Remarks
For
Vice President Al Gore
to
The National Academy of Engineering
on the Occasion of the Draper Award
Washington, D.C.
September 26, 1995

(ACKNOWLEDGEMENTS FROM ADVANCE)

In the mid-1950s a scientist came to Cambridge University hoping to meet Paul Dirac, who had earlier won the Nobel Prize in Physics. The scientist succeeded in being seated next to Dirac at dinner but, once in the distinguished man's presence, became speechless. Finally, turning to the bad weather outside as a convenient topic, the scientist said, "It is very windy, Professor." Dirac said nothing but, after a few seconds, rose and left the table. The scientist was mortified, convinced that he had somehow offended his hero. Dirac went to the door, opened it, looked out, came back, sat down and said "Yes."

That anecdote tells much of the story of modern science: searching for data to support even the most self-evident hypothesis.

But that view of science, obvious to us now, has not always prevailed. The arrival of the Scientific Revolution, when Galileo and Kepler and Newton changed our vision of the universe, dramatically changed not only what we were able to discover but also how we were able to think about the world around us.

There are many theories on what caused the Scientific Revolution in Europe: the rise of religious pluralism; the increased status of scientists in society; the end of feudalism; the invention of the printing press and its contribution to the rapid dissemination of information.

These changes in external society were mirrored by two changes internal to human thinking.

Fundamental was the separation of Scientific Ideology from Scientific Fact. No longer would the laws of motion be what Aristotle said they must be; no longer would a geocentric theory of the universe be free from challenge; no longer would medical students observe an autopsy while professors of medicine read from Roman texts that were obviously wrong, but devoutly followed.

A second fundamental change was that scientists and inventors were now free from restrictive notions of what they could achieve. They were free to engage in a profoundly optimistic enterprise -- the discovery of science and the invention of technology.

Both aspects of the heritage of the Scientific Revolution are critical to us today. First, the contest between ideology and fact, in the context of the federal budget, is a clash between those who imagine the world as conforming to rigid ideology and those, like President Clinton, who look to the facts and seek concrete results for the American people.

Second, the freedom to take advantage of new opportunities is reflected in the President's commitment to progress that creates jobs and strengthens families.

We are now facing in Washington a debate about the work of government. The President and the Republican Congress have both proposed to balance the budget. Yet the great divide that remains is over the priorities that this nation will endorse over the next decade. And whether, as the President and I believe, science and technology must remain a key priority of our budget.

Look at the evidence.

From basic research to product development, public and private investment in science and technology have made this nation the most innovative in the world. We have generated new knowledge, spawned new industries, created new jobs, sustained economic and national security and increased our standard of living. Research by government and private industry working together has lead to the computer, the Internet, lasers, microwave ovens, aircraft, satellites and medical devices that have changed the way that we work, play and live..

These are the facts.

Since World War II, innovation has been responsible for at least a quarter -- and possibly as much as half -- of the Nation's economic growth.

It is no accident that industries that grew from federal investments -- in agriculture, aeronautics, computers, biotechnology and medical devices, to name a few, dominate world markets today.

Take, as just one example, the Internet. Begun as an experimental partnership between the federal government, the private sector and university researchers, it has grown into a vibrant platform for education and creativity.

And for commerce, sales of products through on-line services are expected to soar from about $200 million this year to $4.8 billion in 1998. One magazine estimates that more than 21,000 businesses -- up from just over 1,000 in 1990 -- are connected to the Net. We've all read about the early success of stock offerings in companies that propose to make use of the Internet easier and more productive.

In other words, the federal government, through a farsighted and wise investment, allowed us as a nation to do together what no one would have accomplished alone. And then get out of the way when its work was done.

Yet, despite this evidence, Congress has proposed to dramatically reduce funding for science and technology. The American Academy for the Advancement of Science estimates that the Republican budget resolution cuts federal investment in civilian R&D by one-third over the next seven years.

In the name of ideology, the Republican Congress is taking particular aim at federal investments in high-risk, long-term R&D -- and in particular those merit-based, cost-shared efforts that bridge the gap between basic research, on the one hand, and commercial development of products, on the other.

These are investments that are highly leveraged, with huge potential payoffs to the economy. And they are a small, but absolutely critical, part of our nation's R&D portfolio.

Let me emphasize that this is an ideological choice made by the congressional majority, not an economic necessity. The President's balanced budget preserves critical science and technology investments.

The congressional choice reflects misguided ideology -- the view that the private markets will immediately replace lost federal support and continue our technological leadership in the world.

There is no doubt that the private marketplace is the prime driver of science and technology. There is no doubt that the freedom to compete has made this nation a world leader in information technology and in telecommunications, to name just two areas of success. Competition improves the quality of products, lowers prices and increases consumer choice.

But the marketplace is fallible and can fail to devote sufficient resources to research and development -- especially long-term, risky projects whose benefits are difficult for any single firm to capture.

Markets themselves, and our economy as a whole, are facing new challenges that make our present support of future technologies even more important. As a nation, we face two dominant trends: the increased globalization of markets and the fast pace of advancing technology. We face relentless competition from all sides, at home and abroad. Companies now measure product life-cycles in months, not years.

It is a fact, spurred by the changes in our economy, that American business today spends only about 5 percent of their R&D dollars on basic research.

It is a fact that public and private sector investment in R&D in the United States has been anemic for more than a decade.

It is a fact that premier U.S. high-technology firms continue to reduce long-term R&D investments, instead focusing on short-term product commercialization. Since 1992, companies like AT&T, General Electric, IBM, Kodak, Texaco and Xerox -- world renowned for their investment in long-term R&D -- have dramatically reduced their R&D spending.

It is a fact that our foreign competitors grasp the economic importance of research and development. Japan currently invests 35 percent more than the United States on a per capita basis and recently announced plans to double the country's R&D spending by the year 2000. Germany invests 30 percent more on the same basis. Even emerging economic powers like China, India, Taiwan, Singapore, and South Korea have been aggressively promoting investment in and deployment of technology. Just this year, China announced that it will increase publicly-supported R&D by nearly 1 percent of GDP by the year 2000.

In the absence of private-public efforts, will the private sector step in?

That's not what the evidence suggests. Independent analysis shows that over the past 30 years a decrease in federal funding of R&D on average is followed by a decrease in industry spending on R&D on year later. In other words, lower federal spending in the future will be matched by lower private spending.

We cannot, as a nation, afford to spiral into technological obsolescence, particularly when technology is becoming more important to economic growth and quality of life -- not less. To be competitive, our nation must balance our budget, must ensure that our workers continue to be the best in the world, must take advantage of foreign trade, and must continue to make this nation a center of innovation, scientific and technological advance.

Technology underpins America's fastest growing industries and high-wage jobs.

That, in the end, is why the President's vision -- and plan -- for a strong and prosperous future maintains investments in science and technology, including pragmatic industry-led technology efforts like Commerce's Advanced Technology Program; technology transfer programs like Energy's Cooperative Research and Development Agreements; support of dual-use technologies, through the Defense Department's Technology Reinvestment Project; and work to enhance market-led solutions to environmental challenges, like the EPA's Environmental Technology Initiative.

This is work that must not be abandoned.

And that fact is recognized by businesses and academicians who reject these proposed cuts as unwise, unacceptable and unnecessary.

Consider Robert Cross, chief executive of NanoPhase Technologies Corp., a former participant in the Advanced Technology Program. He said, "I'm a Republican and fiscal conservative. I hate government programs. . . But this one works."

Consider the Institute for Electrical and Electronics Engineers, which warned that the "current proposed cuts to Federal R&D funding [are] short-sighted, disproportionate, detrimental to the profession, and potentially harmful to our economic and technological competitiveness."

Or consider the Industrial Research Institute, which predicted that the "proposed cuts clearly will have a long-range impact on industry's capacity to carry on technological innovation and compete globally in the next century."

This is not about "basic" versus "applied" R&D, as some have tried to cast the debate. As you all know, those are simplistic, artificial, and unrealistic distinctions. This debate is about ensuring that our nation has at its disposal all the tools necessary for generating new ideas, promoting innovation, and helping American companies and workers compete and win in the global economy.

Oliver Wendell Holmes once said that "[t]he life of the law has not been logic, it has been experience." Yet today's lawmakers seem determined to harm our nation's competitiveness through bad logic that ignores experience and the facts.

By contrast, President Clinton has emphasized that his budget is based, not on ideology, but of a firm commitment to securing a strong, prosperous and optimistic future for this nation.

That is what the President's balanced-budget will accomplish and that it why it must be enacted into law.

We can only be successful, however, with your help. Each of you, in this distinguished audience, must make your views known. I urge you to tell Congress what you and I both know -- that the investments in science and technology -- like the ATP, TRP, CRADAs, and Environmental technologies -- must be maintained.

Even when that fight is won, however, our work will not be finished. We must confront doubts about the heritage of the Scientific Revolution.

The Scientific Revolution helped introduce the idea of progress because it was, after all, a profoundly democratic change. It meant that the truth need not come from the ancient scientists or established authorities. It meant that truth could be discovered by anyone and that any person's discovery or opinion was worthy of as much respect as that of the most revered scholar. By opening opportunity, it unleashed creativity and innovation.

Indeed, it is not, I believe, wholly coincidental, that the creation of modern political democracy followed the Scientific Revolution: the Age of Enlightenment and the founding of this great nation: secured upon the principle, which we have ever worked to realize, that in the political realm as well, all of us are created equal.

Nor is it wholly coincidental that the author of our Declaration of Independence also wrote that "Science is more important in a republic than in any other government."

In other words, our nation exists not as heirs to dynastic conquests or ancient empires, but as an experiment in democracy led by people schooled in the epic of the Scientific Revolution.

But to attack the pursuit of science and technology is wrong -- and itself dangerous. Science is knowledge and technology is a tool. The knowledge we have gained and the tools that we have used have improved our lives, safeguarded our children from disease and created jobs and industries for the benefit of the nation.

That is why we must keep in focus, however, what the founders of the Scientific and American Revolutions kept uppermost in their minds: That knowledge and opportunity are ours to achieve.

After all,it is science and technology that help us to discover the nature of global warming; the hole in the ozone over Antarctica; the means of communicating knowledge across great distances. It is science, carried on through the GLOBE program, that permits children in over 1,900 schools and over twenty countries to monitor our environment, share their data and learn the importance of science by doing science.

That is why we must remember that the legacy of the Scientific and American Revolutions is a story of optimism and a cause for hope.

If we are determined to ensure that technology will create new jobs and new markets for new products and new services, then we can work to that end.

If we are determined that information technologies will enrich the education of all of our children, then, as President Clinton and I recently emphasized, we have the power to do that too.

If we are determined that television will not isolate us from one another; then we have the power to strengthen communities and families.

I began by telling a story about one Nobel Laureate. Let me quote another now. When William Faulkner won his Nobel Prize in 1950, he was celebrated for a body of work that included "The Sound and the Fury", a book whose last line said simply "They endured."

But when William Faulkner accepted his Nobel Prize he did not counsel mere acceptance of fate. Instead, he said: "I believe that man will not merely endure; he will prevail."

We can stop supporting science and technology and education and yet we may endure. But if we are determined to prevail, we must do more.

Last week, President Clinton and I traveled to San Francisco to announce a private effort that will, by the end of this school year, make Internet access available to every California K-12 school and that will wire 20% of the K-12 classrooms in that state.

These commitments are a major step forward; but, as we made clear, they are only a beginning. To be effective it is not enough merely to have connections; to be effective education itself must be enriched.

That is why the President and I made plain our national goals: To ensure that every student has access to computers; to ensure that every classroom is connected to each other and to the outside world; to ensure that teachers are trained in the use of technology; and to boost the creation of challenging educational software.

We made a commitment to establish these goals as a national vision of what we must do to enhance the future of our children. This fall, we will meet with businesses, state and local governments, teachers, and parents. With them, we will create a national vision that will be implemented and led by communities and parents across the nation.

Through these efforts, and with the spirit of optimism that has always characterized invention, we will prevail.

The Draper Award is, in my view, is a symbol of that optimism. Past winners include the developers of the semiconductor microchip, the jet engine and the first general-purpose programming language for computers.

These works demonstrate concretely that we can build and prosper together -- if we are willing to expand our knowledge and invent new tools: If we build on experience and facts and ignore hysteria and blind ideology.

It is the responsibility of an informed citizenry, but especially of you, who work every day as heirs to the Scientific Revolution, to remind and teach and counsel our fellow citizens; to remind and teach and counsel them about the prospect of scientific and technological achievement -- and about the hope that it brings for our future.

Thank you.

Prepared Remarks of
Vice President Al Gore

American Association for the Advancement of Science
Baltimore, MD
February 12, 1996

The Technology Challenge: What is the Role of Science in American Society?

Over the next three days, I will be delivering three speeches on America's technology challenges. Tomorrow, in Virginia, I'll ask: How must we update our notions of self-government and bring them into harmony with the Information Age? On Wednesday, in Philadelphia, I'll celebrate the 50th anniversary of the ENIAC computer and ask: Are we providing the spark to ignite private innovation, new industries, and better jobs?

But today, before this extraordinary collection of minds, I'll ask the question that in many ways must precede the others: What is the role of science in American society? Why does science matter anyway?

These are complex questions. And no one person has all the answers. I certainly don't. In fact, before I proceed further this morning, I want to recalibrate your expectations. As you listen during the next half-hour; feel free to think our session as a biology class. But don't think of me as the professor. Think of me as the frog.

So let me begin by describing a deep -- but little noticed -- change in the pond of our public life. Not too long ago, the metaphors of science migrated easily to the realm of political and economic affairs. In previous generations, the logic and lingo of science -- from Newtonian physics to the industrial science of Frederick Taylor -- informed our public conversation. But not today -- or at least not very often. When when I day that our current, chaotic political culture reminds me of Ilya Prigogine -- that because our system has more and more energy coming in, it will eventually reorganize itself into a complicated and unpredictable new system . . . nobody has a clue what I'm talking about.

As a result, the language we use to discuss public problems is less vivid and less robust than it ought to be. Chaos theory may offer clues for when government should intervene in the economy. Economic policy perhaps should focus less on "priming the pump" -- and more an "imprinting the DNA." Evolution could offer insight into our social structures. But at the moment, we lack the vocabulary to even begin such discussions.

We either avoid scientific metaphors altogether -- or we lean against the crutch of Industrial Age metaphors that are splintering with age. In particular, we continue to rely on the metaphor of the factory -- of mechanized mass production -- well after it has exhausted much of its supportive force.

So today, in the spirit of academic inquiry, let me propose an alternative metaphor . . . an updated metaphor . . . a metaphor more appropriate to the times and more muscular in its power to explain. It is the metaphor of <u>distributed intelligence</u>.

In the beginning of the mainframe computer era, computers relied almost totally on huge central processing units surrounded by large fields of memory. The design was much like a mass-production factory. The CPU would send out to the field of memory for raw information that needed to be processed, bring it back to the center, do the work, and then distribute the answer back into the field of memory. This technique performed certain tasks well -- especially those that benefited from a rigid hierarchy or that depended on the outer reaches only for rote tasks.

Then along came a new architecture called massive parallelism. This broke up the processing power into lots of tiny processors that were then distributed throughout the field of memory. When a problem was presented, all of the processors would begin working simultaneously, each performing its small part of the task, and sending its portion of the answer to be collated with the rest of the work that was going on. It turns out that for most problems, this approach is more effective.

But somehow this idea, revolutionary as it was in the computer world, never travelled to other regions of our life -- and didn't come anywhere near politics. And that's a shame. Because in the realm of politics or economics or public policy, the metaphor of distributed intelligence has enormous explanatory power. It offers an insight into why democracy has triumphed over governments that depended exclusively on a central authority. And it illuminates why private sector organizations are shedding their middle layers and pushing power, information, and influence to frontline workers. Taken a step further, it even helps explain phenomena as diverse as virtual communities on the Internet and television programs like "America's Funniest Home Videos."

All of which raises a question much like the one Lily Tomlin asked me last week when the President signed into law landmark legislation reforming American telecommunications. As I tried to explain something to her during the bill-signing ceremony, Lily -- actually, her character, Ernestine the operator -- asked me: If you know so much, how come <u>you're</u> not signing the bill? In other words, if this is such a great metaphor, why hasn't it taken hold?

Here's one possible explanation: I've got it wrong. Perhaps the metaphor of distributed intelligence simply isn't as powerful as I've claimed.

Here's another possibility: the increasing segmentation of society -- in particular, the segmentation of scientific disciplines. At their best, the scientific community and the university community embody the ideal of distributed intelligence. The great power of science derives in part from specialization into disciplines. But much of the power also comes from open criticism and communication across disciplines. Indeed, some of the most significant discoveries have emerged from the productive friction that occurs when different perspectives rub against each other and produce the spark of new insight. But if the physicists don't talk to the chemists, and the chemists don't talk to the economists, and if the economists don't talk to the climatologists, then distributed intelligence is more aspiration than reality. So a second explanation for the absence of this metaphor is that it describes a phenomenon that itself disappearing.

Finally, here's a third possibility why the notion of distributed intelligence has not migrated to our public conversation: the growing disconnect between science and democracy. Walk through the halls of Congress, and you'll see the Gucci loafers of corporate lobbyists, but not the white lab coats of American scientists. Page through a directory of members of Congress, and you'll find well over 150 lawyers, but only six scientists, two engineers, and one science teacher among the 535 people in the House and the Senate.

As a result, scientific concepts sometimes elude the vast majority of our elected officials. That is inherently unfortunate, because we want well-rounded leaders.

But let me dwell a moment about some of the harder-edged consequences -- in the hopes that it will solidify my case for this new metaphor: Lack of scientific understanding undercuts support for the pursuit of further understanding, which fosters deeper ignorance, which in turn further erodes support for battling that ignorance. It's a vicious cycle.

And it's already underway. Listen to what some members of Congress have been saying recently.

Two weeks after the Nobel Prize in chemistry was awarded to scientists for their work on ozone depletion, Texas Congressman Tom Delay said -- and I'm quoting -- "The science underlying the CFC ban is debatable." The agreement to terminate the use of CFC's, he said, was "the result of a media scare."

Congressman Delay also said that DDT was -- and I'm quoting -- "not harmful."

And just a few weeks ago at a hearing on clean drinking water, Oklahoma Congressman Tom Coburn said -- and I'm quoting once again to assure you I'm not making this up -- "I want to touch on cryptosporidium for a minute. . . this disease can sometimes be very helpful, because it helps us identify those who in fact are immune compromised."

These comments ought to send shivers up our spines, because they suggest that the lack of scientific metaphors is merely the symptom of a deeper disregard for science itself and further proof of the vicious cycle I mentioned a few moments ago.

And that's precisely the opposite of how it should work in America. For much of this century, Americans have benefited from a virtuous circle -- a virtuous circle of science and success. As the nation generated wealth, a portion of that wealth was invested in research, science, and technology. Those investments helped answer what seemed answerable -- and eventually spawned still greater wealth, which was then invested in still more research. On and on it went. In this virtuous circle -- launched with bipartisan agreement -- prosperity generated investment, investment generated answers, and answers generated further prosperity.

But now -- because of the woeful lack of knowledge that you just heard -- that virtuous circle risks coming undone. At the very moment a new age demands continued investments in science and technology, there are some in Congress threatening to turn the clock backward with the largest cuts in 15 years.

In their most recent budget, according to AAAS's own study, the Congressional leadership proposed reducing federal funding for science and technology by one-third by the year 2002, adjusted for inflation. And get this: several years after the Cold War ended, defense R & D is going up, while civilian R&D is going down. More for Star Wars, less for environmental research. At the very moment global economic competition and global environmental degradation demand civilian research and the technologies it often produces, this Congress is proposing the sharpest cuts in nondefense research since America was fighting World War II.

This organization's study a few months ago laid out the numbers plain and simple. The only investment the Congress wants to increase was in health sciences. And that's great. But in almost every other realm, they're approaching science with all the wisdom of a potted plant.

Research on issues that will affect the health of our children, the condition of our planet, and the vibrancy of our economy -- risks being slashed to the bone. Global warming . . . down. Supercomputers . . . down. Nuclear nonproliferation . . . down. New materials . . . way down. Solar energy . . . way down. Environmental satellites . . . down. Water quality . . . down.

It's like they're living in a gravity-defying universe. Everything that ought to be up is down. Everything that ought to be open is closed. Their science policy is straight out of science fiction. A few may talk like Johnny Mnemonic, but most support policies designed for Fred Flintstone. They promise to boldly go where no Congress has gone before, but their flight plan will take us into the ground.

President Clinton vetoed several of the bills containing these cuts -- but not before that other side shut down the government, and furloughed thousands of government scientists. And right now, several agencies -- in particular, the National Science Foundation -- are sputtering along with stopgap funding that makes it almost impossible to plan and difficult even to finance day to day activities.

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But the saddest part is that it doesn't have to be this way. Last week, President Clinton proposed a budget outline that leads to the first balanced budget in seventeen years. And he gets there without compromising our values, without abandoning our commitments to education, the environment, and science and technology.

Of course we've got to balance the budget, but there's both a sensible path and a dangerous path that can take us there. Consider: federal investments in basic research now total 0.27 percent -- that's .0027 for any humanities majors in the crowd -- 0.27 percent of America's gross domestic product. That's considerably less than American households spend each year on pet food or breakfast cereal.

Only a few years ago, the United States -- public and private combined -- invested three percent of its GDP in research and development. Today, it's sunk to 2.6 percent. But if that weren't enough, consider the long-term consequences if these deep cuts are imposed: by the year 2000, for the first time in history, Japan will spend more on research and development than the United States, in real terms. Not more per capita, or more as a portion of their Gross Domestic Product. More. Period. Even though Japan's economy is considerably smaller than ours and its population is about half our size.

If our guiding metaphor is the factory, such proposals don't seem outlandish. After all, the goal of the factory is to crank out more and more of the same thing at a lower and lower cost. Shaving a little here and little there is smart business.

But if the guiding metaphor is distributed intelligence, such proposals are terribly misguided. Because distributed intelligence combined with this virtuous circle of riches and research is needed now more than ever, and has already made a difference in this country.

For instance, the discovery of the structure DNA led to new drugs for Lou Gehrig's disease. The Hubble Telescope, besides opening new vistas on our universe, helped produce to new treatments for breast cancer. A federally-supported agency, the National Academy of Sciences, sounded the first alarm that chloroflorocarbons were eroding the ozone layer. The MRI was a product of four separate discoveries in four separate fields of scientific inquiry. And the Human Genome Project is now determining the location and sequence of an estimated 100,000 human genes, and generating new strategies to battle illness and disease.

If we abandon our commitment to science, and fail to understand the power of distributed intelligence, this is what we risk losing -- the chaotic, convoluted, unpredictable breakthroughs that basic science produces.

But we also risk losing something even more significant, the effects of which could be even more tragic. We risk losing our children.

It would be tragic if the richest nation on the planet, through its inaction, told its own future that discovery doesn't matter. Anybody who has kids -- or remembers being one -- knows the ferocious curiosity that bubbles in our youngsters. Kids capture bugs and ask questions about clouds and wonder how cars work. Kids like you never stopped.

But if we extinguish that natural creativity with a fire hose of needless reductions -- if we broadcast an unending stream of signals that discovery doesn't matter, that science is for someone else -- then all of us will pay an emotional and financial price impossible to calculate. And if we fail to reform our schools -- away from the model of the factory and toward the model of distributed intelligence -- we will have only ourselves to blame.

Fortunately, President Clinton is trying to do better. On education, he's made real progress . . . launching direct student loans . . . opening the doors of college to more Americans . . . establishing education standards so every diploma means something . . . promoting education technology in the classroom . . . proposing a tax deduction for families' investments in higher education.

And on science and technology, he's also scored big -- in large part because he's fielded a scientific dream team. Jack Gibbons has become the most influential science advisor the White House has seen in a generation. Cabinet secretaries like Bruce Babbit, Ron Brown, Carol Browner, Hazel O'Leary, and Donna Shalala have fought for a cleaner environment, a strong technology base, national laboratories, and health care research. Dan Goldin has helped take NASA to the stars, while keeping the costs here on Earth. And every layer of the Administration is peopled with women and men dedicated to discovery.

And that team has delivered results. We've extended the R&D tax credit for three years . . . lowered capital gains taxes for investments in emerging companies . . . scaled back the anti-trust barriers to joint ventures in research . . . beefed up protection of intellectual property, giving inventors real protections for their patents . . . boosted funding for the nation's flagship research agencies . . . launched an education technology initiative . . . established the National Science and Technology Council . . . supported research into global climate change . . . and ensured our environmental regulations meet the tests of common sense and cutting-edge science.

But we cannot do it alone. That is not how democracies work. And this is where you come in. Democracies, too, depend on distributed intelligence. And this democracy needs the sound of your voices and the dedication of your hearts. You must take up the call for knowledge. You must enlist in the army of persuasion whose battle cry says knowledge is important for knowledge's sake. Because when you say something is important -- and you say it with enough force -- others might pay attention. But if you view your own pursuit of knowledge as divorced from the nation's pursuit of progress, both endeavors will fall short of their goals.

In a sense, at the edge of a new century, we have a choice of two paths. One path retreats from understanding, flinches in the face of challenges, and disdains learning. It's a know-nothing society -- a society in which the storehouses of knowledge dwindle, the spigots of discovery are twisted and turned off, and missions of exploration are stalled on the ground. This know-nothing society bases regulations on suspicion instead of science, says that DDT isn't harmful, and claims that global warming is the empirical equivalent of the Easter Bunny.

That's the path we will be forced onto if these Congressional cuts become the law of the land, because scattered throughout their proposals are cuts in funding -- and **outright prohibitions** on research. The guiding principle is an old saying applied to a modern nation: what we don't know won't hurt us. Trouble is, that's the recipe for destruction in a distributed intelligence society.

But there's another path -- infinitely brighter, considerably more American. It's a path on which government continues funding basic science and applied technology. It's path that keeps the virtuous circle of progress and prosperity alive and functioning. It's a path whose signposts say "education is a matter of national security," "environmental protection is a matter of national security." It's a path dotted with investments that open the doors of education to all our people. It's a path that applies what we've learned from science to the rest of our lives.

And it's a trail that's within our power to blaze. We have in our hands and our minds and our souls the power to create this learning society. That's partly what this year's presidential elections will be all about.

Last year, another President -- Chuck Vest, President of MIT -- decided to present his annual report as a series of questions his faculty told him were the most urgent ones in their fields. What he told us in that report underscores the need to deliver on these crucial investments in science and technology.

He reminded us that we don't know "which aspects of climate change are predictable." And we need to know.

We don't know "how best to use our information infrastructure and new media to promote learning among children." And we need to know.

We don't know "how to produce materials with no waste by-products." And we need to know

We don't know "how to extract all the energy from existing fuel sources." And we need to know.

We don't know "how and why cells die." And we need to know.

We don't know "how know old the universe is, what it is made of, or what its fate will be; we do not understand what mechanism generates mass in the building blocks of matter." And we need to know.

We need to know these things. We need to understand these things. We need to discover these things.

We need to create a learning society, a society that harnesses the power of distributed intelligence and uses it to lift our lives. And as the very embodiment of that ideal, you have an obligation to help make it happen.

As always in America, it's possible -- but it's up to us. As always in America, it's possible -- because it's up to us. Let's get to work.

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Remarks as Delivered by
Vice President Al Gore

Commencement Exercises
Massachusetts Institute of Technology
Cambridge, MA
June 7, 1996

Dr. Gray, President Vest, members of the MIT Board and faculty, Mayor Sheila Russell, parents and families, alumni and alumnae, students, and especially those of you who are graduating seniors:

Thank you for inviting me this morning. It is truly an honor to be MIT's Commencement speaker. It's a pleasure to return to this city where I myself graduated 27 years ago, from a school just up the river.

That school, Harvard, and MIT have had a long and sometimes tumultuous relationship. In the early days, beginning in the 1860s, Harvard tried to absorb MIT. But this school's founder and very first President, William Barton Rogers, fought back. He was adamant that an institution devoted to fostering scientific knowledge **and** a liberal education must remain independent.

Many things have changed since those days. For example, tuition for first-year students in 1866 was $100.

President Barton, incidentally, literally gave his life for this institution. When he returned after his retirement to deliver the commencement speech in 1882, right in the middle of his speech, he died. As a result, I have the rare comfort of knowing that whatever your reaction today, I will not be remembered as the stiffest speaker in your school's history. I am fully prepared, however, to be remembered as the second stiffest.

In preparing for this speech, I engaged in a dialogue with the graduating class by way of the Internet and your university's computer network, the Athena system. More than 100 of you responded in some detail, and I thank you very much. For those of you who didn't respond, I know who you are. I read every response thoroughly -- on the World Wide Web -- and I learned a great deal. Among other things, several of you emphasized the fact that MIT not only educates scientists and engineers but also architects, linguists, designers, economists, even poets.

Nevertheless, because this is MIT, I want to share some thoughts today about the relationship between science and technology on the one hand and humankind and society on the other.

When Winston Churchill spoke here in 1949, he spoke about the relationship of science and society. Ten years later, in a celebrated lecture in England, scientist and writer C.P. Snow introduced the concept of the "two cultures." In his subsequent book, entitled *Two Cultures*, he wrote that the culture of science and the culture of society's literary arts "had almost ceased to communicate at all." He noted that the popular culture in England and America spoke the same cultural language. But both "had about as much communication with MIT as though the scientists spoke nothing but Tibetan."

Why is there such a gulf between science and society?

This schism between science and the rest of society -- which began at least as early as Galileo's trial in 1633 and continued with the trial of John Scopes in 1925 in my home state of Tennessee -- has not narrowed since the publication of Snow's famous book.

Indeed, eighteen months ago, Sheila Tobias examined this schism and concluded that it has grown worse. "Science illiteracy has entered a second, more pernicious stage, fueling widespread opposition to science," she said, noting that physicist and science historian Gerald Holton has written that this new opposition to science "threatens to topple the Enlightenment-based tradition on which scientific discourse and democratic politics are based."

Two cultures separated by a great divide.

One of the consequences of the widening of this divide is that the metaphors of science are no longer migrating into our popular culture at the rate they once did. In the early decades of the scientific revolution, during the 17th century, there was an explosion of new metaphors that crossed the permeable boundary between science and culture. It was more common in that era for individuals to be fully conversant in both science and the rest of culture. And there was less to master before the scientific revolution speeded up. John Stuart Mill was described as "the last man to know everything." In that age, people generally acquired an intuitive sense of Newtonian physics, and spoke of the universe as an apparatus that ran like clockwork. They spoke of social organizations resembling machines. Later on, Charles Darwin's theory of natural selection supplied metaphors for competition in economics and life, and still later supplied the language for a social movement that misused his theory and borrowed his name.

But now, in the second half of the 20th century, while the number of new discoveries flowing out of the still accelerating scientific revolution is at least a thousand-fold greater, the flow of these metaphors into the rest of society has slowed to a trickle.

I believe it is time for a new effort to build bridges between these two cultures. I agree with my late friend Jerry Weisner, who said in his inaugural address as President of MIT in 1971, that it is our responsibility "to understand what our learning and discoveries may do to man and society, and to transmit that knowledge to new generations -- to . . . leaders who may be wiser than we in applying it, or wiser in judging how slowly or rapidly these technologies may be absorbed."

I am convinced that a more robust discourse between science and society could empower us to fruitfully apply some powerful new metaphors from science in an effort to better understand society and better understand the relationship between science and technology and our society.

Let me illustrate what I mean with an example. I have a friend who's an MIT graduate, named Danny Hillis. A few years ago, he patiently explained to me the workings of a massively parallel supercomputer by pointing out that the first computers relied on a central processing unit surrounded by a field of memory. To find the answer to a particular problem, the CPU would send out to the memory to retrieve data, then bring it to the center for processing. The result would then be placed back in the memory. Three trips, back and forth, consuming precious time and generating unwanted heat.

The architectural breakthrough associated with massive parallelism was to break up the power of the CPU and distribute it throughout the memory field in the form of smaller, separate processors, each co-located with the memory it processes. When a task has to be performed, all of the processors begin to work simultaneously and process a small quantity of information. Then all of the separate parts of the answer are sent simultaneously to the center where they are assembled. One trip. Less time and heat.

When you think about it, the metaphor of massive parallelism, or "distributed intelligence," offers a nice explanation for why our representative democracy is superior to a governmental system run by a dictator or a king. Where totalitarian regimes rely on a central processor to dictate all commands, representative democracies depend on the power and insight of people spread throughout the society, each located adjacent to the part of society in which he or she is most interested.

Or take capitalism. The Soviet Union's economy collapsed because it relied on a central processor to make all economic decisions. It didn't work very well. Innovation withered and corruption took root. The North Korean economy continues to rely on a central processor, and today its people are starving. But capitalist economies distribute the power to those located outside the center -- entrepreneurs and consumers, who make their own decisions independent of each other, and those accumulated activities create a stable system that marries supply and demand and keeps prices stable.

To take a third example, many of the latest techniques from the world of management -- as graduates of the Sloan School know very well -- rely on the same principles of distributed intelligence, even if they don't call it that. By distributing intelligence and information and responsibility to workers on the front lines, organizations are transforming themselves, serving customers better, and producing greater value.

Each of these examples relies for its success on the same basic architecture. Instead of insisting that all decisions be made in a single place, the power is widely distributed throughout the organization. Each individual's portion of the answer is then assembled as part of a collective conclusion. In capitalism, it's called supply and demand. In representative democracy it's called self-determination. In each case it is essential that all the individuals involved share some basic characteristics: for example, the freedom to obtain information that flows unimpeded throughout the system.

In organizations that are based on this design, it is crucial that all the individuals who are part of the organization feel a sense of cohesion that is based on a common understanding of the organization's guiding vision. It is crucial that they all understand the organization's basic goals, and that they all share the same basic values upon which a decision can be based, whether it is made by the CEO or a clerk behind a word processor.

Some organizations find this cohesion deceptively easy to establish, simply because they're new, and everyone involved has been present at the creation and is eager to accomplish the goals easily kept in mind until the initial burst of enthusiasm wanes. For example, NASA put a man on the moon and returned him safely in less than 10 years. It was an inspiring sprint. But once that goal was achieved, the organization's culture began to quickly erode and has had recently to be painstakingly rebuilt.

Likewise, some of the institutions of government created in the burst of enthusiasm we call the New Deal were remarkably successful until the first generation of managers passed from the scene, and then we began to see bureaucratic rigor mortis set in.

The challenge for any organization is not simply to establish these conditions and gain the advantages of distributed intelligence, but to nurture and sustain this creative state. There's no better example of how to do that than the U.S. Constitution, with its checks and balances and careful design intended to sustain the creativity of self-government, even after more than 200 years. Our Constitution is, in a sense, the software guiding the operations of a massively parallel system for processing political decisions.

Our Founders rejected the idea of a pure democracy, not as some suppose because the information technologies of the 18th century simply couldn't accommodate a plebiscite on every question. Rather, as the Federalist Papers make clear, they insisted upon the importance of a reflective process, with an intermediate institution placed between the people and the exercise of power -- an institution capable of reasoned debate and deliberation, which would cool passions and distill judgment and look beyond the present moment to the future consequences of the decisions made.

Many people feel that valuable processes like these in our society are threatened by the still accelerating scientific and technological revolution. They wonder in this case, for example, about the impact of television and 30-second commercials on our ability to be deliberative and reflective in our political decisions as a nation. Passionate beliefs held by a temporary majority, when powered by the extra force of new technology, may not be cooled or slowed down at all by the institutions of our self-government.

This concern that science and technology now regularly unleash forces that threaten to seriously damage some delicate balances important to the fabric of society is one of the principal issues our society must resolve in order to establish a healthier relationship between the two cultures.

Until recently, this dialogue was difficult to even begin because of a philosophical preference in the scientific method for narrow specialization, which often resulted in the splitting of large questions into smaller and smaller component parts, each of which was then analyzed by expert specialists -- independent of those studying the other component parts. Not only was communication difficult between scientists and generalists. It was difficult between specialists in one field and specialists in another field. The often frustrating result was a tendency to ignore important relationships between the different parts that made up a whole.

As Goethe said in anger and frustration, "How often do they strive to divide that which, despite everything, would always remain single and whole."

In more recent decades, there has been a new appreciation within science for the study of whole systems. Here at MIT in the early 1960s, for example, the System Dynamics Group was founded by Jay Forrester, a professor of electrical engineering. And the new emphasis on systems creates new possibilities for a fruitful dialogue between the two cultures.

For example, both cultures can describe how the invention of nuclear weapons radically transformed the age-old habit of war. The destructive consequences of all-out war between superpowers became unthinkable, and a "cold war" emerged in its place. In the same way, a large cluster of new technologies that enhance our capacity to exploit the earth for sustenance has radically transformed the relationship between humankind and the global environment. For example, the air we are breathing in this great court contains six times as many chlorine atoms in each lungful than it did when these buildings were constructed. The same is true of the air at the North Pole and the South Pole and the Equator and everywhere on earth.

The concentration of chlorine in the entire atmosphere of the earth has increased sixfold in only a few decades because of a single new family of chemicals invented in the 1930s and used in large quantities only since World War II -- chlorofluorocarbons. There are, so far as we know, no direct health consequences of breathing six times as many chlorine atoms. But the impact on the earth's environmental system is quite harmful. The hole in the stratospheric ozone layer and the increased irradiation of the earth's surface by ultraviolet rays is a direct consequence of this new technology.

Similarly, the burning of fossil fuels by five and a half billion people and the destruction of forest land at an unprecedented rate worldwide is now leading to the rapid accumulation of carbon dioxide and other greenhouse gases in the atmosphere of the earth. The resulting global climate change is increasing global temperatures, threatening the disruption of the climate balance we are used to that has remained relatively stable for thousands of years. It is also causing the rise of sea level at six millimeters per year, the retreat of nearly every mountain glacier in the world, the rapid disintegration of important ice shelves in Antarctica, and the disruption of important ecosystems upon which much of the diversity of life on earth depends.

A third potentially destabilizing set of new technologies is what is commonly called genetic engineering. One graduating MIT senior wrote that recombinant DNA technology represents "a powerful tool for countless therapies. However it could also be very harmful in the wrong hands."

In all these examples, there is a clear sense that what is needed and what is at risk is <u>balance</u>. The new capacities conferred by new discoveries in science and technology clearly have a promising potential for good and beneficial effects, but simultaneously provoke widespread and deep concern that the use of these new powers can be disruptive and harmful. Another graduating senior expressed his concerns in these words: "I believe that technology in any form is a new power that can potentially disrupt society. With the current pace of advances, our society is undergoing a destabilizing revolution constantly. Maintaining the delicate balance that we have achieved between individual liberty and societal needs requires diligence and a watchful eye. Failure to do this will lead to either chaos (Lord of the Flies), or tyranny (1984)."

How can we create a richer, more productive dialogue about these possibilities that is accessible to men and women who inhabit both of "the two cultures?"

Let me suggest a second metaphor that is based on a new discovery in science, which I believe has explanatory power directly relevant to the society's need for a discussion of this problem: "Complexity Theory" is a new science useful for describing what are called non-linear systems that exist "at the edge of chaos." By that definition, our society certainly qualifies as a complex system.

Here is how the author Mitchell Waldrop describes the phenomenon: "Complex systems have somehow acquired the ability to bring order and chaos into a special kind of balance. This balance point -- the edge of chaos -- is where the components never quite lock into place, and yet never dissolve into turbulence either. The edge of chaos is where life has enough stability to sustain itself and enough creativity to deserve the name of life.

"The edge of chaos is where centuries of slavery and segregation suddenly give way to the civil rights movement of the 1950s and 1960s; where seventy years of Soviet communism suddenly give way to political turmoil and ferment; the edge of chaos is the constantly shifting battle zone between stagnation and anarchy, the one place where a complex system can be spontaneous, adaptive, and alive."

There are a number of societies in our modern world which appear to be in a state of equilibrium and balance, but move suddenly toward chaos or totalitarian stagnation.

Consider, for example, Somalia. The clans which organized traditional Somali society often engaged in confrontation at the boundaries of their respective territories, in clashes which consisted largely of symbolic conflict with few casualties.

The introduction of automatic weapons in large numbers and then the mounting of machine guns on light pickup trucks -- a combination that became known as "technicals" -- tragically transformed the consequences of these once symbolic conflicts, and the entire system slipped out of equilibrium and into utter chaos.

To take a second example, in Sarajevo, the stadium that was the centerpiece of the world's celebration of peaceful competition at the 1984 Winter Olympics became a cemetery a few short years later when that society slipped into chaos.

In the 1930s, fragile democracies in Germany and Italy moved not toward anarchy and chaos but toward totalitarianism with horrific consequences for much of the world.

The challenge for modern societies -- including our own -- is of course to avoid either extreme -- either chaos or stagnation -- by maintaining the essential balance between stability and creativity.

And part of the challenge is how to integrate the changes that flow out of new technologies and new scientific knowledge, the new powers and enhanced capabilities, and use them as a source of energy for adaptive change that benefits society as a whole.

There is a model for understanding how such change occurs that I have found helpful.

Nineteen years ago, as a freshman Congressman, I met a scientist named Ilya Prigogine who had just won the Nobel Prize for Chemistry for describing how systems can adapt to sudden and dramatic change.

He described characteristics of what are called "open systems" -- meaning systems where energy or matter (or both) flow in and through and out the other side. When the flow of energy in such a system suddenly and dramatically increases, the system responds in a two-step process: first, it breaks down; second, it reorganizes at a higher degree of complexity.

Societies can behave the same way, when there is a sudden and dramatic increase in the flow of energy through the society -- automobiles in place of horses and buggies, massive waves of immigration, new trading relationships with new flows of products, surges of new information with the introduction of new technologies like television or the Internet. First, long-stable patterns break down. Then new ones emerge at a higher degree of complexity.

Societies are vulnerable to misinterpreting the first stage as a descent into chaos and then overreacting with the imposition of a rigid, stagnating order.

The science historian Gerald Holton wrote, "History has shown repeatedly that a disaffection with science and its view of the world can turn into far more sinister movements." So while we are right to raise questions about the challenges to our society posed by new technologies -- as many of you did in your e-mails to me -- we must strongly reject the neo-Luddite voices in our society seen in their most extreme and repugnant form in the writings and actions of the Unabomber.

By contrast, the conditions that maximize a society's ability to integrate rapid change in a healthy pattern include: the maintenance of the free flow of information; the maintenance of strong intermediate institutions such as families, schools, places of worships, civic associations, and communities; and the avoidance of gross inequities. As one graduating senior put it, "I fear that technological advances, if done in the wrong way, will cut off the poor or anyone who doesn't have access to these changes."

If individuals within a society are left behind when others gain new powers and capacities, they can lose their attachment to the society, begin to feel powerless and then define their relationship to the whole in terms of anger and alienation.

For four years President Clinton and I have been working to ensure that as we enter this new age, our nation addresses the challenge of maintaining a free flow of information, avoiding gross inequities in the access to such knowledge, and in sustaining the private institutions that promote dissemination of this learning.

Just last week, the President announced a new plan to put two years of college in the grasp of all Americans -- young and old -- with a refundable tax credit that would make tuition free at most community colleges. We have also proposed new tax deductions for educational costs, lessened the cost of student loans, and promoted an ambitious plan to have every classroom and library in the country connected to the information superhighway by the year 2000.

New information technologies have a special power to engender dramatic change in society. For example, the invention of print technology in the 15th century distributed large quantities of civic information, thereby creating the conditions which made possible the emergence of the nation-state and eventually representative democracy.

In our day, the new technologies of radio and television broadcasting have dramatically increased the flow of information throughout the world. In Tiananmen Square, fax machines and CNN were seen by Chinese authorities as deadly threats to civic order. The Ayatollah Khomeini spread his revolution inside Iran with audio cassette tapes and telephone lines. The Internet will soon distribute a million times the information accessible in print to billions of people on every continent.

As another member of the graduating class says, "Each of us may speak with equal voice and be easily heard by any who choose to listen. The powerful or rich no longer have the monopoly on mass communications."

Along with the Internet, the most important new tool we now have to extend our ability to create new personal paradigms of understanding is the computer. Computers can magnify our ability to cope with the information explosion in four important ways:

First, they can sift through vast quantities of data, searching for the needles in the haystacks that are directly relevant to the questions of interest to us.

Second, they can form these data into patterns that are far more accessible to our brains than endless bits of information strung together sequentially.

Third, they can artificially alter the scale and speed of the world to make images too large or too small for our comprehension just the right size for us to understand. Processes that are extremely slow can be speeded up for our inspection, and processes that occur naturally at the blink of an eye can be slowed down for our convenient analysis.

And finally, the largest and most powerful of these machines have led to the emergence of a completely new form of knowledge creation. In addition to inductive reasoning and deductive reasoning, we now have a new variety that blends aspects of the first two. "Computational science" can create artificial realities within which experiments can be conducted.

How will society adapt to the dramatic changes that will accompany this new revolution?

The reemergence in our world of rigid, stultifying, fundamentalist ideologies can be seen as one extreme in reaction to the vast increase in data that is now washing through world civilization.

At the opposite extreme, the fear of chaos was expressed by another graduating senior on the Athena system: "Free speech uncontrolled can break down our social norms and common beliefs, allowing extreme opinions to find and strengthen each other or allowing unsubstantiated unfounded 'truths' to be disseminated without challenge or resistance."

Hers is a concern I share. For example, I believe we have an obligation to assist parents who want to exercise responsibility for protecting young children from materials which they as parents believe their children are not ready for.

But let me also state my clear and unequivocal view that a fear of chaos cannot justify unwarranted censorship of free speech, whether that speech occurs in newspapers, on the broadcast airwaves -- or over the Internet.

Our best reaction to the speech we loathe is to speak out, to reject, to respond, even with emotion and fervor, but to censor -- no. That has not been our way for 200 years, and it should not become our way now.

In 1962, the great historian of science, Thomas Kuhn, described the way in which our understanding of the world evolves when faced with a sudden increase in the amount of information. More precisely, he showed how well-established theories collapse under the weight of new facts and observations which cannot be explained, and then accumulate to the point where the once useful theory is clearly obsolete. As new facts continue to accumulate, a new threshold is reached, beyond which a new pattern is suddenly perceptible and a new theory explaining this pattern emerges.

It is an important process not only at the societal level but for each of us as individuals as we try to make sense of the growing mountain of information placed at our disposal.

But while the breakthroughs in understanding that we need in order to adapt to change may be facilitated by the new capabilities computers and the Internet make possible, they will not be *caused* by computers and they will not take place *inside* computers. They will only take place in our *lives*. They will only have meaning in relation to human *values*.

The noise level in our civilization is rising. The flood of information on every subject makes the task of understanding change more difficult than ever. The temptation to rely on new technologies as a substitute for reflective thought is a dangerous trap.

How many of you have tried to see the hidden three-dimensional images in modern computer-generated pictures called, by one brand name, the "Magic Eye?" Could I see a show of hands? For those of you who have not seen these novelty pictures, they consist of complex patterns that seem like busy, partly incoherent designs, and they are intended to be viewed in a special way. My children taught me the technique. You hold them close to your eye and focus on a distant point beyond and through the plane of the image. Then you wait until your brain has processed the information in the image, which then reveals a three-dimensional picture that comes into sharper focus when you slowly move the image back, keeping your eyes focused beyond the plane.

The most important breakthroughs and advances in understanding can only come when we take the time to look beyond the surface of the problems we face and focus on what is most important in our lives. The same is true for you today.

If you are seeking a deeper understanding of what your life is all about, you will not find that meaning on the surface of your life. You must look beyond and through your life, and focus on a distant point far from this plane and be patient.

Nor can you understand your life in isolation from its context: your family, your community, your nation, your world, and the fabric of existence of which you are a part. If you are seeking healing in your life, healing is to be found in these relationships. If you are seeking spiritual meaning in your life, you will not find it by thinking of what you want to do next, but rather by reflecting on your whole life in its largest context.

If you are pursuing happiness, it will not be found in a set of rigid nostrums, nor in the undisciplined pursuit of pleasures, but is more likely to be found by living your life with enough stability to faithfully discharge your responsibilities to others, and also with enough spontaneity to adapt continually to the new challenges you will encounter and to seize the new opportunities inherent in a life with creativity and balance.

That is my wish for you. God bless you; and good luck.

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OFFICE OF THE VICE PRESIDENT
WASHINGTON

June 3, 1997

MEMORANDUM FOR THE VICE PRESIDENT

FROM: JIM KOHLENBERGER

SUBJECT: THE 7 PERCENT SOLUTION

David Gergen wrote a recent editorial in which he argues that the federal investment in R&D has declined every year for the last 4 years in real terms and further argued that we call for another cut next year. He urges us instead to increase federal spending on R&D by 7 percent next year contending that 7 percent is enough to make up for past inflation and to reverse the trend.

5 Years of Increased R&D Investment

We have a record to be proud of on R&D investments. This is the fifth year in a row that we have proposed increasing research and technology funding while making deep cuts in other spending. The President's FY98 budget increases R&D funding by more than $1.6 billion over 1997 to roughly $75 billion -- a 4 percent increase over 1993 and a 2.2 percent increase over 1997. And the President's baseline outyear budget plan proposes civilian R&D grow by 2% (nominal) between 1998 and 2002. We have gone from 70 billion to 75 billion or an increase of about 7% since we've been here.

So why does Gergen argue that we have cut investments every year? The difference is in how you calculate inflation, the fact that he ignores the end of the cold war, and that he ignores productivity gains we have seen in research. When you account for inflation we are preserving our overall commitment to R&D. Our civilian R&D investments are not only increasing in nominal terms, they are growing faster than inflation.

The Real Story is in Defense vs. Civilian R&D

It's important to draw a distinction between civilian R&D and defense R&D, which Gergen unfortunately does not do. With the end of the cold war, we can invest relatively more in productivity enhancing civilian research. Under our budgets, civilian R&D spending has risen by 11 percent -- from $30 billion in 1993 to $34 billion in 1997. That is faster than the rate of overall inflation of 9.8 percent. As a share of total Federal R&D investments, civilian R&D has risen from 42 percent in 1993 to 45 percent this year. Its also clear that Basic, Applied and Civilian R&D did much better than overall discretionary funding between 1993 and 2002 under our budget.

The budget agreement proposes $74.9 billion in FY98 R&D funding, a 3.3 percent increase -- less than what we originally proposed but still an increase.

We are doing more productive investments.

As demonstrated by NASA, funding levels are not the best way to justify R&D. NASA is doing more research with fewer resources by focussing on smaller, cheaper, and faster missions. The same can generally be said across the board. As the very technologies that basic research eventually spins off make it back into the lab, the efficiency with which we do research increases. For instance, the number of genes that we can now sequence in a day has increased several fold over the last few years because of some of the developments that come out of our human genome effort. Thus, we are now seeing some of the most productive years in science.

Another False Prediction

Every year it seems there are a number of well-publicized predictions -- fears may be a better description -- within the science community that balancing the budget would require deep cuts in civilian research programs -- cuts on the order of one-quarter to one-third over the next five years. Every year that we have been hear, we have heard rumors of the imminent demise of our nation's S&T enterprise. This year is no different. The fact is that we have protected our commitment to R&D -- even in the outyears -- while Republicans would gut these investments. Increasing our 75 billion investment in R&D by 7 percent would require coming up with another $5 billion in new money -- something that is politically undoable.

Republicans would gut our investments

Let's not forget that Republican budget proposals in the 104th Congress included cuts of more than a third to the nation's science and technology budget, cuts that would have decimated our nation's ability to perform world-class research, develop new technologies to sustain economic growth, and train a new generation of scientists and engineers. Fortunately we prevailed.

Summary

Should we continue to increase investment in R&D in the future -- you bet. Gergen is right when he points out that half of all economic growth since World War II is rooted in innovation. That is why maintained our commitment here. But he is wrong to imply that we are not committed to investing in basic scientific research.

FY98 R&D BUDGET OVERVIEW

The President's FY98 budget increases total federal research and development funding by more than $1.6 billion over 1997, to roughly $75 billion (as traditionally reported). This is the fifth year in a row that President Clinton has proposed to increase research and technology funding, at the same time that he has cut the budget deficit and has put our country on track for a balanced budget.

The President's FY98 budget boosts funding for basic research. The budget proposes $15.3 billion for basic research, an increase of $418 million (3 %) over 1997. This includes, for example, a 4% increase for R&D at the National Science Foundation on the civilian side, and a 5% increase in defense basic research. Basic research funded by the Department of Energy is slated to increase by more than 4 %. In the outyears, basic research is projected to increase steadily by nearly 5% to the year 2002.

The President's FY98 budget strengthens university-based research. University-based research is key to America's future; it provides new knowledge and new technology, while at the same time training the next generation of scientists and engineers. We are proposing to increase university-based research by $289 million, to a total of $13.3 billion in FY98.

The President's FY98 budget provides major new support for technologies that ensure that America benefits from the revolution in information technology. Investments in computing and communications R&D are increased by 10 %, to $1.1 billion. This includes a 3-year, $300 million Next Generation Internet initiative. This initiative will create the foundation for the networks of the 21st century by connecting more than 100 U.S. universities and national labs at speeds that are 100 - 1,000 times faster than today's Internet -- with an ability to transmit voice, video and virtual reality in a secure and reliable fashion.

The FY98 Budget provides significantly increased support for programs that will bring the power of modern information technology to classrooms throughout America. The budget includes $524 million for research and development in education technology. This includes $75 million for the Technology Innovation Challenge Grants program that funds competitive grants for consortia of schools, businesses, universities, and other organizations to develop innovative applications of innovative technology. In addition to these R&D programs, the budget more than doubles, to $425 million, the funding for the President's $2 billion, 5-year Technology Literacy Challenge Fund designed to stimulate public-private partnerships focused on fully integrating education technology into teaching and learning.

The President's FY98 budget increases investment in technologies essential for ensuring continued US economic leadership and job creation. A 6 % increase in civilian applied research ensures that the U.S. will benefit from a continuing flow of technological advances. The budget boosts investments in critical technology initiatives like the Advanced Technology Program at the Department of Commerce, which gets a 22% increase over FY97 (to $275 million), and provides a 36% increase for the Manufacturing Extension Partnership program that operates in close cooperation with state governments to ensure that our nation's small and mid-sized companies are able to compete worldwide with state-of-the-art technology. Funding for the Partnership for a New Generation of Vehicles initiative is increased 7%, to $281 million*, and funding for the construction and building technologies initiative is increased 15%.

The President's FY 98 budget includes tax incentives to encourage private sector investment in research and technology. The budget proposes a one year extension in the Research and Experimentation tax credit. In addition, benefits of the Foreign Sales Corporation tax credit would be extended to computer software producers whose products are licensed for reproduction abroad.

The President's FY98 budget increases funding for environmental research. Science and technology investments are critical for enhancing environmental quality, and this budget funds vital research needed to ensure clean air, pure water, and safe food. The FY98 budget allocates $5.3 billion for environmental research, a four % increase over FY97. This funding supports a broad research agenda, including sustainable use of natural resources, preservation of biodiversity, ecosystem management and restoration, social and economic dimensions of environmental problems and environmental technologies. The largest component is $1.9 billion for understanding and predicting global climate change and its regional impacts.

The President's FY98 budget provides increased support for health, food and safety research. The budget for the National Institutes of Health (NIH) contains a 2.6 % increase, primarily going to investigator-initiated, peer-reviewed research grants. This increase will fund high priority research areas such as HIV/AIDS-related illnesses, breast cancer and other women's health issues, minority health initiatives, disease prevention research and spinal cord injury research.

The President's FY98 budget continues the President's strong support for the nation's civil space program. The budget maintains funding for the International Space Station program at $2.1 billion; strengthened commitment to Mission to Planet Earth at $1.42 billion (a 4% increase over FY97); and solid support for the X-33 Reusable Launch Vehicle program ($330 million) and aeronautics initiatives ($456 million). In addition, NASA's space science budget has been augmented by $1 billion over the next five years.

The President's FY98 request continues to support the investments in research and technology that ensure our nation's security. We are emphasizing investments which sustain our military defense capabilities, prevent conflict before it occurs, and address other global threats to the well-being of our nation.

In the years between 1998 and 2002, the President's plan will preserve civilian research funding while completing the job of balancing the budget. The President's baseline outyear budget plan proposes civilian R&D to grow by 2% (nominal) between 1998 and 2002. This represents a solid investment, given the fact that the budget will eliminate the deficit (and actually produce a surplus) over the same time period.

President's FY 1998 Budget

Overall R&D Funding. The President's budget proposed $75.5 billion in 1998 for R&D funding, a 4.0 percent increase (8 percent real decrease) over 1993 and 2.2 percent increase over 1997. The budget proposed $73.4 billion for 2002, a 1.2 percent increase over 1993 (18.9 percent real decrease). **Overall discretionary increased about 7 percent between 1993 and 2002 (a 14 percent real decrease).**

Between 1993 and 2002:

- **Basic.** Increased 20 percent (a 4 percent real decrease).
- **Applied.** Increased 18 percent (a 6 percent real decrease).
- **Development.** Decreased 10 percent (a 28 percent real decrease).
- **Civilian.** Increased 17 percent (a 6 percent real decrease).
- **Defense.** Decreased 10 percent (a 28 percent real decrease).

Conclusion: Basic, Applied, and Civilian R&D did much better than overall discretionary funding between 1993 and 2002 in the President's FY 1998 budget.

Agreement

Overall R&D Funding. Worst case and on average, the Functions that contain R&D in 1998 will be reduced about 0.74 percent and about 2.81 percent in 2002 by the Agreement. Thus, the Agreement proposes $74.9 billion in 1998 for R&D funding, a 3.3 percent increase (8.9 percent real decrease) over 1993 and 1.5 increase over 1997. The Agreement proposes $71.3 billion for 2002, a 1.7 decrease from 1993 (21.2 percent real decrease). **Under these same assumptions, overall discretionary would increase about 4 percent between 1993 and 2002 (a 17 percent real decrease).**

Between 1993 and 2002:

- **Basic.** Increased 16.5 percent (a 6.7 percent real decrease).
- **Applied.** Increased 14.3 percent (a 8.4 percent real decrease).
- **Development.** Decreased 12.4 percent (a 29.8 percent real decrease).
- **Civilian.** Increased 13.9 percent (a 8.7 percent real decrease).
- **Defense.** Decreased 13 percent (a 30 percent real decrease).

Conclusion: Basic, Applied, and Civilian R&D also did much better than overall discretionary funding between 1993 and 2002 in the Agreement.

As demonstrated by NASA, dollars are not the best way to justify R&D. NASA is doing more research with fewer resources by focusing on samller, cheaper, and faster missions.

S&TAG

THE WHITE HOUSE

WASHINGTON

June 3, 1997

MEMORANDUM FOR THE VICE PRESIDENT

FROM: JACK GIBBONS

SUBJECT: Gergen Op-ed "The 7-Percent Solution" (U.S. News & World Report, May 1997, p. 79)

Gergen reiterates the broadspread concern that support for science and technology, especially federally funded R&D, has slackened and is headed downward as we move toward a balanced budget.

As you recall, the 104th Congress tried to deeply slash R&D but persistent efforts by our Administration and allies outside government largely blunted those efforts. Things are somewhat easier with the 105th Congress but we are a long way from home. For example, Congress is trying to deeply cut the President's request for R&D in renewable energy technology, energy efficiency, and global climate change just when we need such activities more than ever.

Some members of Congress (e.g., Gramm (science in general), Mack (medical research)) have called for a doubling of support for research over 10 years, roughly equivalent to the "7 percent solution" (but only in authorization, not appropriation). George Brown submitted an Investment Budget Bill which would significantly increase (about 5% per year) civilian research, infrastructure, and education and still balance in 2002 by not including tax cuts. His bill lost (91-339) but he believes he's helped raise the level of awareness.

I've discussed with Janet Yellen the notion of the Administration taking a position of maintaining our basic research budget at least at constant dollars but, as we progress to a balanced budget, moving toward a support level that rises proportionately with long-term economic growth. This could be called the 5 percent solution. Yellen generally agrees with me; but, not surprisingly, Raines doesn't favor our taking such an explicit position at this time. The position I took at the 1997 AAAS S&T Policy Colloquium (April 23) on the budget favors such a long-term direction (see highlight on page 2 of attached).

Joe Stiglitz (CEA) published a paper 18 months ago at my urging which underscores the high social rate of return on research. The paper, which includes Michael Boskin's paper by reference has been widely quoted.

My bottom line is that I hope the President will be able to continue and perhaps make more explicit his "protection" of the R&D budget, especially for basic research. Given the strong and growing support for research in Congress and elsewhere, I hope we can stay ahead of the curve.

Attached are some additional background materials and talking points for you.

Attachments
(1) Background and Talking Points
(2) Gibbons AAAS Speech
(3) Gergen article

June 3, 1997

Background: Joint Statement on Scientific Research

On March 4, 1997, 23 organizations spanning the scientific and engineering community issued a Joint Statement on Scientific Research calling for an increase in federal research budgets in the range of 7 percent for FY 1998. (Full text of the Joint Statement on Scientific Research is attached.) They called upon Congress and the Administration "to renew the nation's historical commitment to scientific research and education and indicated that funding increases of this level are necessary for meeting the challenges of the next century. The statement further indicated that A[t]o constrain still further federal spending on their scientific programs would jeopardize the future well-being of our nation.

The effort was notable because the 23 organizations represent a cross section of scientific and engineering disciplines, representing 108 different societies, associations, and organizations with well over 1,000,000 members. Several members of Congress, Representative George Brown (D-CA), Senator Phil Gramm (R-TX) and Senator Joseph Lieberman (D-CT) released their own statements (excerpts attached) in conjunction with and support of the Joint Statement.

The Joint Statement and the comments by Rep. Brown, Sen. Gramm, and Sen. Lieberman emphasize the importance of science and technology investments for our nation's economic growth and overall standard of living. They express a growing concern that it will be impossible for the U.S. to maintain technological leadership unless federal investments in R&D are given priority. Among the statistical trends cited which indicate the erosion of the U.S.'s commitment to investment in science and technology:

- federal investment in basic research has declined in real terms for the past five years,
- since 1970, Japan and Germany have spent a larger share of their GDP on research and development relative to the U.S., and
- research investments as a percentage of GDP are approaching a 40-year low.

Analyses of the Administration's FY98 request for science and technology have found the recommended funding level to be stable or a slight decrease over FY1997, depending on how one adjusts for inflation. The House Science Committee found the FY98 budget increased the administration's budget request for NSF.

Highlights of the Administration's R&D Budget Proposal

- The administration's Science and technology investments accounted for approximately 2.5 percent ($75 billion) of the Federal budget in the President's FY98 request.

- The Administration's FY1998 budget augmented stable funding levels with targeted increases including:

A 3% increase in the funding of NIH and in science, engineering, and education R&D at the National Science Foundation.

A five-year, 1 billion dollar increase in NASA's space science budget, funding research into the origins of the galaxy and the possibility of life beyond Earth.

An 8% increase in the basic research budget of the Defense Department.

A 4.6 % increase in basic science research programs at the Department of Energy.

A $289 million increase in funding for university-based research to strengthen the University-Government partnership and a $497 million increase in peer reviewed R&D programs.

Talking Points

- The administration is completely convinced that federal research pays high returns – CEA estimates returns greater than 50%.
- The administration strongly supported federal R&D in our FY98 budget and we expect that our R&D programs will be supported within the framework of the recently negotiated budget agreement.
- We have taken pains to provide funding within the context of a balanced budget. Increases in research would pay high rates of return but these federal investments must be weighed against other budget priorities. We are willing to discuss increases in R&D but only in the context of an overall budget which achieves balance.

Joint Statement on Scientific Research

As the federal government develops its spending plans for Fiscal Year 1998, we call upon the President and Members of Congress to renew the nation's historical commitment to scientific research and education by providing the requisite funding for the federal agencies charged with these responsibilities. Our call is based upon two fundamental principles that are well accepted by policy makers in both political parties.

The federal investment in scientific research is vital to four national goals: our economic competitiveness, our medical health, our national security and our quality of life.

- Scientific disciplines are interdependent; therefore, a comprehensive approach to science funding provides the greatest opportunity for reaching these goals.

We strongly believe that for our nation to meet the challenges of the next century, agencies charged with carrying out scientific research and education require increases in their respective research budgets of 7 percent for Fiscal Year 1998. These agencies include, among others, the NSF, NIH, DOE, DOD, and NASA. The increases we call for strike a balance between the current fiscal pressures and the need to invest in activities that enable long-term economic growth and productivity. Such increases would only partially restore the inflationary losses that most of these agencies suffered during the last few years.

Prudent planning argues for strengthening the respective activities of major research agencies, as already recognized in pending legislation. To constrain still further federal spending on their scientific programs would jeopardize the future well-being of our nation."

This statement was endorsed by the Presidents (or the equivalent officer) of:

American Association of Physicists in Medicine
American Astronomical Society
American Chemical Society
American Geological Institute
American Geophysical Union
American Institute of Biological Sciences
American Institute of Physics
The American Institute of Professional Geologists
American Mathematical Society
The American Physical Society
American Society of Engineering Education
Association for Women in Mathematics
Association for Women in Science
Astronomical Society of the Pacific
Council on Undergraduate Research
Engineering Deans Council

Federation of Materials Societies
Geological Society of America
The Institute of Electrical and Electronics Engineers, Inc.
Materials Research Society
Mathematical Association of America
Optical Society of America
Society for Industrial and Applied Mathematics

Joint Statement on Scientific Research: Excerpted Statements by Members of Congress

REPRESENTATIVE GEORGE E. BROWN, JR:"I am very pleased to see that the Nation's science community is speaking out against efforts to balance the Federal budget on the backs of research and development investments. I hope that today's press conference and joint statement will be the first of many actions taken by these prestigious organizations.

"Investments in research and development programs are among the most important expenditures the Federal government can make. Economists estimate that as much as half of our Nation's economic growth in the last hundred years is due to technological innovations. If we continue to under invest in science and technology, our efforts to balance the budget will leave our children a less prosperous future.

"Federal R&D has, as in the joint statement of these science organizations points out, declined in real terms over the last five years. Further, every balanced budget plan offered by any Republican or from the Administration calls for further reductions in these investments over the next five years. While there are some on both sides of the aisle that have called for either spending increases in particular areas of research (such as health research) or across the board in science, none of those proposals identifies how such increases will be accommodated in a balanced budget scenario. Until you take that step you are just playing with monopoly money....

"Just as we have a generational obligation to balance the budget and not make the next generation pay for our consumption, we also have an obligation to continue to invest in those programs that will leave the next generation in a position to enjoy a robust, growing economy. I believe that my budget proposal does that, and I hope that the science community can work to educate others in Washington about the importance of these investments."

SENATOR PHIL GRAMM: "I want to thank the leaders of the American Chemical Society, the American Physical Society, the American Astronomical Society, the American Mathematical Society, and the other societies here today for their support for increasing federal investment in science. This is exactly the goal of my legislation, which would double the amount of federal investment in basic science and medical research over ten years....

"If we as a country do not restore the high priority once afforded science and technology in the federal budget and increase federal investment in research, it will be impossible to maintain the United States' position as the technological leader of the world.

"Since 1970, Japan and Germany have spent a larger share of their GDP on research and development relative to the U.S. We can no longer afford to fall behind. Expanding the nation's commitment to research in basic science and medicine is a critically important investment in the future of our nation."

SENATOR JOSEPH I. LIEBERMAN: "Several months ago during the heat of the summer of 1996, President Clinton and every member of Congress received a letter signed by 60 Nobel Laureates which contained a simple message: America's investment in research over the last fifty years has been a vital source of our economic and political strength around the world, as well as the quality of life Americans enjoy at home.' It has only been through the Federal Government's patient investment in science, argued the Nobelists, that Americans have benefited in so many extraordinary ways from advances in the understanding of our world.

"I am...optimistic that the stage is set to move forward on policy decisions that will guarantee increased economic growth and national security, and represent a very important investment in America's future.

"My optimism is a product of two recent events. The first was introduction of S. 124 by three Senators Gramm, Mack and Hutchison entitled the National Research Investment Act, calling for a doubling of federal investment in basic science, technology and medical research over the next ten years. Second, in last month's release of President Clinton's budget, science and technology programs were increased almost across the board about three percent on average, which is significant given the considerable fiscal constraints and the intense scrutiny to which every program and agency is subject.....

"I believe the optimism of the present moment comes primarily because of some troubling facts which have convinced members of both parties that something more must be done to stimulate good research and development.... If you believe as I do, that our current prosperity, intellectual leadership in science and medicine and the growth of entire new industries are directly linked to investments made thirty years ago, then you have got to ask where will this country be thirty years from now? It is likely that several countries, particularly in Asia, will exceed on a per capita basis, the US expenditure in science. Japan is already spending more than we are in absolute dollars on non-defense research and development. These facts led Erich Bloch, the former head of the National Science Foundation, to write that the whole U.S. R&D system is in the midst of a crucial transition. Its rate of growth has leveled off and could decline. We cannot assume that we will stay at the forefront of science and technology as we have for fifty years.'

"Although difficult, the partisan conflicts and rifts of the past several years may have performed a useful service in clarifying the debate over when public funding on research is justified. I believe it is a mistake to separate research into two warring camps, one flying the flag of basic science and the other applied science. Rather the research enterprise represents a broad spectrum of human activity with basic and applied science at either end but not in opposition. Every component along the spectrum produces returns - economic, social and intellectual gains for the society as a whole. If we can put this division behind us, we can examine regions within the spectrum which need federal support, those best developed through the encouragement of the market, and finally, those which require a mixed approach. This is a process in which pragmatism should be encouraged.

"The challenge that faces us is to take the remarkably broad consensus for federal research and build a similar consensus as to what actions can help us to achieve our shared goals. Participants in the complicated dance of science include the federal government, private industry, national laboratories, large and small universities, professional societies and entrepreneurs willing to risk their wealth on the commercial success of a new idea. If we are to maintain and build on our world leadership, the Federal government must continue to play a pivotal role."

Remarks of

JOHN H. GIBBONS

Assistant to the President for Science and Technology

Director, Office of Science and Technology Policy

AAAS Policy Colloquium

April 23, 1997

Washington, DC

Science and Technology Policy in the Dawn of the Twenty-First Century

It is with special pleasure that once again I greet this distinguished body. The range and depth of scientific talent gathered here represent not only continued American leadership at the frontiers of science and technology, but a vital commitment to ensuring a better quality of life for future generations of all Americans.

Since I last addressed this colloquium, we have witnessed a remarkable string of scientific discoveries and technological advances. Hardly a week goes by without major breakthroughs reported in the pages of that learned journal of science -- *The Washington Post*: possible water on our moon, and perhaps on one of the moons of Jupiter, the prospect of ancient life on Mars, cloning of a mammal from a fully differentiated cell, confirming the existence of a third branch of life on earth, first steps toward demonstration of an "atom laser." Just last week, we read of the use of satellite data to document a significant response by Northern Hemisphere ecosystems to global-scale warming during the 1980s, which can be described as a longer growing season in high latitudes. The list goes on and on. All are magnificent discoveries, all generating a new series of questions and possibilities.

Contrary to these recent noteworthy discoveries, it is remarkable how much of the S&T policy discussion remains stuck on gloomy "budget talk," agency fortunes, and the outyears. There have been many dire predictions that balancing the budget would mean deep cuts in civilian research programs, on the magnitude of one-third over the next five years. Every year in this office, I have heard these rumbles. And every year I have warned that our research budgets *were* in real peril. This year is more hopeful, although the yellow caution flag is still out.

I will return to the budget later, but I first want to dwell on the overarching *national interest* – with an eye on the future and *its* constituency. You are an integral part of that future and therefore have a stake in the *long view* of policy that OSTP seeks to provide as interagency coordinator and advisor to the President.

Budgetary and Policy Climate

First and foremost, let me assert that the President and Vice President remain unwavering in their support for science and technology as crucial investments in our future. They share our convictions that such investments enable our nation to compete aggressively in the global marketplace, protect our environment and manage our natural resources in a sustainable manner, safeguard our national security from emerging threats, and spur the technological innovation that has contributed so much to our economic prosperity and quality of life. Despite the prognosis of some pundits, last year we often sailed against the wind, but we always held our rudder true. And, as a result, with a lot of help from outside government, we successfully held the line in the purchasing power of the aggregate Federal S&T budget. This is the *fifth* year in a row that President Clinton has proposed to increase research and technology funding, while at the same time putting our country on the path to fiscal sanity. This is especially encouraging news, and I believe that once Federal spending is brought under control, our Federal S&T investments should grow and track at least with the Gross Domestic Product.

Within the scientific community and in Congress, there have been calls for significant increases in federal R&D budgets above what the President has requested. Some proposals are genuine. Others are little more than nicely wrapped, rhetorically-filled, empty presents. Yet these calls for more research support signal an endorsement of one of the Administration's priorities, and hint of a welcome return to the traditional bipartisan political support for investing in future research.

I am heartened by those scientists, university and industry leaders, and policy makers advocating greater Federal investment in R&D. Such activism *has* made a difference by amplifying the scientific community's voice. But make no mistake: the constraints on Federal research funding are driven by a budget deficit and national debt that recklessly tripled during the 1980s, and that still stifles investment today. Would I like to see an increase in federal funding for research? Of course! Do I believe that our nation's taxpayers and future generations would be well-served by greater investments? Absolutely! Would better understanding of how S&T changes the lives of our citizens help the cause? Unquestionably! For I believe that the future is best-served if science and technology are widely understood and valued.

We struggle with these difficult choices to ensure, as the President consistently points out that "the future does indeed *have* a constituency." S&T funding is a high-stakes, high-leverage investment in the Nation's continued stability and prosperity. Our President's economic plan is working. Our deficits are lower. Our economic growth is higher. And it is this steady growth that fuels the economy, making it easier to increase S&T investments and still reach a balanced budget by the year 2002. Look no further than the President's R&D budget projections that are *far* more favorable than anticipated. For the first time since 1981, I repeat, since *1981*, the budget deficit could slip *below* $100 billion this year, thanks to a robust economy that is boosting tax revenues.

Shaping the S&T Portfolio

How can you help shape the S&T portfolio? You need to continue to be political activists in explaining the intricate processes and beneficial outcomes, revealing the complexity, uncertainty, and inherently long time horizons that characterize your research and innovation. While the S&T enterprise may not be growing at the rate of the 1980s, our job is still to nourish American science in all its vitality. We are shaping an S&T portfolio that is consistent with existing budget projections, that addresses national goals, and that is faithful to the exciting opportunities we glimpse daily.

So how will we effectively expand the frontiers of knowledge under current budget scenarios? As the Cheshire Cat pointed out in *Alice in Wonderland*, "how you get there depends very much on where you want to go." In the final analysis, our Federal S&T investment priorities must be balanced against *all other* needs to invest in infrastructure such as transportation and environment, crime prevention, national security, housing, health care, and education.

Even as the Federal budget deficit is tamed, the Administration has protected the level of investment in key Federal basic science programs, not only those in the National Science Foundation and the National Institutes of Health, but also those in numerous mission agencies, such as the Department of Energy, and the National Aeronautics and Space Administration.

Our S&T policy is a *national* — not just a Federal — policy. The benefits of research are not fashioned in Washington, they are forged in factories, laboratories, and universities and colleges across America. We are shaping a national program to address national goals.

Therefore, a centerpiece of the Administration's portfolio is our commitment to S&T partnerships between the Federal government and universities, states, and industry. Such collaboration is not only desirable; it is essential. No sector, sponsor, or performer can do it alone. The linkage of research and education – anchored in universities but practiced in facilities built, staffed, and shared by state government and industry – has proved an exceptionally effective public policy for decades. From planning to execution to evaluation, we are bringing to the table all the players in science and technology — the business community, research universities, non-profit institutions, and state and Federal governments.

In many research fields, the productive path to scientific advances increasingly involves international collaboration. Major research endeavors, such as space missions, particle accelerators, astronomical observatories, the quest for fusion energy, climate change research, and mapping the human genome, are so resource-intensive and necessarily one-of-a-kind that international cost-sharing, exchanges, or in-kind contributions have become commonplace. Reflecting the global growth in sources of innovation, working with other nations on research activities for mutual benefit has grown as a priority.

The Federal investment in university-based research is about $13 billion annually in university research alone. This investment has yielded new knowledge, technological innovation, and a scientific and technical workforce that remains the envy of the world. But national, political, corporate and education leaders have advised the President that the Nation's universities are experiencing growing stresses and strains. Such pressures stem from a constellation of changes, and the President's Committee of Advisors on Science and Technology (PCAST) recommended a government-wide policy and administrative review of our university research system. In response, last September, the President ordered a multi-agency review of the university-government partnership to identify the principal areas of stress, and to recommend ways of coping and adapting without sacrificing excellence or productivity. This review will assist us in developing strategies that promote cost-effectiveness, allocate research costs fairly, strengthen the research-education linkage, and develop appropriate measures of accountability.

As many of you already know, the White House and the Nation's governors recently agreed to work together in an Innovation Partnership to promote economic growth by stimulating the development and use of improved technologies in areas such as advanced manufacturing, education, health care and electronic commerce. We will also extend the capacity of the Manufacturing Extension Partnership to help modernize the nation's 380,000 small- and medium-sized manufacturers. We will continue the work we have begun to streamline the regulatory environment for research and technology.

We will also persist in our efforts to have Federal agencies work more closely with each other, and with the private sector. We have had some notable successes, including the Partnership for a New Generation of Vehicles, a cooperative effort among numerous government agencies and the U.S. automobile industry, to produce a production prototype vehicle capable of 80 miles per gallon by 2004. Another standout is the Commerce Department's Advanced Technology Program, which forms partnerships with companies that have the greatest potential for developing technologies to achieve broad-based economic benefits with high rates of social return. These programs are now approaching a level of experience that should permit definitive review and optimization of future investments.

Other exciting interagency initiatives include the Global Climate Change Research Program, the High Performance Computing Initiative, convergence of civil and military weather satellites and advanced aviation and space launch technologies, and a major effort on Emerging and Re-emerging Infectious Diseases.

I cannot stress enough that bipartisan support will be critical for shaping a sustainable agenda. The American people want us to be partners, not partisans, and the vast majority in Congress support a strong Federal research program. The scientific and engineering communities also have the opportunity and the responsibility to help forge consensus about the future's requirements for America's research and education investments. History suggests that the cost of not making these key investments in technical and human resources will be far greater than that of moving ahead.

Today, the challenge is to make the best use of the Federal investment -- to make each public dollar purchase more scientific impact and attract additional finding from other stakeholders in the R&D enterprise. Lean but accountable research administration, both in the Federal government and in the performing institutions -- universities, medical schools, and national laboratories -- will help sustain our competitive position, even as expenditures are constrained. Consequently, the Administration has begun a process of management reforms to improve the effectiveness of the investment. Examples include: revising and streamlining regulations and agency directives; identifying regulations that are outdated or add no value; automating research support functions; and developing performance-based organizations. Identifiable goals, measures of progress, and accountability for the outcomes achieved with Federal S&T dollars are also needed -- and, I might add, a responsibility of researchers. The Government Performance and Results Act codifies this and will assure the investors in S&T, the American public, that their tax dollars are well spent.

In the FY98 budget request, we continue to promote the growth of programs that benefit basic research:

- NSF and NIH would each be increased by 3%;
- Basic research funded by DOE is proposed for a 4.6% increase above FY97 funding levels (remember that previous out year projections had DOE programs sharply decreasing);
- The peer-review competitive grant programs at both the USDA (the NRI program) and EPA (the STAR program) are up 38% and 21%, respectively;
- DOD basic research in the 6.1 account is up by almost 8%; and
- Science research at NASA is up 3%, including a projected 7% increase in academic R&D.
- Support for environmental research, as well as health, food and safety research also rises.
- Investments in computing and communications grow by 10 percent. There is significantly enlarged support for programs to bring modern technology to America's classrooms to raise

students' achievements to rigorous and challenging standards.

- Investment increases are also included for R&D essential for ensuring continued U.S. economic leadership and job creation.

In sum, to maximize balance and effectiveness of the S&T investment portfolio, the Administration is promoting R&D programs that are: selected through a merit-based competitive process; are planned, funded, and conducted jointly through partnerships; provide realistic and objective measures of progress and performance; enable technology development through sustained interactions with industry and state and local governments; build professional capacity in the workforce; and promote international cooperation.

The Research-Education Link

Let me return to an issue I only alluded to earlier. The S&T portfolio must reconsider the linkage of research and education, the connection between discovery and learning. In his recent State of the Union message, the President clearly placed the next generation at the top of his priority list. He has redoubled his commitment to excellence in education and is establishing performance goals, starting with 4th grade reading and 8th grade mathematics exams beginning in 1999.

In a Directive issued last month, the President created an NSF-Department of Education Working Group to Improve Math and Science Education, coordinated jointly through OSTP and the Domestic Policy Council. In June, we will recommend an action strategy to improve the teaching and learning of mathematics and science pegged to international benchmarks. We will focus on incorporating the best practices in teaching, identifying challenging instructional materials, and integrating technology into classrooms. Perhaps most importantly, we will seek to mobilize the professional communities to convince students that the math and science learned in the classroom today is critically related to the skills they will need in the jobs of the 21st century.

We need to think of science and math as part of a seamless web of formal education not for a select few, but for *all* children who earn a high school diploma, a two-year, or a four-year degree. Today's 11-year-olds will be voters in 2004. They will need to understand and routinely use what we in this room consider "specialized" knowledge. That is the legacy of the link between research and education, and between science and social progress. The Nation's colleges and universities must view their mission as the refinement of "works-in-progress" that begin, as researchers at last week's White House Conference on Early Learning reported, long before children enter school. Thus, the process of recruitment and growth must start with investments long before students arrive on a college campus.

Conclusions and Prospects

Over a half a century ago, the Manhattan Project demonstrated in graphic terms the power of applying the tools of science and technology to critical national needs. With a shift in our national priorities, our science policies, traditions, and practices must also evolve. Together we must seize the opportunity to shape our national research agenda and tackle other large, technologically complex problems that enhance our quality of life and national security. For while we respect the principles of excellence and competition that underpin the future health of U.S. research, we must continue to nurture the human capital that educates, invents, and administers – not just for the sake of science and technology, but for our society as a whole.

Once again, allow me to underscore this Administration's vision for science and technology:

- Advances in S&T – spectacular and often built on partnerships – are inseparable from the Nation's future.
- Despite dire predictions, we have held the line in the aggregate purchasing power of Federal S&T. Two years ago, during a period of S&T budget frenzy on Capitol Hill, I quoted the wise advice of Thomas Jefferson who once counseled "A little patience, and we shall see the time of witches pass over, their spells dissolve, and the people, recovering their true sight, restore their government to its true principle." I believe that after we've finished the task of getting the budget deficit under control, support for S&T should grow and track at least with the GDP, along with our success in demonstrating the added value from such investments.
- Research links with education are absolutely essential, and not just in graduate school since developing human capital is a long-term, overarching goal.
- We are inventing new ways of doing business. By coupling research choices more explicitly to national priorities, we reshape the S&T portfolio, with advances in fundamental knowledge at the core.
- Unless the scientific community stays involved and talks to its "investors" – citizens and their elected representatives – we will suffer in the budget wars through "silence" and forfeit our competitive advantage.

This is part of a new social contract, one that demands explicit links between knowledge production and its applications in policy and practice. As President Kennedy once reminded us, "Scientists alone can establish the objectives of their research, but society, in extending support to science, must take account of its own needs." I urge you to look under, over, and beyond budget trend lines. We must emphasize strategic thinking and organizational change, *not* budgets per se, since resources will inevitably lag our aspirations and promising ideas. As Congressman George Brown wisely points out, if we are to preserve the future health of the Nation, we need to focus on *S&T* policy, not solely *budget* policy. The two are clearly linked, but too often we lose sight of the long-term S&T policy while getting exercised annually over numbers in the budget ledger.

In the dawn of the twenty-first century, I do not close on a somber note, for ours has been a century of scientific conquest and technical triumph.

Never in our country's short history or even in the longer history of science has the prospect been brighter, or the need greater for collaboration between those in government shaping S&T policy and those of you who work at the lab bench.

The challenges we grapple with today are without precedent in human history. Let us always remember that wisdom is the child of experience as we move toward a new era in which science will be increasingly challenged to fulfill its promise. And as we lean into the future, let us also resolve to encourage other talented young men and women to join us in these disciplines which require so much from them but which have so much to give to our citizens and to the people of the world.

So to each of you I express my deep appreciation for your contributions to the welfare of mankind, to the priceless storehouse of knowledge, and to the options of new technology so essential for the future.

Finally, I am reminded of what the great French Marshall Lyautey once said when he asked his gardener to plant a tree. The gardener protested that "the tree would not bear fruit for a hundred years. "In that case," Lyautey responded, "plant it this afternoon."

That is how I feel about your work. Godspeed to each of you, and may the best be yet to come!

Thank you very much.

Copied VP COS

BY DAVID GERGEN / EDITOR AT LARGE

To VP

The 7 percent solution

Funding basic scientific research is vital to America's future

As many of us gazed up at the Hale-Bopp comet this spring, wondrous and serene in the heavens, an angry E-mail ripped through the scientific community below. It was written by Alan Hale, one of the men who discovered the comet two years ago.

Hale, it turns out, earned a Ph.D. in astronomy from New Mexico State University in 1992 and has since had terrible trouble finding decent-paying work. His wife, a nurse, is the family's main source of income. So disillusioned is he with America's "scientific illiteracy" and the drying up of research jobs that he would not encourage today's students to pursue scientific careers.

For many in the field, there is poignant irony in Hale's story. He is one of many younger Ph.D.'s who could put their names on new discoveries in science and technology in the years ahead. A recent visit to the California Institute of Technology and the Jet Propulsion Laboratory nearby found scientists bubbling with excitement about prospective breakthroughs. Yet there is a legitimate and growing fear among these same people that the nation really doesn't understand or support their endeavors. Few are as gloomy as Hale, but nearly all share his concerns.

> There is a legitimate fear among scientists that the nation doesn't understand or support their work.

Down, down, down. The clearest form of national support for science is the federal budget, which funds 60 percent of the country's basic research. For decades, expenditures increased. In each of the past four years, however, federal investment in research has declined, and President Clinton's budget calls for yet another drop next year.

Since March, in an unprecedented show of unity, the heads of over 40 organizations representing more than 1.5 million scientists, engineers, and mathematicians have endorsed a joint statement expressing alarm that research investments as a percentage of GDP are approaching a 40-year low. They urge that federal spending on research and development be increased by 7 percent next year—enough to make up for past inflation and to reverse the trend. A growing number of Republicans, led by Texas Sen. Phil Gramm (a deficit hawk), and some Democrats are joining the fight. Gramm wants a doubling of science spending over the next decade.

The arguments for substantial increases are compelling. Some believe the end of the cold war means we no longer need scientific research to protect our security. What they ignore is that the lag time between basic research and military application is often 20 to 30 years; weapons used in the Persian Gulf war, for example, emerged from research in the 1960s. Who can say with certainty today that we will not need advanced military technology a quarter century from now?

Economists believe research is also essential to growth and keeping our competitive edge. Stanford's Michael Boskin estimates that half of all long-term economic growth since World War II in industrialized nations is due to technological progress—which, in turn, is rooted in basic research. At the University of Pennsylvania, Edwin Mansfield has found that academic research in science has a "social rate of return" in the form of lower prices, better products, and higher productivity that exceeds 20 percent.

Finally, we should understand how science advances our quality of life. Allan Bromley, science adviser to President Bush and now dean of engineering at Yale, points out, for example, that in the past five years "we have learned more about the human brain and central nervous system than in all prior history," thanks to imaging and chemical tests developed by engineers from basic physics, chemistry, and mathematics. Since brain-related disorders send more Americans to the hospital than any other disease group, this progress is very good news indeed.

At a time of scarce resources in Washington, it is tempting to see the scientific community as just one more hungry claimant. That's shortsighted. Like public education, serious funding for science is a vital national investment. The men and women in our laboratories stand at the threshold of dazzling new breakthroughs, and the nation should be standing there with them, supporting their work and sharing in their joy of discovery. ■

November 20, 1997

MEMORANDUM FOR RON KLAIN

FROM: JIM KOHLENBERGER

SUBJECT: **SCIENCE AND TECHNOLOGY IDEAS**

Yesterday you asked for a collection of big new ideas in Science and Technology. I have attached two separate pieces.

- **Science and Tech Big Ideas.** The first piece is a collection of big ideas that we could do if we were in a perfect world. More staff work would have to be done to move forward on any of these. This is more of a wish list of items.

- **Science and Tech Priorities New for FY99 That Are Already in Play.** The second piece is a collection of FY99 items that we are working towards and I think are achievable in the FY99 budget process with some lifting.

Let me know if these are what you are looking for.

FY 99 Budget Priorities

1. **21st Century Teachers.**
For about $200 million, with some coming from existing edtech budgets, we could train every new teacher and provide a technology specialist in every elementary school in the country. This new initiative allows teachers to catch-up with the rapid deployment of technology in the classroom that our various educational technology initiatives are bringing ($2.25 billion a year e-rate and $500 million in other edtech money). It also helps to dispel the notion that all we care about is hardware and don't understand that for it to be successful, teachers must be trained.

2 **Digitizing National Treasures**
A new $17 million public/private partnership to capture the cultural and scientific treasures held in federal collections in digital form, make they widely available through the Internet, and develop interpretive and instructional programs to make them more accessible. We can put over 5 million national treasures on-line by the year 2000 from the collections of the Smithsonian, the National Park Service, the National Archives, the Library of Congress and other Museums across the country. We would launch a 5 year program funded at $17/year . The federal funding would be matched by donations from private firms. The request is for Smithsonian 5M, National Archives $2M, National Park Service $2M, NEH $4M, NEA $2M, and IMLS $2M.

3. **Increase in Cancer Research**
Increase cancer funding by $250 million to $714 million more than more than the FY 98 request ($2.442 billion for FY 98) for funding to fight cancer. The funds will be used to: 1) enhance cancer prevention research, 2) improve early detection and diagnosis to make cancer more treatable, 3) new interventions 4) more patients involved in clinical trials and 5) increase access of the American people to state-of-the-art information about cancer and cancer interventions.

4. **Digital Globe: A Next Generation Information Infrastructure**
The Vice President has long envisioned a "digital globe" accessible to anyone anywhere that allows researchers and others to "drill-down" to information in a digital version of the planet in an Internet like infrastructure. This effort, to create a geographically based information infrastructure, is comparable to the original federal investment that led to the Internet itself. The request is for $25 million a year for to launch the first step which would make available 1 meter resolution imaging of the entire earth in a new digital infrastructure that allows scientists, historians, and others to build upon this shared electronic resource.

5. **Public Broadcasting's Transition to Digital Television**
CPB has submitted a proposal to OMB for $771 million over three years in new

federal money leveraging $1.7 billion total for an early conversion to Digital Television. The FCC has mandated that all station's convert to digital programming by 2003. Public broadcasting has historically led the way in the deployment of new technologies including satellite transmission and closed captioning. We certainly don't want to leave public broadcasting behind in the transition to digital. And it could revolutionize educational technology. However, there are several questions raised by the proposal. Should their transition occur ahead of the private sector's transition? Could the cost of conversion be reduced through public interest obligations by commercial broadcasters to allow tower co-siting or other means? Will Congress decide instead to use the money for a trust fund to wall off public broadcasting from the annual appropriations debate (as we have called for in the past) leaving public broadcasting behind?

6 **R&D for Learning Technology**
$100 million for R&D for evaluation and tool development in educational technology. This money helps us answer the question of how and why educational technology works in the classroom. ($48M DOD, $58M NSF, $2M ED)

7 **Learning on Demand**
New $100 million initiative to bring technology to lifelong learning. Sperling will probably take the lead. The Vice President just announced a new Executive Memorandum that charged NEC with coming up with a national Learning on Demand strategy.

8. **Build National Spallation Neutron Source (NSNS) in Tennessee**
In 1999, the project warrants about $140-157 million, to begin long-lead procurement and detailed technical (Architectural & Engineering) design. Failure to deliver this funding will be an indication to the Energy Community that the Administration is not serious about building the NSNS.

Possible Science and Technology Initiatives

1. **Expanding the frontiers of knowledge - maintaining our commitment to basic research.** To reclaim a Clinton-Gore priority from Congress and ensure that America continues to reap the long-term benefits of R&D, we could invest in our R&D budgets to beat inflation and beat Japan's investment. Japan plans to double their R&D spending by 2002. If U.S. trends continue, Japan will overtake the U.S. in R&D -- in total dollars, not just as a share of GDP.

   - Seperately we could permanently extend the R&E tax credit -- which is currently scheduled to expire in mid-1998. We could also explore additional credits for industry support for university research.

   - Expansion of university-based R&D could be linked to a set of "**grand challenges**" - big questions we do not have the answer to, such as:

     - How do we cure cancer?
     - How old is the universe?
     - How do we learn and remember?
     - How and why do cells die?
     - How do we produce materials with no waste by-products?
     - Are planets in other solar systems capable of sustaining life?
     - How can we transform raw data from a variety of disciplines into new insights and useful knowledge?

2. **Permanent Telepresence on Mars**
   Establish a permanent robotic presence on the surface of Mars by 2010 that can serve as a virtual laboratory for scientists and educators around the world using the capabilities of the Internet and other advanced computing and communications technologies.

3. **Opportunity for all in the Information Age**
   We could expand investment in the <u>uses</u> of information technology, such as:
   - Improving the quality of life for people with disabilities with technologies such as speech recognition, text-to-speech
   - Creating opportunity for working Americans to learn "anytime, anywhere" through distance education
   - Putting government online, and making it more efficient, responsive, and user friendly
   - A "Digital Globe" [3-D map of the entire planet at 1 meter resolution] that would serve as a powerful tool for education, crisis management, and

decision-making on environmental issues (a "Sit Room" for the planet)

- Secure electronic medical records that automatically let doctors know about new treatment options for patients
- Digitizing America's cultural heritage (e.g. Smithsonian, Library of Congress) as one of the Millennium "gifts"
- Fighting crime by allowing swat teams from different agencies/level of governments to communicate on secure wireless networks - and access law enforcement databases from squad cars

4. **Expand investment in maintaining U.S. leadership in information technology**. Information Technology is now the single biggest U.S. industry. This would involve research like:

- Making U.S. networks "hacker-proof"
- Developing easier-to-use computers that "understand" human speech
- Finding a specific piece of information in a huge sea of digital information
- Putting a "supercomputer-on-a-chip" that will allow devices like a Dick Tracy watch that fits on a lapel pin
- Intelligent agents

5. **National Food Genome Initiative.** We could achieve Global food security by the year 2015 by establishing a Food Genome Project to ensure and utilize our base of genetic resources. Food production is the nation's largest industry -- about 15 percent of GDP. By mapping the genetic sequences of agriculturally important plants and animals, we can dramatically increase our agricultural productivity and exports. This could cost about $100 million a year.

6. **Preserve the Nation's Biological Heritage/Stem Biodiversity Loss** Establish mechanisms and put them in place nationwide to preserve the vital functions of our ecosystems, including the diversity of life they contain, by 2010?. Complete the foundation of basic knowledge of species and their interaction with the environment. Develop a solid, scientifically-based predictive capability, an operational "calculus of biodiversity". Put in place, through public-private partnership, comprehensive habitat management plans covering all areas of the country, including a system of conservation areas, incentives for private property owners, and assurances for the development needed for growth of the country.

7. **Early diagnosis and treatment of diseases with a genetic component (e.g. cancer)** Thanks to the Human Genome Project -- we are well on our way to sequencing the entire human genome. However, knowing where the genes are is

not the same as knowing what they do. For example, according to the President of MIT, "we do not know all the specific genes whose mutations contribute to the development of cancer, nor do we understand the mechanisms by which they do it. This includes both "oncogenies," which can cause cancer, and "tumor suppressor genes," which suppress excess growth and, if absent or damaged, allow tumors to develop."

Investments in the field of **functional genomics** will allow us to link specific genes to specific traits and diseases - which will eventually lead to more effective diagnosis and cures of a wide range of diseases, including cancer.

Remarks by Vice President Al Gore
"Creating New Jobs for the 21st Century: Investing in Research and Technology"
Announcement of R&E Tax Credit Extension, Genentech
Thursday, January 29, 1998

Two nights ago, in his State of the Union address, President Clinton summoned all Americans to strengthen our nation for the 21st Century --to build the future that is now within our reach: a future of new jobs for a new economy; a future that is stronger, healthier, and more hopeful than any time in human history. As the President said on Tuesday, a child born in 1998 may well live to see the 22nd century.

And it is fitting to come here to Genentech, one of the leading Biotechnology companies of the world --a company with an astonishing 2,900 patents worldwide, and another 1,900 pending --to tell America what you clearly know to be true: that in the 21st Century, a growing share of our prosperity will be built on research and discovery.

Of course, that is because the work you do here saves lives, and improves lives --for those who suffer from strokes and heart conditions, for children with growth deficiencies, for women with breast cancer, for young people with cystic fibrosis. Our administration's commitment to that kind of path-breaking research is clear.

This morning at the White House, I announced that we will propose the largest increase in history for cancer research at the National Institutes of Health --to unlock the dark secrets of disease, and to help our generation become the one that finally wins the war against cancer.

But here at Genentech, you have taught us another lesson: in the 21st Century, research and experimentation --innovation and ingenuity --is about our livelihoods as well as our lives.

Today, the high-tech industry is already the biggest employer in the United States --and it's growing. And high-tech means high-wage --with pay that is 73% above the private sector average.

It's not every day that we can celebrate an industry that is about new jobs and groundbreaking, life-saving discovery at the same time. But President Clinton and I believe that we must promote that kind of industry.--as actively and as aggressively as our balanced budget allows.

Today, I am pleased to announce that in the budget we will submit to Congress next week, we will propose an extension of America's $2.2 billion Research and Experimentation tax credit. In a world where imagination is only one small step ahead of reality, a relentless focus on the future --and targeted investments in research and development --are the best ways for America to succeed. This R&E tax cut means more high-wage jobs for the 21st Century. Here at Genentech alone, it will mean 150 new jobs for Californians.

New tax cuts for research and experimentation are just one part of our commitment. As the President announced two nights ago, as part of our gift to the new millennium, we are also proposing a new 21st Century Research Fund for path-breaking scientific inquiry --the largest investment in civilian research and development in American history. As part of a one-third overall increase in research funding, this new fund will include the largest-ever increases in the budgets of the National Science Foundation and the National Institutes of Health.

Taken together, the $31 billion in the 21st Century Research Fund will help us to cure deadly diseases; to find new sources of clean energy, a subject I will address when I visit British Petroleum's brand new solar plant in Fairfield tomorrow; to build the next generation of the Internet, moving 1,000 times faster than the current one; and to continue to explore the heavens.

In the old economy, growth depended largely on capital and labor. But we have learned that the true engines of growth today are ideas --and the technologies and higher productivity those ideas create. As the economist Paul Romer has shown, as much as half of our nation's economic growth in the last few decades has been due to technological innovation. And unlike investments in plants or equipment, our investments in innovation do not face the problem of diminishing returns.

That is why the impact of today's announcement goes far beyond the high-tech industry. More research and development means higher productivity, rising wages, and lower costs throughout our economy.

Over the past half-century, we have split the atom; spliced the gene; put men on the moon; invented the microchip, the laser, and the Internet --and none of these accomplishments would have happened without federal investment. In fact, Genetech's 3,200 jobs might not be here at all if our federal government had not invested in the research that led to the discovery of DNA. These achievements have expanded our frontiers of knowledge, spawned entire industries, and created millions of jobs.

I don't know what innovations will create the jobs of the next half-century --but with the investments I am announcing today, I am counting on all of you to find out.

It has been more than 200 years since explorers first landed on the coast of California. Today, you are America's new explorers --building a better life for all our people. I'm proud that we are investing in making your job easier --so that you can bring more jobs and more progress to America, to keep the State of our Union strong.

Meeting with Professor Stephen Hawking

West Wing Office
3:40 p.m. - 4:00 p.m., Tuesday, January 26, 1998

Meeting requested by you.
Briefing prepared by Jim Kohlenberger and Dan Taylor.

EVENT

You are meeting with Professor Stephen Hawking, one of the greatest minds of our day. He has often been compared to Einstein or Newton. While you and the President spend your day working on the laws of the country, as a cosmologist, Hawking spends his days working on understanding the laws of the universe. Since you didn't get a chance to spend time with him last year when he delivered one of the Millennium lectures, we thought this would be a good informal opportunity to get to know him better. **Note: this event is closed press.**

PROGRAM NOTES

- Professor Hawking is visiting Washington as part of an American lecture tour that will also take him to Chicago. The night before your meeting he will deliver a lecture at the Kennedy Center on *"The Expanding Universe and the Power of the Human Mind."*

- As you recall, Professor Hawking was last at the White House on March 6, 1998, as the guest lecturer for the second Millennium Evening. His speech was titled, *"Imagination and Change: Science in the Next Millennium."* You asked Professor Hawking a question via email (you were in New Hampshire). *Note: your question and his answer are attached. A picture of Professor Hawking and the President at this event leads off Professor Hawking's Web page.*

- His best-selling book about the evolution of the universe, *A Brief History of Time: From the Big Bang to Black Holes*, has been translated into 33 languages and has sold 9 million copies. Professor Hawking is the Lucasian Professor of Mathematics at Cambridge University, a position once held by Sir Isaac Newton. He is also the head of the General Relativity and Gravity Group in the Department of Applied Mathematics and Theoretical Physics.

- Hawking's other books include *The Large Scale Structure of Space-Time* (1973); *General Relativity: An Einstein Centenary Survey* (1979); *Superspace and Supergravity* (1981); and *Black Holes and Baby Universes and Other Essays* (1993)

- Professor Hawking is scheduled to make a guest voice appearance on the animated TV series *The Simpsons* in April.

- Hawking recently celebrated his 57th birthday (January 8). He is married to Jane Wilde, a linguist, and has three children: Robert, Lucy and Timothy.

ATTACHMENTS

- Professor Stephen Hawking's bio
- Hawking's comments on his disability
- Hawking's Millennium series lecture, *"Science in the Next Millennium"*
- Q&A with Professor Hawking, March 6, 1998

A Brief History of Mine

Stephen William Hawking was born on 8 January 1942 (300 years after the death of Galileo) in Oxford, England. His parents' house was in north London, but during the second world war Oxford was considered a safer place to have babies. When he was eight, his family moved to St Albans, a town about 20 miles north of London. At eleven Stephen went to St Albans School, and then on to University College, Oxford, his father's old college. Stephen wanted to do Mathematics, although his father would have preferred medicine. Mathematics was not available at University College, so he did Physics instead. After three years and not very much work he was awarded a first class honours degree in Natural Science.

Stephen then went on to Cambridge to do research in Cosmology, there being no-one working in that area in Oxford at the time. His supervisor was Denis Sciama, although he had hoped to get Fred Hoyle who was working in Cambridge. After gaining his Ph.D. he became first a Research Fellow, and later on a Professorial Fellow at Gonville and Caius College. After leaving the Institute of Astronomy in 1973 Stephen came to the Department of Applied Mathematics and Theoretical Physics, and since 1979 has held the post of Lucasian Professor of Mathematics. The chair was founded in 1663 with money left in the will of the Reverend Henry Lucas, who had been the Member of Parliament for the University. It was first held by Isaac Barrow, and then in 1663 by Isaac Newton.

Stephen Hawking has worked on the basic laws which govern the universe. With Roger Penrose he showed that Einstein's General Theory of Relativity implied space and time would have a beginning in the Big Bang and an end in black holes. These results indicated it was necessary to unify General Relativity with Quantum Theory, the other great Scientific development of the first half of the 20th Century. One consequence of such a unification that he discovered was that black holes should not be completely black, but should emit radiation and eventually evaporate and disappear. Another conjecture is that the universe has no edge or boundary in imaginary time. This would imply that the way the universe began was completely determined by the laws of science.

His many publications include The Large Scale Structure of Spacetime with G F R Ellis, General Relativity: An Einstein Centenary Survey, with W Israel, and 300 Years of Gravity, with W Israel. Stephen Hawking has two popular books published; his best seller A Brief History of Time, and his later book, Black Holes and Baby Universes and Other Essays.

Professor Hawking has twelve honorary degrees, was awarded the CBE in 1982, and was made a Companion of Honour in 1989. He is the recipient of many awards, medals and prizes and is a Fellow of The Royal Society and a Member of the US National Academy of Sciences.

Stephen Hawking continues to combine family life (he has three children and one grandchild), and his research into theoretical physics together with an extensive programme of travel and public lectures.

Home

Disability advice

My Experience with ALS

I am quite often asked: How do you feel about having ALS. The answer is, not a lot. I try to lead as normal a life as possible, and not think about my condition, or regret the things it prevents me from doing, which are not that many.

It was a great shock to me to discover that I had motor neurone disease. I had never been very well co-ordinated physically as a child. I was not good at ball games, and my handwriting was the despair of my teachers. Maybe for this reason, I didn't care much for sport or physical activities. But things seemed to change when I went to Oxford, at the age of 17. I took up coxing and rowing. I was not Boat Race standard, but I got by at the level of inter-College competition.

In my third year at Oxford, however, I noticed that I seemed to be getting more clumsy, and I fell over once or twice for no apparent reason. But it was not until I was at Cambridge, in the following year, that my father noticed, and took me to the family doctor. He referred me to a specialist, and shortly after my 21st birthday, I went into hospital for tests. I was in for two weeks, during which I had a wide variety of tests. They took a muscle sample from my arm, stuck electrodes into me, and injected some radio opaque fluid into my spine, and watched it going up and down with x-rays, as they tilted the bed. After all that, they didn't tell me what I had, except that it was not multiple sclerosis, and that I was an a-typical case. I gathered however, that they expected it to continue to get worse, and that there was nothing they could do, except give me vitamins. I could see that they didn't expect them to have much effect. I didn't feel like asking for more details, because they were obviously bad.

The realisation that I had an incurable disease, that was likely to kill me in a few years, was a bit of a shock. How could something like that happen to me. Why should I be cut off like this. However, while I had been in hospital, I had seen a boy I vaguely knew die of leukaemia, in the bed opposite me. It had not been a pretty sight. Clearly there were people who were worse off than me. At least my condition didn't make me feel sick. Whenever I feel inclined to be sorry for myself I remember that boy.

Not knowing what was going to happen to me, or how rapidly the disease would progress, I was at a loose end. The doctors told me to go back to Cambridge and carry on with the research I had just started in general relativity and cosmology. But I was not making much progress, because I didn't have much mathematical background. And, anyway, I might not live long enough to finish my PhD. I felt somewhat of a tragic character. I took to listening to Wagner, but reports in magazine articles that I drank heavily are an exaggeration. The trouble, is once one article said it, other articles copied it, because it made a good story. Anything that has appeared in print so many times, must be true.

My dreams at that time were rather disturbed. Before my condition had been diagnosed, I had been very bored with life. There had not seemed to be anything worth doing. But shortly after I came out of hospital, I dreamt that I was going to be executed. I suddenly realized that there were a lot of worthwhile things I could do if I were reprieved. Another dream that I had several times, was that I would sacrifice my life to save others. After all, if I were going to die anyway, it might as well do some good. But I didn't die. In fact, although there was a cloud hanging over my future, I found to my surprise, that I was enjoying life in the present more than before. I began to make progress with my research, and I got engaged to a girl called Jane Wilde, who I had met just about the time my condition was diagnosed. That engagement changed my life. It gave me something to live for. But it also meant that I had to get a job if we were to get married. I therefore applied for a research fellowship at Gonville and Caius (pronounced Keys) College, Cambridge. To my great surprise, I got a fellowship, and we got married a few months later.

The fellowship at Caius took care of my immediate employment problem. I was lucky to have chosen to work in theoretical physics, because that was one of the few areas in which my condition would not be a serious handicap. And I was fortunate that my scientific reputation increased, at the same time that my disability got worse. This meant that people were prepared to offer me a sequence of positions in which I only had to do research, without having to lecture.

We were also fortunate in housing. When we were married, Jane was still an undergraduate at Westfield College in London, so she had to go up to London during the week. This meant that we had to find somewhere I could manage on my own, and which was central, because I could not walk far. I asked the College if they could help, but was told by the then Bursar: it is College policy not to help Fellows with housing. We therefore put our name down to rent one of a group of new flats that were being built in the market place. (Years later, I discovered that those flats were actually owned by the College, but they didn't tell me that.) However, when we returned to Cambridge from a visit to America after the marriage, we found that the flats were not ready. As a great concession, the Bursar said we could have a room in a hostel for graduate students. He said "We normally charge 12 shillings and 6 pence a night for this room. However, as there will be two of you in the room, we will charge 25 shillings." We stayed there only three nights. Then we found a small house about 100 yards from my university department. It belonged to another College, who had let it to one of its fellows. However he had moved out to a house he had bought in the suburbs. He sub-let the house to us for the remaining three months left on his lease. During those three months, we found that another house in the same road was standing empty. A neighbour summoned the owner from Dorset, and told her that it was a scandal that her house should be empty, when young people were looking for accommodation. So she let the house to us. After we had lived there for a few years, we wanted to buy the house, and do it up. So we asked my College for a mortgage. However, the College did a survey, and decided it was not a good risk. In the end we got a mortgage from a building society, and my parents gave us the money to do it up. We lived there for another four years, but it became too difficult for me to manage the stairs. By this time, the College appreciated me rather more, and there was a different Bursar. They therefore offered us a ground floor flat in a house that they owned. This suited me very well, because it had large rooms and wide doors. It was sufficiently central that I could get to my University department, or the College, in my electric wheel chair. It was also nice for our three children, because it was surrounded by garden, which was looked after by the College gardeners.

Up to 1974, I was able to feed myself, and get in and out of bed. Jane managed to help me, and bring up the children, without outside help. However, things were getting more difficult, so we took to having one of my research students living with us. In return for free accommodation, and a lot of my attention, they helped me get up and go to bed. In 1980, we changed to a system of community and private nurses, who came in for an hour or two in the morning and evening. This lasted until I caught pneumonia in 1985. I had to have a tracheostomy operation. After this, I had to have 24 hour nursing care. This was made possible by grants from several foundations.

Before the operation, my speech had been getting more slurred, so that only a few people who knew me well, could understand me. But at least I could communicate. I wrote scientific papers by dictating to a secretary, and I gave seminars through an interpreter, who repeated my words more clearly. However, the tracheostomy operation removed my ability to speak altogether. For a time, the only way I could communicate was to spell out words letter by letter, by raising my eyebrows when someone pointed to the right letter on a spelling card. It is pretty difficult to carry on a conversation like that, let alone write a scientific paper. However, a computer expert in California, called Walt Woltosz, heard of my plight. He sent me a computer program he had written, called Equalizer. This allowed me to select words from a series of menus on the screen, by pressing a switch in my hand. The program could also be controlled by a switch, operated by head or eye movement. When I have built up what I want to say, I can send it to a speech synthesizer. At first, I just ran the Equalizer program on a desk top computer. However David Mason, of Cambridge Adaptive Communication, fitted a small portable computer and a speech synthesizer to my wheel chair. This system allowed me to communicate much better than I could before. I can manage up to 15 words a minute. I can either speak what I have written, or save it on disk. I can then print it out, or call it back, and speak it sentence by sentence. Using this system, I have written a book, and dozens of scientific papers. I have also given many scientific and popular talks. They have all been well received. I think that is in a large part due to the quality of the speech synthesizer, which is made by Speech Plus. One's voice is very important. If you have a slurred voice, people are likely to treat you as mentally deficient: Does he take sugar? This synthesizer is by far the best I have heard, because it varies the intonation, and doesn't speak like a Dalek. The only trouble is that it gives me an American accent. However, the company is working on a British version.

I have had motor neurone disease for practically all my adult life. Yet it has not prevented me from having a very attractive family, and being successful in my work. This is thanks to the help I have received from Jane, my children, and a large number of other people and organisations. I have been lucky, that my condition has progressed more slowly than is often the case. But it shows that one need not lose hope.

You can request information on ALS and Motor Neuron Disease from The Motor Neurone Disease Association,

There is also a helpline on 0345 626262, (Monday to Friday 9.00 – 22.30, Calls charged at local rate within the UK)

The International Alliance of ALS/MND Associations may also be useful in providing information

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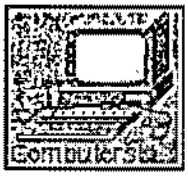

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Science in the Next Millennium
Remarks by Stephen Hawking

My theme tonight is science in the new millennium. The popular picture of science in the future is shown on television every night in science fiction series like Star Trek. They even persuaded me to take part, not that it was difficult.

[Clip from Star Trek shown]

Because of the red alert I never collected my winnings. I approached Paramount studios but they didn't know the exchange rate.

The Star Trek appearance was great fun, but I show it to make a serious point. Nearly all the visions of the future that we have been shown from HG Wells onwards have been essentially static. They show a society that is in most cases far in advance of ours, in science, in technology, and in political organization. (The last might not be difficult). There must have been great changes with their accompanying tensions and upsets in the period between now and then. But by the time we are shown the future science, technology, and the organization of society, are supposed to have achieved a level of near perfection.

I want to question this picture and ask if we will ever reach a final steady state of science and technology. At no time in the ten thousand years or so since the last Ice Age has the human race been in a state of constant knowledge and fixed technology. There have been a few set backs like the Dark Ages after the fall of the Roman Empire. But the world's population which is a measure of our technological ability to preserve life and feed ourselves has risen steadily, with a few hiccups like the Black Death. In the last two hundred years the growth has become exponential, that is, the population grows by the same percentage each year. Currently the rate is about 1.9% a year. 1.9 % may not sound very much but it means that the world population doubles every 40 years. Other measures of technological development in recent times are electricity consumption, or the number of scientific articles. They also show exponential growth with a doubling time of 40 years or less. Indeed, we now have such heightened expectations that some people feel cheated by politicians and scientists because we have not already achieved the Utopian visions of the future. For example, the film Two Thousand and One' showed us with a base on the Moon and launching a manned, or should I say personned, flight to Jupiter. I can't see us managing that in the next three years, whoever wins the election.

There is no sign that scientific and technological development will slow down and stop in the near future. Certainly not by the time of Star Trek which is only about 300 years away. But the present exponential growth can not continue for the next millennium. By the year 2600 the world's population would be standing shoulder to shoulder and the electricity consumption would make the Earth glow red hot. If you stacked the new books being published next to each other you would have to move at 90 miles an hour just to keep up with the end of the line. Of course by 2600, new artistic and scientific work will come in electronic forms rather than as physical books and papers. Nevertheless, if the exponential growth continued, there would be ten papers a second in my kind of theoretical physics, and no time to read them.

Clearly the present exponential growth can not continue indefinitely. So what will happen? One possibility is that we wipe ourselves out completely by some disaster such as a nuclear war. There is a sick joke that the reason we have not been contacted by extra-terrestrials is that when a civilization reaches our stage of development it becomes unstable and destroys itself. Of course it is possible that UFO's really do contain aliens, as many people believe, and the government is hushing it up. I couldn't possibly comment!

Personally I believe there's a different explanation why we have not been contacted, but I won't go into it here. However even without that there is a very real danger that we will kill everything on this planet now that we have the technological power to do so. Even if we don't destroy ourselves completely there is the possibility that we might descend into a state of brutalism and barbarity like the opening scene of Terminator.

But I'm an optimist. I think we have a good chance of avoiding both Armageddon and a new Dark Ages.

So how will we develop in science and technology over the next millennium? This is very difficult to answer. But let me stick my neck out and offer my predictions for the future. I will have some chance of being right about the next hundred years, but the rest of the millennium will be wild speculation.

Our modern understanding of science began about the same time as the European settlement of North America. In 1687 Isaac Newton, the second Lucasian professor at Cambridge, published his theory of gravity and in 1864 Clerk Maxwell, another Cambridge man, discovered the equations that govern electricity and magnetism. By the end of the 19th century it seemed that we were about to achieve a complete understanding of the universe in terms of what are now known as classical laws. These correspond to what might seem the common sense notion that physical quantities such as position, speed, and rate of rotation, should be both well defined and continuously variable. But common sense is just another name for the prejudices that we have been brought up with. Common sense might lead us to expect quantities like energy to be continuous. But from the beginning of the 20th century observations began to show that energy came in discrete packets called quanta. It seems that Nature is grainy not smooth.

A new kind of theory called quantum mechanics was formulated in the early years of the 20th century. Quantum theory is a completely different picture of reality so it should concern us all but it is hardly known outside physics and chemistry and not even properly understood by many in those fields. Yet if, as I hope basic science becomes part of general awareness what now appear as the paradoxes of quantum theory will seem as just common sense to our children's' children.

In quantum theory things don't have a single unique history as our present day common sense would suggest. Instead they have every possible history each with its own probability. There must have been a history in which the Chicago Cubs won the World Series, though maybe the probability was low. However for large scale systems like base ball games the probability is normally peaked around a single history so there is very little uncertainty. But when one goes to the small lengths scales of individual particles the uncertainty can become very large. For example, if one knows that a particle is at a point A at a certain time then at a later time it can be anywhere because it can have any path or history. To calculate the probability that it is at a point B one has to add up the probabilities for all the paths or histories that take it from A to B. This idea of a sum over all possible histories is due to the American physicist and one time bongo drum player Richard Feynman.

The possible particle histories have to include paths that travel faster than light and even paths that go back in time. Before anyone rushes out to patent a time machine let me say that in normal circumstances at least, one can not use this for time travel. However paths that go back in time are not just like angels dancing on a pin. They have real observational consequences. Even what we think of as empty space is full of particles moving in closed loops in space and time. That is they move forward in time on one side of the loop and backwards in time on the other side. These closed loops are said to be virtual particles because they can not be measured directly with a particle detector. However their effects can be measured indirectly. One way is to have a pair of metal plates close together. The effect of the plates is to reduce slightly the number of closed loops in the region between the plates relative to the number outside. There are thus more closed loops hitting the outside edges of the plates and bouncing off than there are hitting the inside edges. One would therefore expect there to be a small force pushing the plates together. This force, which was first predicted by the Turkish physicist Hendrick Casimir, has been observed experimentally. So we can be confident that closed particle loops really exist.

The awkward thing is that because there's an infinite number of points in space and time there are an infinite number of possible closed loops of particles. This infinite number of loops didn't matter in the calculation of the force between two plates because the numbers between the plates and outside them are both infinite. There is a well defined way in which one can subtract one infinity from the other and get a finite answer. It is a bit like the American budget. Both the government tax revenue, and its expenditure, are very large sums, almost infinite. Yet if one is careful one can subtract one from another and get a small surplus, at least until the next election.

Where the infinite number of closed loops caused trouble was when people tried to combine quantum theory with Einstein's General Theory of Relativity. This is the other great scientific revolution of the first half of the 20th century. It says that space and time are not flat like common sense once told us that the Earth was flat. Instead, they are warped and distorted by the matter and energy in them. An infinite number of closed loops of particles would have an infinite amount of energy and would curl space and time up to a single point.

To deal with this infinite energy requires some really creative accounting. The key concept was a new kind of balance or symmetry in nature called super symmetry, which was first proposed by two Russians, Golfand and Likhtman, in 1971. The idea was that as well as the ordinary dimensions of space and time with which we are familiar, there were extra dimensions that were measured in what are called Grassmann numbers. Of course, science fiction has been telling us for years that there are extra dimensions. But even science fiction did not think of anything as odd as Grassmann dimensions. Here the word "odd" has a technical use as well as the usual meaning of peculiar. Ordinary numbers are said to be even because it doesn't matter in what order one multiplies them. 6 times 4 is the same as 4 times 6. But Grassmann numbers are odd in the sense that x times y, is minus y times x.

The existence of these extra odd dimensions implies that every species of particle must have a super partner species. The super partner species will also have closed loops of particles. But the energy of the super partner loops will have the opposite sign to those of the original species. Thus the infinite energies tend to cancel out. But as the President knows, balancing the budget is a very delicate business. Even if one removes the main deficit smaller deficits have a nasty habit of appearing. Much of the work in theoretical physics in the last twenty years has been looking for a theory in which the infinities cancel completely. Only then will we be able to unify Quantum Theory with Einstein's General Relativity and achieve a complete theory of the basic laws of the universe.

What are the prospects that we will discover this complete theory in the next millennium. I would say they were very good but then I'm an optimist. In 1980 I said I thought there was a 50-50 chance that we would discover a complete unified theory in the next twenty years. We have made some remarkable progress in the period since then but the final theory seems about the same distance away. Will the Holy Grail of physics be always just beyond our reach? I think not. At the beginning of the 20th century we understood the workings of nature on the scales of classical physics which is good down to about a hundredth of a millimeter. The work on atomic physics in the first thirty years of the century took our understanding down to lengths of a millionth of a millimeter. Since then, research on nuclear and high energy physics has taken us to length scales that are smaller by a further factor of a billion. It might seem that we could go on forever discovering structures on smaller and smaller length scales. However there is a limit to this series as there is to the series of Russian dolls within Russian dolls. Eventually one gets down to a smallest doll, which can't be taken apart any more. In physics the smallest doll is called the Planck length and is a millimeter divided by a hundred thousand billion billion billion. We are not about to build particle accelerators that can probe to distances that small. They would have to be larger than the solar system and they are not likely to be approved in the present financial climate. However, there are consequences of our theories that can be tested by much more modest machines. By far the most important of these is super symmetry which is fundamental to most attempts to unify Einstein's General Relativity with Quantum Theory. This would be confirmed by the discovery of super partners to the particles that we already know. The Superconducting Super Collider (the SSC) was being built in Texas and would have reached the energies at which super partners were expected. However, the United States went through a fit of feeling poor and canceled the project half way. At the risk of causing embarrassment, I have to say I think this was a very short sighted decision. hope that the US, and other governments will do better in the next millennium.

I expect super symmetry will be confirmed eventually by experiments at CERN in Geneva. But it won't be possible to probe down to the Planck length in the laboratory. We can study the Big Bang to get observational evidence at higher energies and shorter length scales than we can achieve on Earth. However, to a large extent we shall have to rely on mathematical beauty and consistency to find the ultimate Theory of Everything. Nevertheless I am confident we will discover it by the end of the 21st century and probably much sooner. I would take a bet at 50-50 odds that it will be within twenty years starting now.

The Star Trek vision of the future that we achieve an advanced but essentially static level may come true in respect of our knowledge of the basic laws that govern the universe. But I don't think we will ever reach a steady state in the uses we make of these laws. The ultimate theory will place no limit on the complexity of systems that we can produce and it is in this complexity that I think the most important developments of the next millennium will be.

By far the most complex systems that we have are our own bodies. Life seems to have originated in the primordial oceans that covered the Earth four billion years ago. How this happened we don't know. It may be that random collisions between atoms built up macro-molecules that could reproduce themselves and assemble themselves into more complicated structures. What we do know is that by three and a half billion years ago the highly complicated molecule DNA had emerged. DNA is the basis for all life on Earth. It has a double helix structure, like a spiral staircase, which was discovered by Francis Crick and James Watson in the Cavendish lab at Cambridge in 1953. The two strands of the double helix are linked by pairs of nucleic acids like the treads in a spiral staircase. There are four kinds of nucleic acids. I won't try to pronounce their names because my speech synthesizer makes a mess of them. Obviously it was not designed for molecular biologists. But I can refer to them by their initials, C, G, A, and T. The order in which the different nucleic acids occur along the spiral staircase carries the genetic information that enables the DNA molecule to assemble an organism around it and reproduce itself. As the DNA made copies of itself there would have been occasional errors in the order of the nucleic acids along the spiral. In most cases the mistakes in copying would have made the DNA unable to reproduce itself. Such genetic errors, or mutations as they are called, would die out. But in a few cases the error or mutation would increase the chances of the DNA surviving and reproducing. This natural selection of mutations was first proposed by another Cambridge man, Charles Darwin, in 1857, though he didn't know the mechanism for it. Thus the information content in the sequence of nucleic acids would gradually evolve and increase in complexity.

Because biological evolution is basically a random walk in the space of all genetic possibilities it has been very slow. The complexity, or number of bits of information that are coded in DNA is given roughly by the number of nucleic acids in the molecule. Each bit of information can be thought of as the answer to a yes no question. For the first two billion years or so the rate of increase in complexity must have been of the order of one bit of information every hundred years. The rate of increase of DNA complexity gradually rose to about one bit a year over the last few million years. But now we are at the beginning of a new era in which we will be able to increase the complexity of our DNA without having to wait for the slow process of biological evolution. There has been no significant change in human DNA in the last ten thousand years. But it is likely that we will be able to completely redesign it in the next thousand. Of course many people will say that genetic engineering on humans should be banned. But I rather doubt if they will be able to prevent it. Genetic engineering on plants and animals will be allowed for economic reasons and someone is bound to try it on humans. Unless we have a totalitarian world order, someone will design improved humans somewhere.

Clearly developing improved humans will create great social and political problems with respect to unimproved humans. I'm not advocating human genetic engineering as a good thing, I'm just saying that it is likely to happen in the next millennium, whether we want it or not. This is why I don't believe science fiction like Star Trek where people are essentially the same four hundred years in the future. I think the human race, and its DNA, will increase its complexity quite rapidly.

In a way the human race needs to improve its mental and physical qualities if it is to deal with the increasingly complex world around it and meet new challenges like space travel. And it also needs to increase its complexity if biological systems are to keep ahead of electronic ones. At the moment computers have an advantage of speed, but they show no sign of intelligence. This is not surprising because our present computers are less complex than the brain of an earthworm, a species not noted for their intellectual powers. But computers obey Moore's Law put forward by Gordon Moore of Intel. This says that their speed and complexity double every 18 months. It is one of these exponential growths which clearly can not continue indefinitely. However it will probably continue until computers have a similar complexity to the human brain. Some people say that computers can never show true intelligence whatever that may be. But it seems to me that if very complicated chemical molecules can operate in humans to make them intelligent then equally complicated electronic circuits can also make computers act in an intelligent way. And if they are intelligent they can presumably design computers that have even greater complexity and intelligence.

This is why I don't believe the science fiction picture of an advanced but constant future. Instead, I expect complexity to increase at a rapid rate, both in the biological and electronic spheres. Not much of this will happen in the next hundred years, which is all we can reliably predict. But by the end of the next millennium, if we get there, the change will be fundamental.

Lincoln Steffens once said, "I have seen the future and it works." He was actually talking about the Soviet Union, which we now know didn't work very well. Nevertheless, I think the present world order has a future, but it will be very different.

Mr President, First Lady, This is my view of science in the next millennium.

Back to the Millennium Council

Millennium Evening
Question and Answer Session
March 6, 1998

MRS. CLINTON: Oh, this question is from Al in New Hampshire. (Laughter and applause.) That is, for our British guests, Al Gore, who is never without his computer and, therefore, can log on anywhere, and was very sorry that previous obligations kept him from being here. So here is the Vice President's question:

Within the past month, we have seen evidence suggesting a strong, repulsive force in the universe -- an anti-gravitational force causing the universe to expand, surprisingly, at an accelerating rate. How surprised were you by this finding? What are its most important implications? And how could your national cosmology supercomputer help to prove or disprove these implications?

DR. HAWKING: What the Vice President is referring to is some observational evidence that suggests that there may be an anti-gravitational force that would cause the universe to expand at an increasing rate. The existence of such an anti-gravitational force is very controversial. Einstein first suggested it might exist, but later regretted it and said it was his greatest mistake. If it is there at all, it must be very small. It is difficult to understand why it should be so small, unless it were exactly zero.

We probably won't know if there's a small anti-gravitational force until observations come in from new satellites that the U.S. and Europe will put up in the first years of the millennium. But the data analysis of this satellite observations will require a supercomputer like the national cosmology computer we have in Cambridge. If it turns out that there really is an anti-gravitational force, it will mean that inflation is a law of nature. (Laughter and applause.)

THE PRESIDENT: Dr. Hawking, my position is we have repealed that law. (Laughter.)

Let me say, first of all, in defense of my Vice President, you will all understand that he would love to be here, but there is a peculiar gravitational force in New Hampshire that manifests itself with a remarkable regularity. (Laughter.) Let me also say that in the visual presentation accompanying Dr. Hawking's lecture, there was that remarkable project stamped "canceled" on it. This administration opposed the cancellation of it, I'm proud to say. (Laughter.) But we hope that the Swiss project will take up the slack.

Remarks by Vice President Al Gore
"Creating New Jobs for the 21st Century: Investing in Research and Technology"
Announcement of R&E Tax Credit Extension, Genentech
Thursday, January 29, 1998

Two nights ago, in his State of the Union address, President Clinton summoned all Americans to strengthen our nation for the 21st Century --to build the future that is now within our reach: a future of new jobs for a new economy; a future that is stronger, healthier, and more hopeful than any time in human history. As the President said on Tuesday, a child born in 1998 may well live to see the 22nd century.

And it is fitting to come here to Genentech, one of the leading Biotechnology companies of the world --a company with an astonishing 2,900 patents worldwide, and another 1,900 pending --to tell America what you clearly know to be true: that in the 21st Century, a growing share of our prosperity will be built on research and discovery.

Of course, that is because the work you do here saves lives, and improves lives --for those who suffer from strokes and heart conditions, for children with growth deficiencies, for women with breast cancer, for young people with cystic fibrosis. Our administration's commitment to that kind of path-breaking research is clear.

This morning at the White House, I announced that we will propose the largest increase in history for cancer research at the National Institutes of Health --to unlock the dark secrets of disease, and to help our generation become the one that finally wins the war against cancer.

But here at Genentech, you have taught us another lesson: in the 21st Century, research and experimentation --innovation and ingenuity --is about our livelihoods as well as our lives.

Today, the high-tech industry is already the biggest employer in the United States --and it's growing. And high-tech means high-wage --with pay that is 73% above the private sector average.

It's not every day that we can celebrate an industry that is about new jobs and groundbreaking, life-saving discovery at the same time. But President Clinton and I believe that we must promote that kind of industry --as actively and as aggressively as our balanced budget allows.

Today, I am pleased to announce that in the budget we will submit to Congress next week, we will propose an extension of America's $2.2 billion Research and Experimentation tax credit. In a world where imagination is only one small step ahead of reality, a relentless focus on the future --and targeted investments in research and development --are the best ways for America to succeed. This R&E tax cut means more high-wage jobs for the 21st Century. Here at Genentech alone, it will mean 150 new jobs for Californians.

New tax cuts for research and experimentation are just one part of our commitment. As the President announced two nights ago, as part of our gift to the new millennium, we are also proposing a new 21st Century Research Fund for path-breaking scientific inquiry --the largest investment in civilian research and development in American history. As part of a one-third overall increase in research funding, this new fund will include the largest-ever increases in the budgets of the National Science Foundation and the National Institutes of Health.

Taken together, the $31 billion in the 21st Century Research Fund will help us to cure deadly diseases; to find new sources of clean energy, a subject I will address when I visit British Petroleum's brand new solar plant in Fairfield tomorrow; to build the next generation of the Internet, moving 1,000 times faster than the current one; and to continue to explore the heavens.

In the old economy, growth depended largely on capital and labor. But we have learned that the true engines of growth today are ideas --and the technologies and higher productivity those ideas create. As the economist Paul Romer has shown, as much as half of our nation's economic growth in the last few decades has been due to technological innovation. And unlike investments in plants or equipment, our investments in innovation do not face the problem of diminishing returns.

That is why the impact of today's announcement goes far beyond the high-tech industry. More research and development means higher productivity, rising wages, and lower costs throughout our economy.

Over the past half-century, we have split the atom; spliced the gene; put men on the moon; invented the microchip, the laser, and the Internet --and none of these accomplishments would have happened without federal investment. In fact, Genetech's 3,200 jobs might not be here at all if our federal government had not invested in the research that led to the discovery of DNA. These achievements have expanded our frontiers of knowledge, spawned entire industries, and created millions of jobs.

I don't know what innovations will create the jobs of the next half-century --but with the investments I am announcing today, I am counting on all of you to find out.

It has been more than 200 years since explorers first landed on the coast of California. Today, you are America's new explorers --building a better life for all our people. I'm proud that we are investing in making your job easier --so that you can bring more jobs and more progress to America, to keep the State of our Union strong.

THE WHITE HOUSE

WASHINGTON

February 3, 1998

MEMORANDUM FOR THE VICE PRESIDENT

FROM: TOM KALIL TAK
JIM KOHLENBERGER JK

THROUGH: DON GIPS

RE: MEETING WITH NEAL LANE

Attached are some suggested talking points for your meeting with Dr. Neal Lane to discuss the OSTP position with him. We think that there are four major points that you should communicate to Dr. Lane.

1. **This is an exciting time to be the President's science advisor.**

2. **You are committed to ensuring that he has the access to you and to the President that he needs to be an effective science advisor.**

3. **OSTP can play a more central role in shaping S&T policy and keeping S&T on the "front-burner"if it focuses on a few White House priorities.**

4. **OSTP needs to be more "plugged in" to the rest of the White House** (e.g. proposing exciting "message" events and policy announcements, interacting with the other White House offices and policy councils).

Talking points

- First of all, I wanted to thank you for your willingness to be considered for the position of the President's Science Advisor. I know that you really enjoy your current position as Director of the National Science Foundation, and I am delighted that you are willing to tackle this new challenge.

- I think that **this is an incredibly important time to be the President's Science Advisor**.

  - The President and I have just proposed the "21st Century Research Fund" -- which would increase investment in key civilian research programs by 32 percent by 2003.

  - There seems to be bipartisan support for the idea of increasing federal investment in research and development. Senators like Gramm and Domenici have even proposed doubling R&D - even though they don't have a proposal to pay for it.

  - The pace of scientific discovery and technological innovation has accelerated and will continue to accelerate -- thanks to breakthroughs such as Next Generation Internet, the sequencing of the human genome, and computational science.

  - We need a Science Advisor who can help the President and I make the strongest possible case for sustained increases in civilian research and development. What are the benefits that will flow from an increased investment in R&D? What will the 21st Century be like for the average American? What are the "grand challenges" in science and engineering that can motivate exciting research agendas?

- I want you to know that --- assuming that everything works out -- **I am committed to ensuring that you have the access to the President and to me that you need to be a strong and effective Science Advisor**. This requires:

  - Regular meetings with me and meetings with the President;

  - An effective channel of communication that would allow you to propose new ideas and keep us up to date on new developments in S&T policy; and

  - Participation in senior staff meetings on important planning, policy and budget issues.

<u>If at any point you felt that you did not have the access you needed -- I would be prepared to intervene to solve this problem.</u>

- I think that OSTP can play a more central role in shaping S&T policy **if you focus on a few White House priorities as opposed to trying to cover everything.** I would be very interested in your thoughts on what these priorites should be. Clearly -- some of the priorities that the President and I have identified include:

  - Fundamental, university-based research;

  - Biomedical research;

  - Technologies that reduce the emission of greenhouse gasses;

  - Civilian technology programs such as the Advanced Technology Program and PNGV that will help generate economic growth and create high-wage jobs;

  - Information and communications technologies - such as the Next Generation Internet and NSF's Knowledge and Distributed Intelligence initiative - and the applications of these technologies in areas such as life-long learning; and

  - The exploration of space.

- I also think that **OSTP needs to be more connected to the rest of the White House.** To be effective in the White House -- OSTP needs to interact with:

  - OMB and the NEC on the budget;

  - Communications, Scheduling, Speechwriting, and the Press Office to generate compelling, newsworthy events that the average American can understand;

  - Legislative Affairs - to push our agenda on the Hill;

  - The other policy offices (NEC, DPC, NSC, CEQ) in those areas where S&T intersects with another aspect of public policy. Good advice on science and technology can help support other Presidential priorities such as education, the race initiative, and climate change.

- Obviously, scientists and engineers are most comfortable talking with other scientists and engineers. They are not used to expressing a complicated idea in terms that the average American can understand, planning an event, or building coalitions that can support the Administration's agenda. **I would encourage you to work with Jim Kohlenberger and Tom Kalil to recruit some staff who can handle some of these "political" functions.**

- I plan to talk to the President and let him know that you are my choice for OSTP Director. Obviously, we want to keep this out of the press until this is finalized.

- I am really looking forward to working with you. I think we have an extraordinary "window of opportunity" to make investements in science and technology that will advance the frontiers of knowledge and shape our future.