26 Establishing Federal Priorities in Science and Technology

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This chapter discusses two things. First, it outlines where research and development (R&D) funding is going and some of the ideas we used during the last half of the Clinton Administration to increase funding. Second, it discusses what I consider serious barriers to the continued growth of the R&D portfolio in the United States.

Funding

If we believe that increased funding is good, then we have to determine how we are going to increase it. As we look through the R&D portfolio, there seem to be two ways we can increase the level of funding. One way to do this is to say that science is good, so fund more of it. Scientists believe that this is a compelling argument that everyone should accept, but, in fact, it is not a very compelling argument. It does not go very far outside the scientific community, or with Congress. It is good enough to get an increase of the inflation rate plus one or two percent, but at that rate, it will take 35 years to double R&D funding.

Another way of getting increased funding is to use the initiative-based argument for increasing R&D. With this method, you make such a compelling argument that a certain area is so important for some reason (you have to define the reason), that we should put huge amounts of money into this area. This is how the National Institutes of Health can get such huge budget increases.

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It is quite a simple algorithm. For example, funding basic research in cell biology will lead to a better understanding of some mechanism, which no American now understands, but may (and you must use the word “may”) lead to a cure for “x.” Everybody knows somebody who has “x.” People do not know the first thing about cell biology, but they see the compelling reason for doubling that budget because they do know something about “x.” We have to take that same approach in the physical sciences and engineering. We have to make compelling arguments that people will understand. We also have to stop talking to ourselves so much and spend more time talking to citizens at Rotary Clubs, for example, to make our case. A Rotary Club represents a different constituency than those we usually speak with. We have spent entirely too much time talking to ourselves.

Some examples will illustrate initiative-based funding. Several years ago, we proposed an initiative in information technology and asked for an increase of 32 percent in one year. We got that increase. The next year we asked for another increase of over 33 percent in information technology. And we got that one. We would never have been able to get these kinds of increases from the National Science Foundation without the initiatives.

The next year, we proposed an 84 percent increase in nanotechnology, and we got about a 64 percent increase in one year. One of the elements of this initiative was reporting what other countries are also doing. For budget purposes, we considered Europe one country. Both Europe and Japan are spending far more than we are.

I was recently in Japan and talked about nanotechnology at a meeting of the Japan Society for Precision Engineering. The participants were very pleased to tell me that they are now spending as much money in nanotechnology as we are going to spend this year (about $420 million). I said that was great, because that means we can go back to Congress next year and say that Japan is already spending that much. Then next year, we can ask for the same amount of money, and we can continue to ratchet the number up.

What are the reasons for developing nanotechnology? We have to think about grand challenges, things that people will understand, that they could read on a bumper sticker. For example, we can develop a material that is ten times stronger than steel and a fraction of the weight. Everyone can understand the benefits of this. If we could fundamentally change the way we make automobiles and airplanes, we could change everything that we manufacture. Or we could suggest finding a way to store the Library of Congress on a medium the size of a sugar cube. We would probably never want to do that because the read-out device would present too much of a challenge. But, investigating ways to develop huge storage capacity is very valuable. Everyone can understand this.

Initiatives in nanotechnology and information technology have the compelling argument of economic growth. That is why we always project ten years into the future. If these areas are going to be so important to the economic growth of the United States, we can not afford not to invest in them. So the question is what the next area will be. What will the new initiatives be? What are some emerging areas that we should be looking at?

When I first came to the White House in 1997, a group of us who did science policy dissected the President's State of the Union Address. We took all of the themes from the Address and wrote them on a board. We saw themes on children, crime, Social Security, and so forth. Then we went back and put the word "tech" after each one. So we generated words like kidtech, crimetech, and Social Security tech. We looked at the social agenda first and then tried to determine how the science and technology could support it. Traditionally, we think about things along the discipline axis, but here we turned that around. For example, crimetech meant the use of technology to reduce the cost of crime. In the United States we spend $100 billion a year on policing, incarceration, and the judicial system. That is not even the full cost of crime. That is the number that people can agree on because they can add it up. This does not include costs around social issues. How can we use technology to reduce that $100 billion by $10 billion by the year 2010? What kind of investments would we have to make? If we invested $1 billion every year for the next year, we would get the return on investment back in one year.

Another example is eldertech (this was used as a working title for Social Security tech). Suppose you become deaf. You want a device with directional microphones built into your eyeglasses so you pick up only the sound in your field of view. You have a voice recognition system that is speaker- and accent-independent (which does not exist today) that requires no training and is also built into the glasses. This is where nanotechnology is going to be used to sort an enormous amount of data. Finally, you will need a display unit (which does exist today) that works on the inside of the lenses and shows the words coming across in a marquee display. As you make eye contact with someone speaking, you see the words come across in front of you. The technology enables you to communicate directly with others.

We would invest in some of these technologies anyway (e.g., voice recognition). But this initiative allows us to take that particular part of the agenda and tie it into something that everyone can understand. Your neighbors can understand that it is an important issue.

Some Problems

Figure 1 shows the first of what I see as very serious problems. This chart shows April's unemployment data. The only number ever reported in the newspaper is the overall unemployment rate for people 16 years and over. In this case, that rate is 4.5 percent.

We never see the breakdown by educational field or educational level. But these numbers are extremely important in a high-tech society. We need to see the unemployment rates for people with less than a high school diploma up to college graduates and above. For college graduates (which include people with advanced degrees), the unemployment

Figure 1
Workforce Issues

Unemployment by Education

	Apr-99		Apr-01		Max %	Min%	% Jan 93
Over 25 years of age	Number 1000's	%	Number 1000's	%	Last 24 months		
Less than HS	808	6.8%	813	6.6%	7.7%	6.0%	11.1%
HS-No college	1,337	3.6%	1,403	3.8%	3.9%	3.2%	6.6%
Some College	956	3.0%	978	3.0%	3.0%	2.4%	5.6%
College Graduates	750	2.1%	845	2.3%	2.3%	1.5%	3.1%
Sum	3871	3.3%	4,043	3.4%	3.4%	2.9%	5.8%
Overall Unemployment (16 and over)			6,402	4.5%	4.5%	3.9%	7.3%

All numbers are seasonally adjusted from data of the Bureau of Labor Statistics (www.bls.gov) Tables A-3 and A-9
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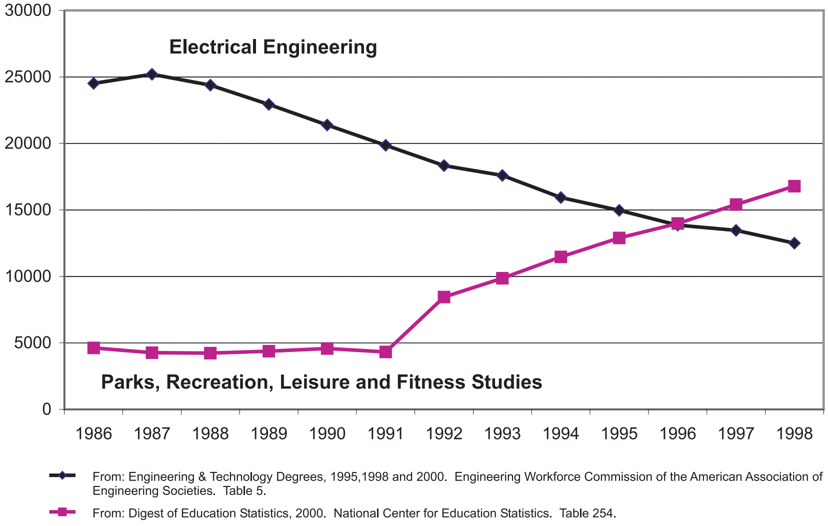
rate is about two percent. Over the last two years the rate in the far two columns has had a very narrow range.

Figure 2 shows that electrical engineering baccalaureate degrees in the last 13 years peaked in 1987 at 25,000. Last year, it was 12,500, one-half of the number in 1987. The 1990s were a high-tech era. We expect people to go into this field during this time because everyone was doing high tech. We would see the same trend in mechanical engineering or any of the physics-based engineering fields. The only trend counter to this is in biomedical engineering (BME). But, largely due to the number of BME programs in this country, we are seeing an increase in BME enrollments.

If the unemployment is so low, why major in something hard like electrical engineering? Students coming out of school today do not know the meaning of the word "recession," so they are not thinking about going into "recession-proof" fields. Figure 3 shows what people are majoring in by area. We graduate about 1.2 million baccalaureate students every year. The number one major is business with about 20 percent of the total. Education is third with about 100,000, or less than ten percent of the total.

Figure 2
Bachelor's Degrees Conferred by Institutions of Higher Education



From: Engineering & Technology Degrees, 1995,1998 and 2000. Engineering Workforce Commission of the American Association of Engineering Societies. Table 5.

From: Digest of Education Statistics, 2000. National Center for Education Statistics. Table 254.

Figure 3
U.S. Higher Education Data (1997–98)

Bachelor's Degrees

Total Number	**1,184,406**	**1%**
Field	**Number Previous Year**	**Change from**
Business	233,119	3%
Social Sciences/History	125,040	0%
Education	**105,968**	**1%**
Health Professions	84,379	-1%
Psychology	73,972	0%
Biological Sciences	65,868	3%
Engineering	**59,910**	**-2%**
Visual/Performing Arts	52,077	4%
English	49,708	1%
Communications	49,385	4%
Liberal/General Studies	33,202	-4%
Computer/Information Sciences	26,852	8%
Multi/Interdisciplinary	26,163	0%
Protective Services	25,076	0%
Public Admin & Services	20,408	-1%
Physical Sciences	**19,416**	**-1%**
Home Economics	17,296	4%
Parks, Recreation, Leisure	16,781	9%
Mathematics	12,328	-4%
All Others	87,458	-1%

Source: National Center for Education Statistics (nces.ed.gov)

One of my favorite topics is K-12 education, so I want to focus on this. In the United States, we have three million K-12 teachers right now. We will need about 2.2 million teachers in the next ten years. That is, we are going to have to replace over two-thirds of our teachers. Of course, a suburban school district can find a social studies teacher, but science, math, technology, and language teachers are in short supply in most places. And some districts with large populations of students have a hard time finding teachers in all areas, even social studies.

With a need for 2.2 million teachers over ten years, we will require 220,000 teachers every year. And the need will get more acute in later years. It is not as bad this year as it will be in the year 2010. Right now we are generating about 100,000 undergraduate education graduates per year, less than half of what we need. But we should look more closely at that number.

If you survey those teaching graduates a year after leaving school, you will find only about 60 percent actually teaching. The rest have left the field or are earning graduate degrees. (Of course, graduate degrees may be required in some states for being a licensed teacher.) About 100,000 graduate degrees are awarded each year, but generating a degree in education does not mean creating a new teacher. Many teachers are receiving their degrees by going to school part-time while they are teaching. We estimate that about 120,000-140,000 new teachers enter the classroom each year with a demand for approximately 200,000. We have a critical problem here, more so in science and math than in other areas.

We have two serious problems at the university level here. One is the number of graduate degrees in engineering and sciences being awarded. Departments recruiting electrical engineering graduate students will get them primarily from two sources: those who receive undergraduate degrees in electrical engineering and those who receive undergraduate degrees in physics. We have halved the numbers in electrical engineering, and physics is at an all-time low. The number of baccalaureate degrees in physics today is about 3,800, which is a 40-year low. In fact, we are graduating fewer people in physics today than we did before Sputnik was launched in 1957. So fewer physics graduates are available to become teachers. The only way to maintain the number of students in graduate programs is to admit more foreign students. Electrical engineering graduates with bachelor's degrees have tremendous opportunities for jobs with good salaries. They can choose between a salary of $55,000 a year or the expense of $15,000 a year to be a graduate student for six years to get a Ph.D. For most, the choice is obvious.

Another problem is finding enough engineering faculty members. (The cost of start-up packages for faculty has become a real drain on academic resources.) Figure 4 shows how we are doing internationally. It shows the top ten countries in the world by the number of baccalaureate degrees they grant. The United States awards the most degrees. The second column normalizes the data to the number of 24-year-olds because that gives a measure of how well-educated the population is. Right now about a third of U.S. 24-year-olds have baccalaureate degrees. That is a high percentage, but the leading country in the world is actually Can-

Figure 4
Undergraduate Degrees

1997 or Most Recent Year

	Number of Degrees	**% of 24-Year Olds**
United States	1,179,815	32.1%
India	750,000	4.8%
Japan	524,512	28.0%
Russia	406,527	19.9%
China	325,484	1.4%
United Kingdom	258,753	35.1%
Brazil	245,401	8.2%
German (Long and Short)	212,970	24.3%
South Korea	196,566	23.3%
Mexico	191,024	9.3%
Total	4,291,052	
Worldwide Total	6,355,621	8.9%

Source: Science and Engineering Indicators 2000, NSF, Table 4-18

ada with almost 40 percent. (But they do not award enough degrees to be included in this chart.)

The most interesting number is the one for China, where only 325,000 people receive baccalaureate degrees each year. This represents only 1.4 percent of the 24-year-olds.

What does this mean in the long term for economic growth? To answer this question, I wanted to know how many of these degrees were awarded to engineering students. Figure 5 reorders the data. The number one nation in the world for engineering majors is China. China awards almost 2.5 times the number of undergraduate engineering degrees than the United States does. Of course, people in China are probably not going to major in sociology. So some majors are not available in China. Students' choices are more limited in China than in the United States. The same thing is true in the former Soviet Union. Bright young people can go into math, science, and engineering because they are apolitical.

Figure 5
Undergraduate B.S.

Engineering Degrees

	Number of Degrees	% of BS/BA Degrees
Worldwide Total	878,449	13.8%
China	148,844	45.7%
Russia	131,777	32.4%
Japan	102,951	19.6%
United States	63,114	5.3%
South Korea	41,309	21.0%
Germany (Long and Short)	39,855	18.7%
Mexico	34,231	17.9%
India	29,000	3.9%
France (Long)	22,828	21.0%
United Kingdom	22,574	8.7%
Total	636,483	72.5%

Source: Science and Engineering Indicators 2000, *NSF, Tables 4-18 and 4-20.*

This has some very interesting public policy implications. What area are these people working in? Are they working in defense/warfare activities? Or are they working in consumer products? Those are entirely different public policy agendas.

Figure 6 shows Ph.D.s and advanced degrees. The first line includes about 40,000 Ph.D.s and 5,000 education doctorates. The next line shows the number of lawyers we are generating every year. We are generating about one lawyer for every Ph.D. in education. This has some very serious implications for innovation in the long term.

The lines in the bottom half of the figure break down by field the 45,000 Ph.D.s/Ed.D.s. The number one area is education, which is good, but there are only about 7,000 degrees awarded. Engineering has 6,200. We are graduating only 6,200 engineering Ph.D.s every year in this country. People are shocked that this number is so small. They think it is a huge number because of the H-1B visa program. About 3,000 of this total were foreign students. So there are only about 3,200 degrees awarded to U.S. citizens. This, of course, has implication for national labs and defense contracting.

Figure 6
Ph.D.'s and Other Professional Degrees

	Number	**Change from Previous Year**
Ph.D. and Ed.D.	45,925	0%
JD	39,331	-2%
MD	15,424	-1%
Divinity	5,873	5%
D.D.S.	4,032	9%
Chiropractic	3,735	2%
Pharmacy	3,660	35%
D.V.M.	2,193	0%
All Other Fields	4,105	3%
Total	124,278	1%
Ph.D. and Ed.D.:		
Education	6,729	0%
Engineering	**5,980**	**-4%**
Biological Sciences	4,961	3%
Physical Sciences	4,571	2%
Social Science/History	4,127	3%
Psychology	4,073	0%
Health Professions	2,484	-7%
English	1,639	4%
Theological Studies	1,460	5%
Business	1,290	-3%
Computer Science	**858**	**0%**
All Others	7,838	1%

Source: Digest of Education Statistics, 2000*; National Center for Education Statistics (nces.ed.gov)*

The bottom line shows computer science. Only 857 Ph.D.s were awarded in computer science that year. This number was down one percent from the previous year (which is only eight or nine people).

Information technology (IT) relies on computer science departments. But where are we going to get the faculty to train the next generation of students? People with computer doctorates have tremendous opportunities in the private sector, notwithstanding the stock market's recent decline. IT is going to be with us for a long, long time, and we need to figure out how to supply the resources. If we want to expand the IT field, we need to expand these departments.

One of the key issues for policymakers at universities is the cost of retention versus the cost of recruiting. Universities have to put up their own money from the money available for research in order to recruit faculty. At the University of Rochester, a start-up package for someone in the physical sciences or engineering who is doing experimental research is between $500,000 and $1 million. We do not have good sources of revenue for that money. But we have to put it up because we have a shortage of people and we are all competing with one another. That is good for the faculty, of course, because salaries go up, and increasing salaries move people into the field. But putting that money up front is a real problem for the university.

Solutions

I have some ideas for solutions. The teachers we need over the next decade are currently in our school system. They are between 11 and 21 years of age, fourth grade and higher. And they are taking science and math. How are we going to get them at least neutral on science and math? On average, they are coming out of high school with an apparent dislike for science and math. We need to involve the colleges of education in solving this problem because they have the people we need to turn on to science and math. We have to make all teachers comfortable with science and math so they in turn can engage the students in positive ways. Those of us in science and engineering have to help to educate the teachers who will educate the young people.

We also have to think about increasing graduate student stipends. They have to be at least $20,000. This year's budget has a proposal for the National Science Foundation to raise stipends to $20,000. (They really should be $25,000.) If we are going to attract American students into graduate school, those numbers have to be increased.

Finally, I will repeat what I said above because it is so incredibly important. We have got to spend more time talking to people who are not scientists and engineers. If we are going to have an impact and increase the funding in science and engineering, we will have to make the case to the general public. They are the ones who will decide to fund or not to fund R&D research.