# TALKING TO BILL

On the occasion of the fourth TechFest at Microsoft Research--an event at which researchers demonstrate their work to the company's product developers--Bill Gates talked with *Scientific American*'s Gary Stix on topics ranging from artificial intelligence to cosmology to the innate immune system. A slightly edited version of the conversation follows. (An Innovations column on Microsoft Research, accompanied by a shorter version of this interview, appears in the June issue of *Scientific American* on page 18.)

**Scientific American: Observers have said that the 21st century is going to be the age of biology. If you were starting out today, do you think you would have preferred to go into molecular biology rather than information technology?**

**Bill Gates:** Well, information technology is advancing at a pretty unbelievable rate and some of the most interesting problems, whether they be speech recognition or machine learning or writing provable [testable] algorithms or rich visualization, and other things we've talked about for decades, will be made possible by miracle advances in hardware: chips, optical fiber speed, storage capacity. And software will make that all work on behalf of the user.

And so if you said to me, what's going to change the world the most, from how do people in an office get things done, to how do they understand how to make decisions, to what's going to drive productivity, that's information technology more than anything else. I can also make an argument for biology, the fact that fantastic things will happen in solving major diseases, both of the rich world and developing world in a 20- or 30-year time.

Information technology is becoming sort of like math was to the sciences in the 1800s or throughout history. The tools of information technology, and its ability to process data, are becoming increasingly important. And so there's even an interplay between computation and biology. Some of our top researchers at Microsoft Research are life science Ph.Ds. In fact, two of them are in machine learning and they came to that because as they looked at medical problems, they wanted algorithms that could look at correlations and build models, and so they built these Bayesian systems. And we saw the work they were doing and said we really need that, not just for medical problems.

**SA: Microsoft Research is really of interest because in 1991, at a time when almost the entire big industrial research lab world was cutting back, you were making a commitment to basic research. The question is, do you plan to continue that commitment?**

**BG:** Yeah, our research had a phenomenal payoff for us and for our users. We are dependent on our research, whether it's for creating ultra reliability or deep security, or for making it simple to deal with all the information that we've got. It's the advances out of our research lab that make us optimistic that we'll be solving these tough problems.

And that's really what Microsoft's all about, so it's at the core of what we do. The success has been incredible. We've gotten way more breakthroughs than I would have expected. We will continue to grow it in all the different locations we're in. And each location has its own sort of incredible story. We got started here in Redmond and we brought in Rick Rashid [a developer of the Mach operating system that was the basis for the one used in the NeXt computer and for Apple Computer's OS X] to get the thing going. We've started with natural language and then we've really branched out to all the different areas.

As you said, this is in a period where the Bell Labs research has been fragmented and cut back quite dramatically. The Xerox research is not nearly as large or as ambitious as it was. For a while, the Japanese came in and set up U.S. labs, that's basically gone. So we think it's a mistake that companies aren't doing these investments, but for us it's a huge payoff. I mean, it's so much inculcated into our culture now to take these things and use them to drive the next versions of the product.

The Cambridge [lab's] story is an amazing one, because our lab and the computer science department there are literally two buildings with these big corridors connecting them. And it was actually the head of Cambridge computer science, Roger Needham, who came in and created that lab. He passed away last year, but he did a phenomenal job of really getting that going and drawing talent from all over Europe.

And then Kai-Fu Lee [an expert on computer graphics, artificial intelligence and speech recognition] started the Beijing operation. He's back here running our speech group. He hired smart people and then other smart people wanted to work with smart people. And so what we ended up with in Beijing is just a phenomenon. Well, we said, "Hey, in three or four years we hope you can make some contributions." They were up and running in six months and they were showing us new graphic video algorithms. And all these interesting issues, like how these networks work together, how it can be simple to work with these things, how you're going to let video get around the home without having somebody who understands computer science to set it up and diagnose it. They're really coming up with breakthroughs that are necessary for these scenarios. And I hope you saw a lot of that as you walked around.

**SA: In the area of what you characterize as breakthroughs, what else would you say fits that bill?**

**BG:** Well, many things that we do, once they're commonplace you just take them for granted. Ink recognition is still a little bit of an amazing thing, but we'll soon take that for granted. Taking sets of images and letting the software automatically organize them for you, recognizing who's in them, putting them in a timeline. We'll just take that for granted. Speech recognition: we'll eventually just take that for granted.

In the same way that you do searches nowadays and find information on the entire World Wide Web. You and I grew up without that. We still kind of go, wow, and yet for a kid who uses this stuff it's like, well, didn't the world always work this way? When you were curious about some piece of history couldn't you always just type it in and see who was working on it and what happened and those kinds of things? Taking this for granted allows them to work in a very different fashion.

A good example is this speech server thing we're going to ship in a few months. That was based on a research breakthrough, our speech synthesis stuff. Even with something like Xbox where you say, “Hey, that's just games.” A lot of the ways that we do the deep visualization there, the way we can do forest and grass and smoke and fog, each one of those things is a wonderful breakthrough. In fact, we have some new things now related to real-time shadowing that will let these games look like high-definition scenes. They won't just look like TV scenes that we have today. As we get the next-generation of graphic software and hardware, Microsoft Research is going to bring that new level of reality.

And today if you want to buy books on the Web, you still are in that 2D world. You don't yet have the idea that you're kind of walking through a bookstore, seeing people, seeing things on shelves. Hey, we will do that. The only reason it's not being done today is you've got to make it super realistic, super quick, super easy to work with. And you combine what’s happening in three or four booths down in the Tech Fest and that's the kind of thing you'll get in a product.

**SA: Jim Kajiya [a graphics expert at Microsoft Research], whom I talked with today, said one of the big challenges is to create a set of authoring tools that allows people to work with computer graphics in the same way as, say, working with a word processing system. At this point those endeavors are really being confined to high-end ventures like movies.**

**BG:** We have this demo down there where they take a picture of yourself and they build a model of your face, not a 2D cutout, a real model of your face. And so acquiring new imagery and combining that with a 3D library of imagery, makes an environment where kids who want to learn a little bit of programming can do more than just multiply numbers. They can have objects move around in a 3D space, so it makes it far more compelling and far more accessible.

And editing home movies, that's very avant-garde today, but it won't be. Doing this thing we call Photo Story where you can take images, pan and zoom and provide audio annotations. That will just be standard fare and we'll wonder why in the past you had all these images with no sense of connection and emotion and reaction to those things. You were just sending around these images. The difference will come because the authoring tools will just be built-in to the e-mail and you'll just sit there and talk and it will build them for you.

**SA: One of the things that some critics have said is that while there is an unbelievable collection of talent here, there have not been achievements on the order of things like the transistor or some other major breakthrough. Do you do you see any validity in that?**

**BG:** Well, we do software. And if you look at the papers at SIGGRAPH [a graphics conference] and the proportion coming out of one lab, you see us in many different areas. We wish there were other labs doing more. We are a very high percentage of the non-university work being done in many of these fields. Typically in the computer field, most of the companies don't have long-term research. They just don't. IBM does have some. It's spread across a lot of different physics work and many software architectures, but it is the other big research spender in our industry. After that, the drop is so dramatic.

Take what we've done in machine translation. No, that's not as good as the transistor but it's pretty phenomenal. The stuff we're doing with speech, pretty phenomenal. Ink. Software reliability. If we weren't able to prove [test and validate] programs, we wouldn't be able to get the Internet to achieve its potential. When I left Harvard in 1975, software researchers there thought they were on the verge of being able to prove programs. That field really hadn't moved forward until a few years ago when we came to the universities and got collaboration going with Microsoft Research and said we absolutely need this to build the core software that is provably trustworthy. And now there's been these big advances.

I was on this college tour, visiting U. of Illinois, Cornell, CMU, Harvard, MIT, last week. The quality of work and the advanced things that's been done either just at Microsoft Research or in collaboration with those groups across many areas was quite incredible. An investment of the size we're making, it will be judged 20 years from now. But you'll see so many things that have to do with the digital age and bringing that forward that will have come out of these great people.

**SA: There are arguably other successful models. Gordon Moore apparently instructed Intel never to engage in basic research. That was based on his experience at Fairchild Semiconductor, in which he found that basic research was not fruitful because it never was able to get out the door. There were many worthwhile projects that were just never able to get over to the product side.**

**Now, Intel since then has largely avoided that. They have very close collaborations with universities. But given the pushing of the limits of Moore's Law that is currently occurring, they are producing in collaboration with the**

**national laboratories advanced technologies like extreme ultraviolet lithography.**

**BG:** Yeah, that's basic research. They do basic research. They fund SEMATECH [a consortium of semiconductor manufacturers]. They do that stuff themselves. They work jointly with the equipment manufacturers. They work with universities.

Their field is a different field than ours. We're not in the same field. We're not in the cooking-transistors business. We're in the building software business. We've got to do at least what is for software basic research. We've got to do it because these basic advances need to be in our products. We understand the scenarios that demand the simplicity. Who has the patience to take visual recognition and really make that breakthrough? We've been working on that for eight years. We've got good results. You could have seen in a few of the booths some great progress there.

But Butler Lampson, who's one of the researchers here, said why do there ever have to be car wrecks? Why isn't there just a little bit of hardware and software that says that you shouldn't have car wrecks? Well, he's absolutely right. That's a nice easy-to-describe goal. And yet vision is just one component that would have to be dramatically better to achieve that. And, of course, you would use it for a thousand other things besides avoiding car wrecks, but it just calls to mind and says, wow, with what the hardware people can do, what prevents that goal from being achieved? Just the need for miracle software.

Who's going to take on those various pieces? The universities are a very, very important part of the ecosystem, but they tend to do things that are kind of small scale. You've got to really do large scale things, like an ink recognition or like the ultimate step in speech or natural language-translation type work. Those things need risk-taking and drawing large groups together and getting big field testing with tons of feedback that is more appropriate for a commercial organization. So that's the kind of thing where we come in and do things that are both the same as the university but also some very unique things.

**SA: What do you see as the continuing importance of the Moore's Law curve to achieving the goals that you want for where software should go?**

**BG:** We assume hardware advances. Gordon Bell has his life memory project, where he can go back and see everything. We can store all those photos and audio. We know that storage is going to be cheap, and so let's use it on behalf of users. Another use is solving the problem of creating digital meetings where you could meet with somebody who's at a distance and the way they're brought into the meeting and the way a person can see a panoramic view of everybody. This is way beyond what people think of as videoconferencing. That's a very practical application and yet we need cheap cameras; we need lots of bandwidth.

Having a foundation of big, flat high-resolution screens, high-speed wireless Ultra Wideband is created by better chips that allow us to be ambitious and say, okay, software is the magic element that will take those hardware advances and provide user benefits. And in many cases, users don't know how starved they are. They don't expect to really be able to do sales analysis or rich collaboration or find the best seller of a product that they might want to buy and then check their reputation. Only if computer-science products comes through will they say, “Oh, well, of course, I wanted that. How did I ever get by without it?”--just like e-mail or instant messaging, or these things that have come along in the last decade.

So, yes, the collaboration with the hardware people and continued advances are very important to us. Some of the things you saw at TechFest can be done absolutely with the hardware that's there today, but for the really ambitious stuff, we need new hardware. We have a team of theoretical mathematicians working on models for quantum computing. That is a case where as we make that breakthrough, then we'll tell the hardware people how to actually build a system around it.

**SA: Have you followed the quantum computing area, and do you have any optimism about how that might play out?**

**BG:** If you take a 15-year timeframe, yes, we're investing in it. It's certainly not a guaranteed thing. It's one of the more high-risk things that we do, but we think it's fantastic to have that in our portfolio. There are some interesting theoretical results that our people have come up with. Now, it may not be mapped to an actual physical model and how that would scale and stuff like that. A lot of tough work, a lot of additional breakthroughs have yet to be made.

**SA: Well, some of the physical entities [non-Abelian anyons, a type of sub-atomic particle] need to actually be discovered before they can move ahead from theory to create the type of quantum computer that Michael Freedman is working on at Microsoft Research?**

**BG:** There is an approach that doesn't involve an advance in physics; it involves a missing piece in terms of a physical phenomenon that we don't know about. The models are in terms of existing physical phenomena. Now, can you really build that. Does it scale up? It's hard to say.

**SA: Do you see a continued relevance to the idea of artificial intelligence [AI]? The term is not used very much anymore. Some people say that's because it's ubiquitous, it's incorporated in lots of products. There are plenty of neuroscientists who say that computers are still clueless.**

**BG:** And so are neuroscientists, too. No, seriously, we don't understand the plasticity of the neurons. How does that work? There's even this recent proposal that there is, you know, prion-type shaping as part of that plasticity. We don't understand why a neuron behaves differently a day later than before. What is it that the accumulation of signals on it causes? So whenever somebody says to me, "Oh, this is like a neural network," well, how can someone say that? We don't really understand exactly what the state function is and even at a given point in time what the input-to-output equation looks like.

So there is a part of AI that we're still in the early stages of, which is true learning. Now, there's all these peripheral problems--vision, speech, things like that--that we're making huge progress in. If you just take Microsoft Research alone in those areas, those used to be defined as part of AI. Playing games used to be defined as part of AI. For particular games, it's going pretty well, but we did it without a general theory of learning. And the reason we worked on chess was really not because we needed somebody to play chess with other than humans; it was because we thought it might tell us about general learning. But instead we just did this minimax, high-speed static evaluation, a minimax search on trees. Fine.

I am an AI optimist. We've got a lot of work in machine learning, which is sort of the polite term for AI nowadays because it got so broad that it's not that well defined. But the real core piece is this machine-learning work. We have people who do Bayesian models, Support Vector Machines, lots of things that we think will be the foundation of true general-purpose AI.

**SA: What about the futuristic visions of Ray Kurzweil or Hans Moravec?**

**BG:** I'm with Ray; he's an AI optimist, I'm an AI optimist. Now, he doesn't know the road between here and there. He's been great at writing up from time to time the progress we've made. And some people think we'll never get there. I just disagree with those people. But nobody has any proofs until we really solve the problem. I think there's actually this race going on between figuring out how to do it de novo versus figuring out how evolution has done it and just sort of transferring the algorithm from carbon to silicon, because silicon has certain advantages over carbon in this. But it would be nice to do it de novo and not just do it through reverse engineering.

**SA: What about nanotechnology? Do you have any opinion on that?**

**BG:** Well, nanotechnology, when Drexler wrote his book--God, what is that, 12 years ago now or…

**SA: Actually, the first book came out in '86.**

**BG:** Okay, a long time ago when he wrote that book, the book is kind of this weird mix of hypertext enthusiasm, terrorism, fears and nanotechnology and they're kind of woven together in this weird way. Of course, the guy was a visionary and he met Ted Nelson [inventor of the term hypertext]. He's absolutely right that you can think of science a little bit on the scale of being able to manipulate objects of smaller and smaller sizes. And I'd never thought of it that way, so it was interesting to me.

Nanotechnology is a term like AI where it's been used so broadly that a lot of people prefer more specific terms now. I mean, is biology nanotechnology? Yes, nature does work at very small scales. Yes, we've been able to harness nature to generate proteins, largely medicines, at this point. I guess agriculture is harnessing nature for food. So there is absolutely this ability to move down and scale. There are some wonderful advances that are coming out of what you would broadly think of as nanotechnology.

You know, when I was visiting recently at Cornell, they showed me their building, which is called the Nanotechnology Center. And all the scientists in there I think are doing wonderful work, even if there isn't some grand unifying theory that means that all the different things that are called nanotechnology are all a single discipline.

**SA: Well, one way to look at it is that it's one of the most brilliant ways of packaging chemistry, which on the surface of it doesn't have that much allure to either people in Congress or the general public. But people are really interested in nanotechnology and a lot of it is basic chemistry.**

**BG:** Well, how interesting. I don't know if any interest is generated by naming something cleverly. You have to wonder how deep the interest is. I mean, chemistry is super interesting even if you call it chemistry. Biology builds on these little building blocks of chemistry. I love chemistry.

**SA: If the NSF created a program to look at advanced areas of chemistry, it wouldn't be getting the multi-billion dollars that it's getting for nanotechnology.**

**BG**: Well, that's a sad commentary, but we should try re-labeling some other things…Computer science is the area where the people are deeply underestimating the rate of advances that will take place. Because these tough problems have sat around for decades, there isn't this widespread recognition that the next 10 or 15 years will really be the golden era for these advances.

**SA: I have a question from another editor. He said that the fact that XP is based on the same kernel as the Windows Server line presents the classic monoculture problem, vulnerabilities with the Windows program, which can never be completely eliminated given the complexity and rate of evolution of the system. It allows attackers to exploit or damage or commandeer a large fraction of Internet-connected machines, all of which are effectively clones. One proposed solution to this problem is called metamorphic diversity. The idea is to use compilers that can produce a variety of different binary versions of the same source code by reordering lines and procedures in ways that have no effect on how the software functions. If Microsoft were to use metamorphic compilers so that all these binary codes came in**

**dozens or hundreds of different versions, again, all functioning identically, that would defeat many kinds of attacks. I'd like to know what you think of the idea of injecting these "polymorphisms" into Windows, whether Microsoft Research has tried these approaches?**

**BG:** Yeah, we should have somebody talk to the guy directly. Really. I mean, there's no simple yes/no answer. Absolutely we have things that are of this nature. In fact, there are some very specific things that are of that nature. But the whole term monoculture, that is not the problem. You're never going to have enough diversity. There are two types of things that people do when they attack. They attack a system and compromise it, or they attack it and compromise it and then spread it [the virus] to other systems. Let's say your payroll data is on a thousand different operating systems and your users are learning a thousand different user interfaces and a thousand different word processors and all that. Your payroll data is a thousand times less secure because the surface area that has to be made reliable and secure is a thousand times greater.

And so real security is about being able to say the information is protected. It's not about whether there are swarm attacks. People are over-focusing on swarm attacks. Swarm attacks are important and there are ways of preventing them with firewalls and this idea of polymorphisms he talks about is an idea. But those aren't the real issues. Swarm attacks, in a certain way, are actually forcing the breakthroughs that lead to security, that relates to something coming in and silently using a security hole to go take, say, the payroll or patient data information. And there you need to devote more energy to proving, really getting the reliability there and making sure that the hackers who do swarm attacks can't do anything. A silent attacker is really the malicious case and it's what a corporation really has to worry about. A degree of focus on getting it right a few times is way better than saying, okay, yeah, my payroll data is on a thousand systems, I may have few less swarm attacks but I have way less security.

Also, even if you had a thousand operating systems you'd still have swarm attacks. You'd have to have literally hundreds of thousands and there's just not enough computer scientists in the world to prevent swarm attacks through independent implementation. But this polymorphism thing, yes, there is some real merit to that as one of many approaches. People shouldn't think of it as the primary approach. There are things having to do with walling systems off from each other, detecting unusual behaviors, keeping software up to date, software verification, fixing the password that is a weak link, fixing the mail protocol that is a weak link.

If somebody wants to look at more than just the simplistic "monoculture" thing, and really look at the security issue, we'd love to talk about it, because we're spending billions on it. And it is amazing the breakthroughs that come out. We just had our academic advisory group on security here with the top professors in this area. And these discussions are so fantastic in terms of their seeing what we can do; they're helping push that along. We're the company in this dialogue, partly because of the swarm attacks, but you shouldn't lose sight of the real issue about how you can ever have systems that really are secure in a deep sense, not just in an anti-swarm way.

**SA: There is a company that I was doing an article on called One World Health. They took a kind of entrepreneurial approach to developing a non-profit drug company. Can you give me your estimation of what they're doing?**

**BG:** Well, they're doing great work. We're their primary funders, so you're not getting a truly independent data point here.

**SA: That's fine. I've talked to other people.**

**BG:** They're doing great stuff. Just take that one thing for Kala-azar [a parasitic disease also called leishmaniasis]. Hey, that's going to be a medicine that is going to save lots of lives. And because for these diseases of the developing world, which means the world most people live in, not most *Scientific American* readers but most people in general, these diseases haven't benefited from the advances of biology because nobody is paying attention to them. So taking the low-hanging fruit for a number of diseases--just trying out different compounds that are there--means we can make some real advances. One World is one of about five or six groups we're working with, where literally in the next two or three years they are going to have a new licensable medicine that saves hundreds and thousands of lives and improves living conditions.

This is one of the furthest along, their work on Kala-azar. And Rick Klausner [Executive director of the Global Health program at the Bill and Melinda Gates Foundation] really feels very optimistic about that and that's not the only thing they're working on. We've funded them I think for two different drug activities.

**SA: Kala-azar and then it's Chagas disease and then they're also doing diarrhea.**

**BG:** Yeah, we've got a lot of people doing diarrhea. I mean, diarrhea is big. You know, it turns out that with diarrhea, what you’re having is a transfer of the salt out of the body. Oral rehydration therapy is a way of attacking that. There's also potentially some medicinal ways to block that transfer and we have a few people going after that.

I don't know if you've seen our grand challenges thing, where we went out with NIH and said, “Okay, if you can invent things like a vaccine that doesn't need to be in cold chain throughout, that would save millions of lives because you could get vaccination coverage way, way up or if you could do some manipulation of mosquito genetics so they don't bear malaria in particular, but some others that are in the rich world as well. That would be a huge advance.” So the idea of taking the biology of this decade and the science in general of this decade and not just applying it through economic signals but also applying it through the Grand Challenges programs in health and having people know where they can save millions of lives. That's the idea of the Grand Challenges, to get the IQ to move to the important things.

Because there's a huge failure here. Over 90 percent of the money goes to less than 10 percent of the disease burden. And people ought to feel bad about that. Take the idea of an AIDS vaccine. Money didn't go to it, basically. Money went to an AIDS treatment that by and large focused on what the rich world wanted and not on what the world at large really needed.

**SA: Did you see the bio-informatics exhibit that was down there on the floor at Tech-Fest as being relevant to the work of your Foundation?**

**BG:** What, the AIDS epitope work? There was a corner booth right there. Oh yeah. I mean, that's Jim Mullins here at the University of Washington. I mean, this whole thing of really deep understanding of the immune system. We sort of understand the antibody side of the immune system and what it means to build up the memory cells. We have people like the Institute for Systems Biology [a Seattle-based non-profit institute] that are trying to do readouts of immune system memory.

**SA: Innate immunity is making a big comeback in terms of the research.**

**BG:** Now we understand that the innate immune system really is the front line and everything else is just triggered off the innate immune system. There's this book, Peter Parkham's book, called *The Immune System,* which was the last one that I read on this in which the advances I think are really incredible. I'm kind of a hobbyist in this field, but I love this field.

Anyway, being able to read out the immune system and understand immune systems, particularly the cellular side of it. That appears to be a very fundamentally interesting problem both for things like AIDS. Also, if you think that bio-terrorists will be using viral platforms, you'd like to have medicines available to block various classes of viral transmission, and so you need a kind of a deep understanding of people using Pox as a delivery vehicle and there being a way to block that. Unfortunately, there's a lot of different vectors. So anyway, this decade, next decade there will be a lot of good work there.

What these guys down at that booth use are modeling systems that will look at things as we get more of an understanding of MHC1 and MHC2 [immune cell proteins that participate in triggering the activation of other immune cells]. Exactly how you should define the epitope, particularly in the face of an adversary that is highly mutagenic. HIV is right at the top of the charts.

**SA: It would have to be a fairly sophisticated vaccine.**

**BG:** Oh, absolutely. Absolutely. There's no doubt about that. I mean, there's super-interesting data that shows that, depending on your immune type, the forms of HIV that transmits to you is different than the form that eventually defeats you and that is very dependent on your immune type.

Anyway, I could go on and on all day about this. I mean, I'm still excited about computer science, but biology, there's some very interesting advances in biology right now where tools of computation are used.

**SA: Aren't you funding work on different sub-types of AIDS??**

**BG:** Oh yeah. They don't understand in AIDS actually where the transmission takes place. Is it down low, up on high. How much is HSVII [herpes simplex virus II] involved? We really don't understand a lot about this. And so our whole model is in, say, a five-to-seven-year timeframe getting a microbicide equivalent, like Tenofovir, that can block exponential growth. If you can get just in low-prevalence countries commercial sex workers to use the microbicide or a microbicide equivalent like Tenofovir , then that buys you the time to get a vaccine. And when we say a vaccine, we mean a real vaccine. When people hear about vaccine trials for HIV, they think, "Oh, hey, I know what a vaccine does, it gives 90-some percent coverage." The likelihood that any of the first, say, three generations of trials will give any type of coverage like that is very low.

**SA: Some people have talked about a therapeutic vaccine.**

**BG:** Yes. It may actually have to be something that's useful in terms of treating people after they've got the disease. Because of this long fight between the immune system and the disease, the idea that you tilt the odds in the favor of the immune system is a possibility, a tantalizing possibility.

**SA: Are you worried that not enough people are going into the computer sciences?**

**BG:** That was the big theme of my recent tour. It's a paradox that this is the most exciting time in computer science and these are the most interesting jobs. You can see the work being done to really improve the creativity and the communications and effectiveness of hundreds of millions of people. These jobs should be way more interesting than even going to Wall Street or being a lawyer--or I can argue for anything but perhaps biology, and there it's just a tie.

And yet the number of people going in has gone down and it's hard to measure whether we are getting the best and brightest. Isn't there this huge disparity between the fact that we're getting the best and brightest in China and India, and the numbers are just going up in China and in India, and does that mean that the country will have to let those people come here or does it mean the good work in the future won't be done here?

So we really need a rededication to what's made the U.S. such a leader, and when it comes to computer science research at the university level and commercial level, the U.S. is at this point way, way ahead. I mean, if you took the top 10 universities, most lists would have zero to two non-U.S. universities on it. If you took commercial research centers, the top five would be U.S. based. So anyway the whole point of the tour was having the kids see the potential, have the excitement, and have me listening to their concerns, and seeing what are the faculty concerns and how Microsoft can work better with the faculty members.

**SA: Why is it the most exciting time to be in computer science?**

**BG:** Because this is when we're going to build tools so you can go home and say, “Hey, the way we stay in touch with our relatives, the way we organize our schedule, the way that we choose the shows that would be interesting to watch, all the things we do that are creative or the way you have meetings are so inefficient today.” They’re still done with paper and notes and no follow-up and no way of searching to look back at things. In a digital world, that should not be the case. You should have remote participants, you should have the transcript, you should be able to look the thing up, send it around to other people, that's just common sense. And we're doing that. I mean, there's one group down there alone, the Ping booth, that if you only came to Microsoft and saw that booth, you should go, wow, if you can take all the time people spend in meetings and make it 15 percent more effective, what would that mean in terms of productivity advances that you can apply to cost savings, higher quality products, getting things to market faster.

What we saw in the late '90s in terms of productivity increases was way less than what computer science will deliver in this decade, way less. And yet it was quite impactful, particularly in the U.S., where people took advantage of those things, mostly around the Internet, more than in other countries. And now we have more than double that happening. Now we're building up the infrastructure, dealing with the tough problems of security and reliability, and yet it's not clear whether we're getting the best and brightest in the U.S. to go into these programs and contribute to solving these problems.

**SA: Why is that?**

**BG:** Oh, it's partly that the bubble burst. It's partly articulating the benefits of the field and the variety of jobs. People have to know that these are social jobs, not just sitting in cubicles programming at night. Our field is still not doing a good job drawing in minorities or women, so you're giving up over half the potential entrants just right there.

Carnegie-Mellon has done probably the most on some of these areas, where they do outreach programs down to the high school where they show people what the computer sciences do, they show women and it's actually women who often go out and give these talks. There's definitely some best practices there that need to be pushed forward. One other thing you might want to look at is this thing that Jim Gray [an expert in databases] has done. We have this thing where all the sciences are dealing with lots of data. And astronomy is a nice thing, because people can kind of understand that it's not just about the people who were up at three in the morning who have their eyes sitting there watching the supernova and then they write a Ph.D. about that. It's data from all over the globe with different wavelengths, different resolutions, and any theory you have about, oh, cluster grouping or pulsar aging or background radiation. You want to take all this data, all these observations and see if what you're proposing is consistent with all of that data.

And so Jim Gray, who's a database expert and a Turing Award winner, and very well known within the world of computer science. He said, "Hey, I'll sit down with some people in astronomy and we'll figure out how to create this logical database that you can navigate not sort of in classic computer science terms, not in relational database query type terms, but in the terms that astronomers think of and we'll make that natural to them. And even though the bits are stored all over the world and in these very different representations, I'm going to make it so you can think of that as one thing." And this has gotten to critical mass where people are working with it and connecting the things up. It's already helping people get things done.

That is the kind of thing that needs to be done in the other sciences, and we're just beginning to find partners and to see how to do that in biology. Biology is hard, because the breadth of the data in terms of genomics, proteomics, drug trials. It's just even richer than astronomy in terms of what you've got there. But only by putting this into really navigable, query-rich things can everybody have the benefit of all this work going on. So we take Web services and our database and visualization technologies and sit down with these people in these domains that are very deep and say, okay, how should this be represented, how should you navigate it?

Anyway, that whole thing, that's such an interesting trend in the sciences that it's kind of what we call a digital science. It's an era where the digital information is really a core asset of the science, that all the sciences should have a way of getting that without writing lots of funny code.

**SA: Besides information sciences and biology, cosmology is an area now that's really growing.**

**BG:** Well, partly yeah because researchers have a lot of interesting data.

**SA: The stuff that's happening with dark energy is really interesting.**

**BG:** It's interesting but computer science is what's going to change the world. It's good for you guys to do articles about cosmology, because everybody has a certain fascination with it. But it won't change their lives quite as much. Nor should every kid go into it.

**SA: No, that's true, but there's the idea that you might be able to test string theory in some way.**

**BG:** Yeah, we might be able to eliminate some of the variations of how the unification might get done. As a hobbyist, yes, that is fun stuff.