developed a great deal of very innovative computer technology that Xerox never managed to appropriate - it never did make any money for Xerox. I want to pose the question to you: Are we in the engineering community committing a similar act, are we fumbling the future?

About the Academy of Engineering

Before I do that I'm going to take just a couple of seconds and talk about the National Academy of Engineering. There are academies of engineering and academies of science all around the world. For the most part, they are private entities; they are not part of their governments, and they are honorary societies. That is, to become a member of the Royal Society in London or the Academy of Science in France, one has to be elected by the existing members, and it is considered a high honor to be so elected. Back in the middle of the nineteenth century a group of American scientists decided that we ought to have one of those academies, too. They incorporated the National Academy of Sciences as a private, not-for-profit corporation - what we would now call a 501-C3 - in Washington, D.C., in 1863.

For those of you who remember your civics class, in 1863 there was no city government in the District of Columbia. The federal government acted as the city government. So anyone who incorporated in the District received a Congressional charter for the corporation. We make a great big deal of the fact that the Academies operates under a Congressional charter, but the truth of the matter is it was absolutely standard practice in the middle of the nineteenth century. However, what is special is that some nonstandard language was inserted into the otherwise boilerplate text for the charter. That nonstandard language said that the Academy would provide advice to the federal government on any issue of science or technology, whenever asked, and do it without compensation.

If I fast forward to today, four organizations operate under the charter - the original Academy of Sciences plus the Academy of Engineering, the Institute of Medicine, and the National Research Council. The first three are the honorific societies. The National Research Council is the "operating arm" of the first three, and where most of the advice-giving is done. I am very fond of a phrase that kicks around the Academies. That phrase is "telling truth to power"; what we do is tell the truth to the powerful in government, whether they like it or not. In fact, we frequently tell the government things that they do not want to hear.

Let me give you some quick size information. The Academy of Sciences has about 2,000 members, as does the Academy of Engineering. The Institute of Medicine has about 1200 members. We produce a report in response to a request from the government about every working day, two hundred to two hundred and fifty times a year. You can think of each one of those reports as a Ph.D. dissertation. Each is about three hundred pages, is fact based, tightly researched, and impenetrable, but it's always the truth.

The main point is that, in addition to simply being an honorific society, the Academy of Engineering is a trusted advisor to the federal government, and, in some sense, that will help explain what it is that I'm talking about today and why I'm talking about it.

The Main Message

Now, let's go to the main message of my talk. There are four points I want you to carry away from this lecture. Point one: Engineering and science have had a profound effect on society. Think about the average life of a person in 1900 compared with today; I think you will realize that *all* the differences are due to science and technology. That impact is not likely to lessen, in fact, it is likely to increase in the future. So point one is engineering and science have had and continue to have a profound effect on society.

Point two: For the most part, engineers have not had a deep involvement in the formation of public policy. Of the 535 members of Congress, there are only half a dozen who have technical a education of any kind. That includes one high school science

teacher, one doctor, and two Ph.D. physicists.

Point three: I think the situation is becoming increasingly dangerous as more and more public policy decisions depend in one way or another on an understanding of engineering or science. That's where we may be fumbling the future.

Point four: The last point; it's up to us to do something about it. We cannot sit back and say, not me, I am doing my research, that's all I am responsible for. No! It's up to every one of us to get involved and help make the wisest possible policy decisions.

Before proceeding to the main argument, honesty demands that I make three caveats. First, I admit that I am painting with a broad brush. There are people like Bob Fulton on your faculty who are involved with the political process. So forgive me, I'm not to going mention all the exceptions.

The second caveat is that I fully understand that "where you stand depends on where you sit." The way you view situations frequently depends on your own personal history and circumstances. My career has taken a crazy random walk from being a professor, to being an entrepreneur, to being a government bureaucrat, back to being a professor, and now to being at the Academy of Engineering and focusing on issues of public policy. So it is quite possible that I see policy issues in a sharper focus and with more urgency than you. The last caveat is that I am going to use computers and information technology as a whipping boy for my examples. That's not because I couldn't imagine similar examples for mechanical engineering, bioengineering, electrical engineering, or for whatever disciplines are represented in this room. It's simply that I know more about information technology, and, therefore, I feel I can speak with a bit more authority.

Despite the fact that where you stand depends on where you sit, I think that the culture of engineers, if not actively antithetical to policy issues, is at least indifferent to them. I frequently hear things like "I am too busy doing my own research," or "My company succeeds in spite of Washington," or "Those politicians aren't very bright." Well, I am sorry, but those attitudes do not work. They are digging us into a deep hole, and I am going to try and convince you of that. There are going to be four parts to the argument that I will present.

The first is simply that policy matters. If public policy doesn't matter, then I could just stop talking and get off stage. So I will try to argue that it matters. Second, I want to argue that the issues are urgent, that there isn't a lot of time. Third, I'm going to argue that it is *hard*. Thinking about the public policy issues and the implications of engineering on these issues is not easy. Fourth and finally, at least some of the issues are really intellectually deep and can have a more profound impact on our society than you might imagine.

Policy Matters

Let me begin with *policy matters*. I chose the title *Are We Fumbling The Future* because I want to go straight at what I have heard from so many of my colleagues - that if I get the science right, if I get the engineering right, if I do my research right, *that* is what matters, everything else will follow. Policy is somehow a lesser concern.

That attitude is known as technological determinism - the future follows in a deterministic way from the technology. I think that is just dead wrong! A close relative of that kind of thinking (that is sometimes all too prevalent in academia) is that invention is the same thing as innovation. It's not. Invention is the creation of something new; innovation is the creation of something new *that people will buy*. If you think that simply creating something new is what's important, you have a lesson to learn. I started a company after being an academic who invented some software technology. One of the lessons that I learned was that product development was one of the most intellectually challenging things I have ever done. My research as a professor was much easier, intellectually easier, than producing something that people wanted to buy.

Fumbling the Future is the subtitle of a book by Doug Smith and Bob Alexander about a period in the 1970s at Xerox Palo Alto Research Center, PARC. Several of my students were principals at PARC in the 1970s, so reading the book was especially

meaningful because I had vicariously lived through much of the story.

In the 1970s, PARC invented the personal computer, the ethernet, the laser printer, the concept of windowing, WYSIWYG - what you see is what you get - text editors, and on and on. Almost everything that you currently associate with your desktop computer was invented at PARC in the 1970s, and Xerox appropriated none of it. Xerox never managed to turn a single one of those technological developments into significant profit for itself, except the laser printer, and it did that only after it had been commercialized by a number of other companies.

The point of that story is that invention is not the same thing as innovation! Things other than the invention determine what happens. One of my friends at PARC was Alan Kay, who is one the most inventive thinkers that I know. I remember Alan making a comment that I thought was *so* cute, and at the time I thought was *so* right. He said, "It's easier to invent the future than to predict it." I now believe he was wrong. Inventing the technology does not determine the future. Technology enables many futures. The future that you and I, our children, and our grandchildren experience is one of the futures enabled by the technology, but which one will be determined by other things - and policy is first and foremost among those other things.

A year ago I read two books back to back. One of those was *2025* by Joseph Coates. Coates is a futurist. The book posits about one hundred and seventy, if I remember correctly, technological inventions that will happen by 2025 and then tries to project what that will mean in terms of our lives.

The other book was *Guns, Germs and Steel* by Jared Diamond. Diamond is an interesting character. He is a physiologist, ornithologist and evolutionary biologist. He has studied birds on New Guinea, and that led him to study the culture of New Guinea. About twenty or twenty-five years ago, a native politician asked him why us western guys developed all the cargo? You have to interpret that a little bit. New Guinea had no industry before Westerners came. So everything that we would think of as modern came to New Guinea as cargo. So when he asked about "cargo," he was really asking why westerners have all the technology.

The contrast between these two books is dramatic. Coates takes one hundred and seventy technological inventions and does a straight-line extrapolation.Diamond tells us about the wonderful richness and complexity of why western civilization has come to dominate the planet. I won't try to repeat Diamond's argument for you, it is much too complicated. But let me recommend the book - once you have read it you can never again be a technological determinist. You never again will believe that it is simply possession of technology that leads a society to succeed.

There Isn't Much Time

Let me shift to part two of my argument, that *there isn't much time*. It seems to take a while for ideas to percolate through society to the point of causing action. I will give you just one example in which I was only peripherally involved - military acquisition reform. I can remember conversations in the 1970s about the fact that the Department of Defense could no longer effectively influence the direction of most industry. They were not a large enough purchaser to be able, for example, to influence the direction in which the computer industry went. Commodity chips were the things that controlled not only what was available to the general public, but what was available to the military as well. As a consequence, it was argued, the traditional "milspec" system of specifying items to be acquired was counterproductive.

It wasn't until 1994 that Bill Perry signed a memo that flipped the bit and said the Department of Defense will buy commercial, off-the-shelf commodities whenever possible, and use milspec standards were only when absolutely necessary. It took fifteen or twenty years for an idea that was obviously right in the 1970s to percolate through to being a Department of Defense policy.

As the pace of the technology change accelerates, the time between recognizing that technology poses a social issue and the time we need to do about that issue decreases. Where I live at the Academies, that interval is between when somebody in government asks us a question and they demand that we have a answer. I am worried that the interval has gotten so short that

we cannot give the highest quality advice - there simply isn't the time to get the people together who understand the issue in enough depth to come up with a sensible answer.

I said that I am going to use examples from information technology, but another example on the front page today is genetically modified organisms. The Academy just released a report on the safety of genetically modified organisms; unfortunately, particularly in Europe, the issue has already been framed in nontechnical, nonscientific terms that aren't particularly responsive to rational argument. When you see headlines in London or Paris about "Frankenplants" (Frankenstein plants) rational, scientific argument cannot prevail. These kinds of issues need to be discussed rationally before they have a chance to be reduced to headlines or bumperstickers.

The question then becomes how we can ensure a rational discussion on issues like genetically modified organisms (or some of the information technology issues I will talk about a little bit later) early enough so that we can have a real influence. The only solution that I see is one which involves you - the people who understand where technology is going - thinking hard about the social implications and raising the issues before somebody in government wakes up to them. If you and I are not thinking about the social implications of what we are doing, it is guaranteed somebody will at some point. But at that point, it may be too late for a rational discussion. The problem may have been framed in a way that does not allow for an optimum solution, which brings me to part three.

The Policy Issues Can Be Difficult

It is hard. As Niels Bohr said, "prediction is hard, especially about the future." Computing professionals demonstrate in a particularly graphic way how hard it is to predict the social implications of technology.

I am sure you have all heard these examples. Back in the early 1950s, Univac Corporation did a marketing survey to predict the number of computers that would be sold, and the answer was six. In 1978 - just two years before the IBM PC was announced - at a public annual meeting of Digital Equipment Corporation, Ken Olson said no one would want a computer in their home - at the time, Olson enjoyed a reputation rather like that of Bill Gates today. Speaking of Bill Gates, in the middle 1980s, about fifteen years ago, he claimed that nobody would ever want more than 640 kilobytes of main memory. I have a hundred times that on my laptop today, and I could not survive with a bit less!

I am going to try and explain one of the reasons why it is hard to make these predictions. Grace Murray Hopper was a wonderful woman, who was an early pioneer in computing and also an admiral in the U.S. Navy. She carried a one-foot piece of wire; she did that because that is how far light travels in a nanosecond - she used the wire to help people visualize a nanosecond.

I have been groping to figure out what kind of gimmick I could carry that would get you to understand the effect of Moore's Law. I am sure you have all heard of Moore's Law - it predicts a factor of two in the number of transistors per unit area on integrated circuits every eighteen months. That also implies a factor of two in speed, half the power of consumption, and half the price.

I finally have hit on something. It's not perfect, but it is my analog of Grace's wonderful piece of wire. It is a computer that I carry in my briefcase, just like Grace carried the one-foot piece of wire. This computer is one hundred times faster than the ENIAC - the first electronic digital computer in the United States. It had 18,000 vacuum tubes, weighed thirty tons, and filled a room the size of a squash court. When I say this, I often see people nodding their head assuming that I mean my laptop. Sorry, folks, what I mean is this greeting card. Can you hear it (demonstrates card)? It is playing a Christmas tune. The chip in this card is a general purpose microprocessor; it costs about a quarter, and it is one hundred times faster than the ENIAC.

If you had been at the University of Pennsylvania in 1946 working on the ENIAC, would you have predicted this card? In fact, if you were in a marketing firm working for UNIVAC, would you have predicted it? I think not. The reason that the marketers predicted a worldwide market for six computers was that UNIVAC was designed for computing ballistic tables. ENIAC was built

during the war, and a problem of paramount interest was how far a shell would travel with a particular amount of gunpowder behind it. There probably wasn't the market for a heck of a lot more than a half dozen computer to do that.

If you were Ken Olson and a computer was something the size of a refrigerator, had to have special air conditioning, and had to be down for two hours every morning while the engineer did what was called "preventative maintenance," you would not want one of those in our home, either.

The reason that Bill Gates could not see beyond 640K was that there were no windows, no graphics, no color on your monitor or printer, and no network connection. The applications were very small compared to the way we use machines today.

The unstated assumption that all those people made was that computers would continue to be used the way they were at the time. We aren't any better predictors today - if you listen to the news media and their coverage of PCs or the Internet - it is blindingly obvious that they assume that we will always have PCs, we will always have the Internet, and the worldwide web - pretty much like they are, just faster, better, and cheaper. Any reasonable reading of computing history, however, suggests that the PC and the web will not be terribly important in the future - just as the mainframe is not now. They are going to be supplanted in some dramatic and absolutely irreversible way by something I cannot imagine, but that will be enabled by the relentless march of Moore's Law. So one of the difficulties with predicting the future is simply the unstated assumptions that we make about how technology willbe used. But there are also other deeper reasons. For example, you might want to read the *Innovator's Dilemma* by Christianson at Harvard. He argues that the very best run companies, the ones that are listening most closely to their customers, are the ones which are most likely to be unable to adopt what he calls *disruptive technologies* - technologies that, in a fundamental way, change the technological landscape.

The fact that it is hard to predict the future social implications of technology is not an excuse for not trying to do it. It *is* possible to be smarter and more accurate than we have been in making such predictions. But one thing I am absolutely certain of is that only *you*, only the technical community, only the engineers, have any hope of making that prediction. If you don't do it, it won't be done.

The Issues Are Deep

Now, I would like to spend the rest of the time talking about the depth of the issues posed by information technology - and again, these examples could have come from mechanical engineering or electrical engineering or bioengineering. It is just what I know best. I want to illustrate how deeply woven into our society some of the assumptions that are challenged by information technology.

For example, there are things that I think of as *place-based assumptions*. The first one was pointed out to me a few years ago by a friend who is a professor of law. She observed that there are about a half dozen fundamentally different legal systems in the world - Islamic law is based on a different philosophical basis than our Western law, for example. She said that there are only a couple of things that all the systems share, one of which is the notion of jurisdiction - the notion that law applies in a *place*.

Guess what about cyberspace? There is no place. And so what law applies? Who has jurisdiction? Some of you may be aware of a case in which a district attorney in Nashville indicted an individual in California for hosting a pornographic website. The Supreme Court has said that pornography is defined by "community standards." In this case, the website probably was pornographic by community standards in Nashville and was probably not pornographic by community standards in California. Whose jurisdiction applies? Where is the place?

The same thing applies to Internet sales taxes. Where does the transaction take place when you buy something from Amazon.com? Is it where my computer is? Amazon's? What if Amazon has servers in several places and they are all involved - one for the user interface, another for inventory, another for order tracking, for example? How does that change if we use cyber cash

and a cyber cash company is in yet another place? What happens if Amazon moves to the Cayman Islands?

Here's quite a different place-based assumption. One of the special things about the United States is that civilians really do control the military, and the military believes it. Part of the legal underpinning of that control is a law from the 1880s called *Posse Comitatis.* A very simplified explanation is that law enforcement has jurisdiction within the boundaries of the United States, and the military has jurisdiction outside them. Once again, where is the boundary in cyberspace? Who has the authority? Who has the responsibility, for example, if a U.S. bank is attacked by agents of a rogue nation? The answers are not obvious, but very important.

I am going to switch away from place-based assumptions to illustrate another kind of deep issue. I have watched the Microsoft antitrust case with fascination and frustration. The antitrust laws are about a hundred years old, and based on economic models which are at least that old.

Those economic models simply do not describe the software industry. There are fundamental assumptions in classic economics that aren't true for software - notions such as scarce things being more valuable than plentiful ones. Well, information is funny stuff that is not more valuable because it is scarce; in fact, sometimes it becomes more valuable because it is widely known.

The value to *me* of Microsoft Word is not that it is a wonderful word processor, not that it is small and fast, not that it is inexpensive or ultra reliable. In fact, it is none of those things. What is valuable to me is that I can send you a document in Word as an attachment to an e-mail with almost ninety-nine percent confidence that you will be able to read it, mark it up, and send it back. The value is not in cost or the product itself - it is in the fact that lots of people have it.

What concerns me deeply is the remedies that the judge is considering are being evaluated against economic models that do not work. It's not at all clear to me that the public goodwill be served by whatever remedy they finally come up with. Whether there is one Microsoft or fourteen, for example, will not change the nature of the value of Word for me, and hence, probably will not encourage competition.

Those were my four points - policy matters; it is urgent, it is hard, and it is deep.

One of the things I have learned in Washington is that rationality can prevail, but not after the issue has gotten to the bumper sticker stage. Once the debate has been framed in terms that can fit on a bumper sticker, it is over. If we want scientific and engineering rationality to guide policy, we have got to get involved sooner.

On the issue of Microsoft - there was an article in the *Washington Post* several months ago about the amount of money that Microsoft was spending on lobbyists. I do not remember whether the number was even cited, but the image was that they were hauling money into Washington in freight trains. It would have been much cheaper and more effective if, half a dozen years ago, they had invested in doing the scholarship to understand the economic models underlying the software industry.

There is a long list of other issues where we ought to get out in front instead of just reacting. The policy debate several years ago over cryptography and the Clipper chip, for example, should have happened before the Administration's announcement of Clipper. Another is the handling of the report of a presidential commission that raised the issue of the vulnerability of the United States to cyber attack. Frankly, that problem has gotten worse and very little has been done about it. At some point, a bad thing will happen and we will rush to do something about it, but it won't be the best solution, perhaps it won't even be an effective solution because it's too late. The issue will have been framed in a way that precludes the right solution.

The only way to get out of this reactive mode is for people like those in this room to be thinking about the social and policy implications of technology. This leads to the obvious question, "Okay, what can *I* do?" Let me give you a list of things.

- Everybody sitting in this room ought to think of spending part of their career as a program officer in one of the federal funding agencies, whether NSF, NASA, DoE, or DARPA, doesn't matter. It is a wonderful experience. You will be doing a service to your research community, but you'll also get exposed to the larger policy issues.
- You can be a congressional fellow. One of your colleagues here has done that. It is enlightening not only to know what the issues are, but what the processes are.
- You can also think and you can write. It is not the case that every article or paper you write has to be a technical article. Maybe one in ten or one in twenty might be a piece on the implications of your technology. You understand it better than anybody in the world.
- Almost all of the professional societies have committees concerned with policy issues. Get involved. ASME has one, ASEE has one, IEEE has one, and ACM has one.
- There are organizations like the Academies, the Defense Science Board, the Air Force Science Advisory Board, and so on, which you may volunteer to serve. You may or may not be selected, but all of them deal, at least in part, with the public policy implications of technology.
- Finally, engage your representatives. I have a good friend who is a congressional staffer who says that every congressman's second priority is science and technology. Nobody has it as their first priority, but everybody has it as their second priority - so you will get a sympathetic ear. You would be surprised how effective even a few letters, sometimes maybe a single letter on a topic, can be. Most people do not care about most issues. As a consequence, the number of letters to your congressman on a particular issue is quite small.

CONCLUSION

To conclude, I think the year 2100 will be more different from the year 2000 (in terms of the social implications of technology) than 2000 is from 1900. Just consider the differences between 1900 and 2000 - the telephone, the airplane, the automobile, the computer, the Internet, electricity, and clean water. All of these are due to engineering, and their impact has been profound. But there are lots of possibilities for 2100. You might like some of them more than you like other ones. The technology will not determine which of those in the 2100s will happen. Other things, and especially policy, will!

The policies will be made with or without engineering input. I think they will be made better with the input and leadership from the engineering community. Unless you and I take the initiative, however, that won't happen.

I have to admit that culture matters. The engineering culture is to not be involved with policy, and that culture is very strong - so maybe I am spitting in the wind. (Spitting in the wind is a metaphor my grandfather used for doing something that would only reflect badly on you in the long term. It is very graphic for me because my grandfather chewed tobacco.) Nonetheless, a change in that culture is what I am asking for - what I am challenging you to do. I feel we must.

QUESTION-AND-ANSWER SESSION

Q: Your description of what is needed on process to get a quick response to government and put our technology into policy brings up the image of technology assessment that the United States initiated in the late 1960s and early 1970s and dropped like a rock, but it is an interesting thing now happening in Europe, constructive technology assessment. Any prospects of the United States getting reinterested in the consequences of technology?

A: The United States Congress had an entity called the Office of Technology Assessment, which was headed for most of its life by Jack Gibbons - who was most recently science advisor to the president. In 1994, that office was abolished as one of several economy moves by the Congress. I guess the question was, is there any indication of a move back in the direction of being interested in technology assessment?

You understand that abolishing OTA was a political decision, not a rational one. As long as the Republicans stay in control of Congress, I see very little desire to move in that direction. I don't think Republicans are opposed to technology assessment - it's

just that OTA was a Democratic invention. If the Congress were to change parties, I simply do not know. I have not heard anybody, except some of the old OTA staffers, clamoring for its resurrection.

Your question does raise the issue of whether the Academies or somebody else should pick up that banner and help provide that function. Again, we are totally a soft-money organization. Every time the government asks us a question, we negotiate a separate contract to answer that particular question. Thus, we don't have our own resources to start something like that. We have raised the issue with people on both sides of the aisle and nothing has happened yet. I am afraid that there isn't a clamor from Congress. I am sorry, it is a dismal answer, but as far as I can tell, that is where we are.

Q: Given the fact that most Americans do not know the difference between a million and a billion, how are policy decisions made in regard to technology in general these days? Is there a general pattern in Washington?

A: I was an assistant director of NSF for a couple of years, and I remember the first time that somebody asked "what does *the government* think about X?" I cannot remember what X was, but the question stopped me because it made me realize that there is no government position on most things. There are several million people who work for the government. Some of them may have views on an issue, and some may be in a position to do something about them. That is kind of the way I react to this question, too. There is no "one way" that decisions are made.

Q: It might be interesting to observe that Xerox has not always goofed. I had heard when the company was considering its venture in profit analysis, when the advice was not to proceed, they said there was not a significant demand for Xerox copies in the country. Fortunately, they ignored that advice.

A: I was not trying to pick on Xerox. In fact, Xerox was doing what Christianson talks about in the *Innovator's Dilemma* - they were being the best copier company they knew how to be. They just were not interested in being another kind of company. My point was that simply having a technology does not determine how you use that technology. Developing wonderful technology in your labs here will not determine what our lives will be like in twenty or fifty years.

Q: Are the reports of the National Academies available to the public, and are there any reports on engineering education?

A: The answer to the first question is yes, in fact, in two different ways. Each report is a book that you can buy, or it may be in your library. Every report for the last ten years or so is also available on the worldwide web. If you go to www.nap.edu (nap stands for National Academy Press), you can do full text searches, and find specific reports of interest.

On the issue of engineering education - yes, we have quite a number. Let me add some context. When we do a study, we create an ad hoc committee of the best experts we know how to find for that question. We also maintain about eighty standing committees that have the function of scanning the horizon for issues we really ought to be addressing. We have had such a standing committee on engineering education for more than a decade, and they released a whole series of reports on postgraduate and undergraduate education.

Q: Should engineering schools provide the means for liberal arts majors in the engineering process and if so, how?

A: I was being conscious of the clock, and started cutting some things out of my lecture, or I would have spoken to just this point. First of all, engineering schools need to begin to present engineering as the humanistic activity with a profound impact on society. I do not understand how anybody can consider themselves an educated person in the 21st century who is ignorant of technology and the process by which it is created, that is, engineering.

I had a funny experience last winter of being invited to talk on a panel about democracy in the Internet age. Everybody else was a nontechnologist. The panel never happened; it was scheduled for one of the two days that we had major snow storms in

DC - so I can't report on the actual discussion. But I was assigned a question about how we ensure that technologists develop technology that doesn't undermine democracy. I was dumbfounded. There was no notion that nontechnologists had a responsibility too - at a minimum, a responsibility to understand enough to engage in meaningful discussion of the pros and cons of various policy issues raised by a technology.

I am currently on leave from the University of Virginia. You may know that the University of Virginia was founded by Thomas Jefferson. He did it because he believed that we could not have democracy without an educated citizenry. Jefferson is probably scared out of his gourd at the moment because we have a society that is totally dependent on technology, in some sense addicted to technological change, and yet ignorant of it. I do not mean dumb, I mean uninformed about technology and the process of creation.

I would like to urge engineering schools to stop thinking of themselves as purely professional schools that train engineers, and think of themselves instead as part of the universities that are educating people - where part of "being educated" is understanding the technology process that we have created.

Q: Before you were in Washington, I was curious to hear your comments that - in addition to your comments that after an issue boiled down to a bumper sticker, you were talking about what our role becomes once that happens. If the environmental issues and the genetically modified plans, what do you do after that? What do you see as our role when you have not been able to get out there sooner with your rationale?

A: The right solution is to get out in front of the issue so you don't have to cleanup afterwards. But, of course, we can't just give up if it has gotten past that point. In such cases, however, the odds are good that the process for addressing the issue will be political rather than rational.

Ward [Winer] and I were talking about the situation with respect to nuclear engineering, which is dramatically shrinking in American universities - it is down to three faculty at the University of Virginia and we are shutting down our reactor, for example.

Nobody in the United States has ever died, or even been seriously injured from a nuclear accident. Yet, we are perfectly happy to pump huge amounts of carbon dioxide and sulfur dioxide into the air, perfectly willing to possibly irreversibly alter our climate, and perfectly willing to have acid rain, in order to continue to use fossil fuel and avoid the nuclear option. A lot of people have tried to raise that issue rationally and say, "wait a minute society, are you really weighing all the consequences here?" But society does not listen. Will we ever be able to reverse that pattern? I have no idea, but I am not going to bet on it. I do not have an answer for your question, other than to say, once the issue has gotten to the bumper sticker stage, rationality is not the answer.

Mr. Euan Baird

Chairman of the Board
President, and Chief Executive Officer
Schlumberger Limited

Tuesday, April 10, 2001
3:30 P.M.
Van Leer (ECE) Auditorium
Georgia Tech Campus

Mechanical Engineering was the first degree-granting program established at Georgia Tech. Today, the School is the oldest and second largest of the nine divisions in the College of Engineering at Georgia Tech. The School offers academic and research programs in mechanical engineering, nuclear and radiological engineering, and health physics. The enrollment includes about 1300 undergraduates and 540 graduate students. Studies are directed by 70 full-time professors, 16 research faculty, and three academic professionals, who are supported by 49 staff members. The Woodruff School is the first educational institution to be designated an ASME Historic Mechanical Engineering Heritage Site.

For additional information about the Woodruff School, contact Ward O. Winer, Eugene C. Gwaltney, Jr. Chair in Manufacturing and Chair of the Woodruff School at:

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