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HEARING ON

S. 272

- HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

Tuesday, March 5, 1991

U.S. Senate
Subcommittee on Science,
Technology, and Space
Committee on Commerce, Science,
and Transportation
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:04 p.m., in Room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr., presiding.

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OPENING STATEMENT OF HON. ALBERT GORE, JR., U.S. SENATOR FROM TENNESSEE

Senator Gore: This subcommittee will come to order.

I would like to welcome Dr. Bromley and Dr. Wong and distinguished guests, other witnesses, and ladies and gentlemen.

I will have an opening statement, and then I will call on Senator Pressler, and then we will move right into the testimony of Dr. Bromley.

Today the Science and Technology Subcommittee is considering S. 272, the High Performance Computing Act. This bill is designed to ensure that the United States stays at the leading edge in computer technology. It would roughly double the Federal investment in research and development in new supercomputers, more advanced software, and high-speed computer networks.

Perhaps most importantly it would create a national research and education network, the NREN -- or the National Information Superhighway -- as I like to call it, which would connect more than 1 million people at more than 1 thousand colleges, universities, laboratories, and hospitals throughout the country, giving them access to computing power and information -- resources unavailable anywhere today -- and making possible the rapid proliferation of a truly Nation-wide, ubiquitous network which can do more to enhance our

Nation's productivity than any other single development.

These technologies and this network represent our economic future. They are the smokestack industries of today's information age. We talk a lot now about jobs and economic development, pulling our country out of recession and into renewal.

Well, our ability to meet the economic challenges of the information age and beyond -- tough challenges from real competitors around the world -- will rest in large measure on our ability to maintain and strengthen an already threatened lead in these technologies and industries.

We are witnessing the emergence of a much-heralded, prematurely recognized -- on several occasions -- global civilization. Now it is really here. And those nations best able to deal with information will be the nations most successful in this global civilization.

It is based on shared knowledge in the form of digital code. And our ability to compete will depend on our ability to handle knowledge in that form. It is now the lingua franca of global civilization.

We used to think of our ability to compete in terms of infrastructure -- did we have enough deep-water ports? Did we have enough railroad lines or highways? Now we need to think about information infrastructure.

I have been advocating legislation such as this for more

than 1 dozen years. Because I strongly believe it is critical for our country to develop the best scientists, the best science~~,~~ ~~the~~ fastest, most powerful computers, and the best base of knowledge -- and then to ensure access to these technologies to as many people as possible, so as many people as possible will benefit from them.

This legislation will help us do just that.

Every year there are new advocates. This year, finally, President Bush is among them, including in his budget for Fiscal 1992 $149 million in new funding to support these technologies.

We cannot afford to wait or to put off this challenge -- not if we care about jobs, economic development or our ability to hold our own in world markets.

During the last 30 years, computer technology has improved exponentially, faster than technology in any other field. Computers just keep getting faster, more powerful and more inexpensive.

According to one expert, if automobile technology had improved as much as computer technology in recent years, a 1991 Cadillac would now cruise at 20,000 m.p.h, get 5,000 miles to a gallon, and cost only 3 cents.

[Laughter.]

When my friend Jim Schlesinger heard someone deliver that cliche recently, he said yes, and your Cadillac would be a

few millimeters long, too.

[Laughter.]

But ~~as~~ a result of these amazing advances, computers have gone from being expensive, esoteric, research tools, isolated in the laboratory, to being an integral part of our every-day life. We rely on computers at the supermarket, at the bank, in the office, and in our schools. They make our life easier and better in hundreds of ways.

And yet, the computer revolution is far from over. In fact, according to some measures, the price/performance ratio of computers is improving even faster now than it has in the past. Anyone who has seen a supercomputer in action today, has a sense of what computers can do for all of us in the future.

Today, scientists and engineers are using supercomputers to design better airplanes, understand global warming, find oil fields, and discover safer, more effective medications. In many cases, they can use these machines to mimic experiments that would be too expensive or downright impossible in real life. With the supercomputer model, engineers at Ford can simulate auto crashes and test new safety features for a fraction of the cost and in a fraction of the time it would take to really crash an automobile. And they can observe many more variables in much more detail than they could with a real test.

The bill we are considering today is very similar to the first title of S. 1067, the High Performance Computing Act of 1990, which passed the Senate unanimously last October. Unfortunately, of course, the House was unable to act on the bill before we adjourned because of differences in measures passed by the two bodies.

It is my hope that we will be able to move this bill quickly this year. There is widespread support in both the House and the Senate. In the House, Congressman George Brown, the new Chairman of the House Committee on Science, Space, and Technology, has introduced a very similar bill -- H.R. 656 -- co-sponsored by Congressman Tim Valentine, Sherwood Boehlert, Norm Mineta and others.

On Thursday, the Science Committee's Subcommittee on Science and its subcommittee on Technology and Competitiveness on the House side will be holding a joint hearing on the bill. And I look forward to working with my House colleagues to move this bill as quickly as possible.

This legislation provides for a multi-agency, high-performance computing research and development program to be coordinated by the White House Office of Science and Technology policy, whose director, Dr. Alan Bromley, is our first witness today.

The primary agencies involved are the National Science Foundation, the Defense Advance Research Projects Agency, the

National Aeronautics and Space Administration, and the Department of Energy. Each of these agencies has experience in developing and using high-performance computing technology.

S. 272 will provide for a well-planned, well-coordinated research program to effectively utilize the talents and resources available throughout the Federal research agencies. In addition to the agencies I just mentioned, it will involve also the Department of Commerce -- in particular, the National Institute of Standards and Technology, and NOAA, the Department of Health and Human Services, the Department of Education, the U.S. Geological Survey, the Department of Agriculture, the Environmental Protection Agency, and the Library of Congress as well.

The technology developed under this program will find application throughout the Federal Government and throughout the country. S. 272 will double funding for high-performance computing at NSF and NASA during the next 5 years. Additional funding, more than $1 billion during the next 5 years, will also be needed to expand research and development programs at DARPA and DOE.

Last year, I worked closely with Senators Johnston and Domenici on the Energy Committee, to pass legislation authorizing a DOE high-performance computing program. And I hope to work with them and the other members of the Energy Committee to see that program authorized and funded in FY

1991. Already, Senator Johnston and others have introduced S. 343, authorizing -- which would authorize DOE's part of this multi-agency program.

To fund DOD's part of the program, last year I worked with Senators Nunn and Bingaman and others on the Armed Services Committee to authorize and appropriate an additional $20 million for DARPA's high-performance computing program, money that has been put to good use developing more powerful supercomputers and faster computer networks.

Advanced computer technology was a key ingredient in Operation Desert Storm. But we cannot simply rely on existing technology. We must make the investment needed to stay at the leading edge. It is important to remember that the Patriot Missile and the Tomahawk Cruise missile rely on computers based on technologies developed through Federal computer research programs in the 1970's.

The High Performance Computing Act will help ensure the technological lead in weaponry that has helped us win the war with Iraq, and that will improve our national security in the future.

This same technology is improving our economic security by helping American scientists and engineers develop new products and processes to keep the U.S. competitive in world markets. Supercomputers can dramatically reduce the time it takes to design and test a new product -- whether an airplane,

a new drug or an aluminum can. That means more energy-efficient, cheaper products. It means higher profits and more jobs for Americans.

But perhaps the most important contribution this bill will make to our economic security is the National Research and Education Network, the cornerstone of the program, funded by the bill.

In 1996, this fiber optic computer network will connect more than 1 million people at more than 1 thousand colleges and universities in all 50 states, allowing them to not only send electronic mail and shared data, but access supercomputers and use research facilities such as radio telescopes; log-on to databases containing trillions of bytes of information on all sorts of topics.

This network will speed research and accelerate technology transfer so that the discoveries made in our university laboratories can be quickly and effectively turned into profits for American companies.

Today the National Science Foundation runs NSF NSFNET, allowing researches and educators to exchange up to 1.5 bytes of data per second. The NREN will be at least 1,000 times faster, allowing researchers to transfer all the information in the entire Encyclopedia Britannica from coast to coast in seconds.

With today's networks, it is easy to send documents and

data, but images and pictures require much faster speeds. That will require the NREN, which can carry billions of bytes per second.

That is important. Because one of the only ways we can successfully deal with the mountains of excess data we now have is by organizing it into coherent, mosaic patterns and images which can be comprehended in gulps or chunks, instead of byte-by-byte, one byte at a time. It is impossible to deal with this much information in any other way.

With access to computer graphics, researchers throughout the country will be able to work together far more effectively than today. It will be much easier for teams of researchers at colleges throughout America to work together. They will be able to see the results of their experiments as the data comes in. They will be able to share the results of their computer models in real time, and brainstorm by tele-conference.

William Wulf, formerly Assistant Director for Computer and Information Science at NSF likes to talk about the "National Collaboratory" -- a laboratory without walls, which this network will make possible.

Researchers throughout the country at colleges and labs, large and small, will be able to stay on top of the latest advances in their fields. The NREN and the other technology funded by S. 272 will also provide enormous benefits to American education. And I will include in the record a

lengthy description of how education will be improved by this network.

In conclusion, let me say that with this bill, I believe we can help shape the future and shape it for the better. This is an investment in our national security and our economic security which we cannot afford not to make. For that reason, I was very glad to see the administration propose a high-performance computing and communications initiative, a program very similar to the one outlined in S. 272.

In intent to work closely with Dr. Bromley and others within the administration, as well as my colleagues in Congress, to secure the funding needed to implement this critically important program.

Before turning to Dr. Bromley, I would recognize now, Senator Pressler. I apologize for the length of my opening statement. But after 12 years, I have a lot to say about this topic. And I will now recognize my friend, the Senator from South Dakota.

[The prepared statement of Senator Gore follows:]

STATEMENT OF HON. LARRY PRESSLER, U.S. SENATOR FROM SOUTH DAKOTA

~~Senator~~ Pressler: Thank you, Mr. Chairman.

And I think it is very appropriate that we have Dr. Bromley here at this opening hearing. I want to thank you, Mr. Chairman, for holding this hearing on S. 272, and for your early and continued leadership in support of a national supercomputer network.

Let me say that I am glad that the administration has come with the proposal this year. I challenged the administration to come with a proposal last year. I am a cosponsor of this legislation. But I look forward also to working out the differences and listening very closely to the administration, here today.

Let me -- rather than repeat everything that Al has said in terms of what supercomputers can do -- to cite a special interest that I have. And that is to be sure that small businesses, smaller cities and towns, smaller universities, Indian reservations, and others are taken care of this communications transformation we are going through.

I am very interested, for example, in finding a way that fiber optics cable can be laid to every household and business in the United States, and not leave some out. Generally speaking, in the Communications Subcommittee and this Subcommittee, when people talk about supercomputers or fiber

optics cable, or new electronic services, they are talking about service to the wealthy suburbs. They are talking about serving densely populated areas where there is a market that yields greatest profits.

I always cite as an example that in cable T.V., for example -- my wife and I have just obtained cable T.V. at one of our homes for the first time of last year, we live in Washington, D.C. where we have a home, and Humbolt, South Dakota. In neither place could we get cable T.V. until this past year. We finally have it in Washington, D.C. And we can get it by microwave now, in Humbolt, South Dakota.

But the point is that the rural and smaller town areas have something in common with inner cities, in that all the small scho great talk about the communications revolution they are not talking about rural America people are talking about the largest universities, the wealthiest suburbs, and so forth. ~~And~~ We cannot become a Nation of two or three communication systems.

~~So~~ I am working on legislation in the Communications Subcommittee related to this that would provide that the telephone companies, or whoever, ~~or the cable companies~~ should be laying fiber optics cable rather than copper cable. ~~That~~ we should get fiber optics to everybody. And from there we can rent space on the fiber optics cable for the different users or ~~figure it out somehow~~ determine how so these services can be available on a national basis -- ~~sort of~~ a universal service policy so

to speak.

And The same is true for supercomputers. Of course, every small business does not need a supercomputer. But many of our universities do -- many small businesses will benefit from being hooked-up by fiber optics cable. In my own State there are certain institutions. For example, at South Dakota State University, the bio-stress lab where they are studying new kinds of plants, resistance to drought, very much wants to be connected to a supercomputer.

The EROS Data Center, which has pictures -- ARCHIVES the LANDSAT pictures, -- very much will benefit, and the country researchers will benefit from being hooked to a supercomputer. THE EROS DATABASE

South Dakota School of Mines, the project such as the deep-drilling project, certain EPSCoR-type projects, where professors and individuals are doing research, and they are not associated with a huge university will benefit a great deal.

Indeed, you can build the argument that small hospitals and small universities need this -- need access to a supercomputer more than a big one. Because the big ones probably have their own. So I think this is a very important initiative.

Let me also say small business -- now not every small business is going to want to be hooked to a supercomputer. But if they have the option, as we move into the 1990's, there

are jobs to be created in areas -- everybody does not have to be in the Boston beltway or a place like that to do technical work. And it will enrich our country. Now I am not saying there is anything wrong with being in the Boston beltway area. But we also need a few in the Sioux Falls beltway area, who have access to a supercomputer.

[Laughter.]

I am also concerned, Mr. Chairman, with -- in addition to this, and in this subcommittee -- I hope we look at this year what is happening in our schools in math and science training. I think we are falling behind in science and mathematics. Someone who is 15 or 18 years old and has not gotten the basics is out of the system forever. Where our educational system works, I am told that over half of our graduate students in engineering are from abroad. Part of that is due to our pay structure. The thing to be is an investment banker or a lawyer and move papers that result in no productivity but the pay is pretty good. We have to think very hard about the impact, the long-term impact of losing the math and science edge.

There are a whole series of other things. I was going to go into some of the benefits of supercomputers. The Chairman has done that very aptly in his statement. I have mention South Dakota State University's bio-tress laboratories is developing strains of crops and livestock. With the

supercomputer network, the results of the researched produced in the bio-stress labs could be placed on-line for ready access for users at other universities that are doing similar research.

And let me say that I think many of our smaller universities very much want to be connected to some of the work at larger universities -- certainly some of our smaller hospitals very much are in need of this type of service.

I have mentioned the EROS data center archives -- the pictures that are sent back from our LANDSAT satellite -- since 1971, near Sioux Falls, it has stored over 1 million satellite images on magnetic tape. Government and university researchers and commercial enterprises use the LANDSAT images for oil and mineral exploration, land use planning, map making, climate change monitoring, crop assessments, and many other applications.

With the proposed network, any researcher could use the LANDSAT pictures that are stored in South Dakota without having to leave his or her desk or laboratory. This capability will become even more important when the EROS data center is used later in this decade to achieve the massive amounts of data for the Earth Observing System, EOA, NASA's contribution to our multi-agency global change research program. And I was proud to be on hand last summer when we raised the NASA flag at the EROS data center in Sioux Falls.

The EOS satellites will be transmitting the data equivalent of the entire Library of Congress every 5 days. I think that is really an amazing thing. To use this data effectively, scientists will need ready access to the EROS Data Center database.

Mr. Chairman, I also want to take this time to commend President Bush for his support for our multi-agency supercomputing initiative in its Fiscal Year 1992 fiscal year budget request. President Bush has allocated $638 million to a supercomputer network and research effort. The Bush plan, which has the same purposes as S. 272, is patterned after a program set forth in a 1989 report by the White House Office of Science and Technology Policy. As I have mentioned, I am pleased that Dr. Alan Bromley, the Director of that office is testifying today. I look forward to hearing his details about the administration's initiative.

I am hopeful that during this Congress the administration and congressional supporters of supercomputing will join forces to implement a national, multi-agency supercomputing initiative -- boy that is a mouthful of Washington words -- whether done by statute or otherwise.

Mr. Chairman, I am sure we will all agree that the main goal here is to begin in this Congress a national commitment to supercomputing and a national supercomputing network linking more than 1 million of our country's computers by

1996.

Mr. Chairman, I look forward to hearing from our distinguished panel of witnesses on both S. 272 and supercomputing generally.

[The prepared statement of Senator Pressler follows:]

[COMMITTEE INSERT]

Senator Gore: Thank you, Senator Pressler.

Senator Kasten.

STATEMENT OF HON. ROBERT W. KASTEN, JR., U.S. SENATOR FROM WISCONSIN

Senator Kasten: Mr. Chairman, I am not going to try to compete with you and Senator Pressler in terms of length of opening statements.

So what I would like to do is ask unanimous consent that the entire statement that I have appear in the record and that I be allowed to excerpt a couple of quick points from it.

I first of all want to thank you for the hearing. And I am pleased to be an original co-sponsor of this piece of legislation. I agree with both of you that it is necessary for the continued ability to innovate and compete in the marketplace.

I am also pleased that though there are differences in emphasis, the administration recognizes the needs for the kinds of programs that we are supporting in S. 272. I believe that the legislative initiatives, particularly S. 1067, in the last Congress, Mr. Chairman, some of these initiatives and other pressures from Congress is, in fact, what has helped the administration -- helped assure the Administratif's attention to this important area. And for this I commend you.

And I also commend you for you statement -- in your opening statement saying that we want to work with the administration. Because I believe that we are close on the dollars and not so far apart on the programs. And so we have

the opportunity here now to come together. But I think it was Congressional initiative, and particularly your leadership, Mr. Chairman.

The future developments in the area of supercomputing, hardware, software, and communications, are critical to the country's security -- economically, environmentally, and militarily. It is important that an American company -- it also happens to be a Wisconsin company, Cray Research, is the current world leader in the field. And I believe that our bill will help to keep American supercomputer companies healthy. And it will also assure that American companies, researchers, and others who use supercomputers have the software, the training and the access so that we are all using our capabilities and using them to the fullest.

Both S. 272 and the administration's proposal look to develop the networks that will be necessary if there is going to be broader access and broader utilization of the Nation's supercomputers. Through the computing capability of our supercomputers -- although it is incredible -- our communications systems are not up to the task of transmitting the data between computers or to -- as Senator Pressler discussed -- some remote locations.

So I think we are on the right track here. I will work to assure that America realizes the full promise that supercomputers can offer in so many different areas of

scientific, educational, and commercial endeavor. And I think that we, Mr. Chairman, have not only a hearing on a very important subject today, but we have the beginnings now of a mark-up of a bill that is going to be passed-out by the Committee, going to be passed by the Senate, passed by the House of Representatives, and, in fact, signed into law.

And that is, I know, your goal and your purpose. And I just want to say that I am an anxious lieutenant on this team or in this area that we are going to do something here. And it is more than just simply a hearing on a very important subject. And we all will work together. And I look forward, Mr. Chairman, to working with you.

Unfortunately, I have another hearing that also started at 2:00. And I would ask that in addition to my entire statement appearing in the record, that I be permitted to submit some questions for the record of Dr. Bromley.

Senator Gore: Absolutely, without objection.

Senator Kasten: Thank you, Mr. Chairman.

[The prepared statement of Senator Kasten follows:]

[COMMITTEE INSERT]

Senator Gore: And may I say, before you must depart, on a personal note, I deeply appreciate the key role that you have played in pushing this bi-partisan effort forward. And I want to say the same to Senator Pressler.

Indeed, this has been bi-partisan from the very beginning. And you mentioned the cooperative relationship between the committee and the administration. That is a spirit we want to continue.

In fact, the OSTP plan which Senator Pressler mentioned coming out in 1989, really came about because of legislation this committee passed which both of you supported, the Supercomputer Network Study Act of 1986 which required that study, but more than requiring it, invited the administration to join in a dialogue with the committee which resulted in the OSTP plan 2 years ago.

And it is not accidental, by any means, that the administration plan and the legislation which we here are supporting, are so similar. Because they have both resulted from a meeting of the minds on what is the best interests of our country.

Dr. Bromley, again, let me apologize for the length of time it has taken us to get to your statement. We are very interested in it.

I want to acknowledge the presence of Dr. Eugene Wong, Associated Director for Physical Sciences at OSTP. And among

the many things for which you are due congratulations, is the excellent choices you have made of people to help you.

I remember when you first took the post, you said you were going to do it. I agreed with your assessment that this was one of the keys to making this office a more integral part of the Government. And congratulations on getting the President on board on this initiative.

I know you would probably want me to choose different words in saying that, but that is what I feel about it. I think this is you speaking for the administration now. And we welcome you. So please proceed.

STATEMENT OF D. ALLEN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. Bromley: Thank you, Mr. Chairman.

I welcome this opportunity to appear before you and the members of the committee to discuss this initiative. And I would, in fact, begin by acknowledging the leadership that you and this group have shown in this area that I agree is one of the most important that we could address in terms of its long-term and short-term impact on this Nation.

The hearing, of course, today addresses this whole question of high-performance computing and communication. And I would like to, with your permission, sir, have the formal testimony that I have provided to the committee included in the record and simply abstract it.

Senator Gore: Without objection, that would be fine.

Dr. Bromley: Thank you, sir.

Now, the President's initiative included in the 1992 budget is described in detail in the document that accompanies that, precisely, the report that is called the Grand Challenges: High Performance Computing in Communication. This is a report that was prepared by a working group on high-performance computing and communications that operates under the Committee on Physical Sciences and Engineering, one of the seven umbrella committees that operates under the Federal Coordinating Council for Science, Engineering and Technology.

~~And~~ I see, sir, that you already have a copy of the report.

The goals of the ~~whole~~ initiative, high performance computing and communication, ~~I think, sir,~~ are ones that we have shared for a long time. ~~And~~ my staff and I look forward to working with you to realize these goals for the American people.

In the document that we have provided to you, ~~the Grand Challenges document,~~ we have attempted to illustrate and symbolize the importance of this activity by setting forth a series of very important scientific and societal problems whose solutions simply elude us at the moment, but would become within reach with the kind of program that both of us are talking about.

These include the questions ~~matters~~ of global climate change, mapping the human genome, understanding the nature and helping in the fabrication of tailored materials -- an entirely new frontier -- and problems that are directly applicable to our national security, ~~and that~~ includes -- ~~and~~ I believe you would agree, ~~with us~~ sir -- both military strength and economic strength. It also, of course, includes the design of ever more sophisticated computers. Essentially, ~~And I think that~~ the list ~~essentially~~ is limited only by our imagination ~~at the moment.~~

A great many of these topics, ~~of course, I think~~ are already partially underway. But there is a tremendous frontier out there, promising ~~and~~ qualitative as well as quantitative

changes in our capabilities and in the problems that we can address effectively.

The initiative that we present to you represents a full integration of component programs in a ~~whole series~~ number of ~~the~~ Federal agencies ~~that~~ These agencies have been involved for some time, ~~sir,~~ and in high-performance computing and in the design, development, utilization of their own agency computer networks. And as was noted earlier, the initiative that the President has brought forward proposes a 30-percent increase in the funding in Fiscal Year 1992 ~~in~~ to support ~~of~~ these activities.

~~And I think that~~ I should, at the outset, ~~sir,~~ state that it is our goal in OSTP that between the next 4 and 5 years ~~we double~~ will be doubled. But it is much more important that we increase the speed, the memory capacity, and the data transmission capacity of our systems by factors of between 100 and 1000. ~~And~~ This is certainly within technical reach.

~~Now,~~ I would now like, if I might, sir, to take a moment ~~just~~ to trace the history of this initiative, in which you have been, yourself, very heavily involved. ~~I think that~~ It traces its formative years back to the early 1980's and before, and stems ~~also~~ in part from the recognition in a great many of our agencies, that to satisfy their mission needs, they required computing capacity far beyond anything that was then available.

~~And~~ As the science and the technology in these agencies

improved, it became rapidly obvious that the quantity of data and the number of databases that were being developed made absolutely mandatory the need for more sophisticated data-archiving, data-processing, and data retrieval. ~~And~~ one of the points I would make in passing ~~sir,~~ is that there are now between 6,000 and 7,000 data bases in use around the world. ~~And~~ almost without exception, these are not inter-comparable or readable, ~~one by any other~~. And this is the beginning of a Tower of Babel that we can ill-afford. ~~And~~ that matter is one that ~~I think that~~ we should work together to correct.

In 1982, a FCCSET committee examined the status of supercomputing in the United States, in response, as you suggested, to a request from the Congress, and reviewed the role of the Federal Government in this area of technology.

In 1985 the committee recommended Government action necessary to sustain the technological superiority that we had at that time, and to further the development and use of supercomputers in this country. Subsequent planning resulted in a ~~whole~~ series of workshops that were held in 1987, and a set of reports that set forth the outlines of a research and development strategy. The synthesis of all of this activity appeared in the report entitled the "Federal High Performance Computing Program" that was issued by my office in September ~~of~~ 1989, as you noted. ~~And~~ the initiative that we bring forward now in the 1992 budget is, in my view, a realization

of the goals that were spelled-out by you, by us, by a number of people back in those days, ~~as being~~ then goals, but now they are targets that we fully believe we can achieve.

~~What we have here is a~~ The program ~~that~~ involves 8 partners: ~~And this is~~ the Defense Advanced Research Projects Agency, the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, the National Library of Medicine, the Environmental Protection Agency, the National Institute of Standards and Technology, and NOAA, the National Oceanic and Atmospheric Administration, within Commerce.

~~And~~ The planning and implementation of the HPCC program, ~~I would submit to you, sir,~~ have been the result of a ~~rather~~ remarkable degree of cooperation and ~~-- I must say~~ enthusiastic cooperation ~~-- wherein~~ these agencies have been quite prepared to readjust, ~~to~~ realign, and redesign their programs in ~~and~~ high-performance computing so that together these made parts of a coordinated Federal whole.

~~And~~ I would like to pay tribute to the level of cooperation that we have enjoyed in putting this program together. There is a level of mutual trust, cooperation, and synergism that ~~I believe~~ is remarkable both inside and outside of Government. ~~And~~ I would also have to say that the success of this activity has depended in no small measure on the input that we have received from the private sector. It has been crucially important for us in developing the program

that we have brought before you to have it calibrated, ~~to have it~~ and tested against the real-world environment in which our industries operate, because they, in the long-run, are the ones that we look to to implement this program.

The program itself has four major components -- as you know very well, sir. The first ~~has to do with~~ concerns high-performance computing systems. ~~And~~ we use that phrase advisedly because we wanted to include not just supercomputers, but also high-performance computers on all levels ~~because~~ the synergism there is important and should not be forgotten.

Secondly, we talk about advanced software and algorithms, because without that, all the hardware in the word is essentially useless.

Thirdly, we have the National Research and Education Network, the information superhighway to which you referred. ~~Because~~ without that, very few people have access to either of the first two components.

~~And~~ finally, we have a basic research and human resource component. ~~Because~~ without that, we do not maintain our frontier status, nor do we have the trained personnel who will ~~not only~~ move these frontiers forward. ~~But,~~ I believe, equally important and often forgotten are the technical people who, in fact, operate these systems and make sure that they do what they were designed to do.

We have, in developing this program, set what I believe are ambitious goals -- ambitious but realistic goals. As I ~~just~~ mentioned, we seek a thousand-fold improvement in useful computing capability. That takes us to a trillion operations per second. ~~And~~ the focus ~~here~~ will be on developing the generic technologies that will prove valuable not just in this sector, but in many different industrial sectors.

Where appropriate, we feel it very important that the development be performed on a cost-share basis with industry. ~~Because~~ we want to involve industry as deeply as we can from the very beginning of this activity.

In software development, ~~I think~~ we clearly have a major challenge. ~~Because~~ our software ~~here,~~ in this country -- as ~~indeed~~ in every other country -- is now lagging behind the development of hardware. ~~And~~ most important, as we have discussed many times before, if we are to have the rapid expansion of the use of our new capacities, it is essential that we develop software that is user friendly. ~~And,~~ of course, as we both know, the high-performance software of today is not user friendly by the wildest stretch of the imagination.

The National Research and Education Network is going to dramatically expand and enhance the capability of the existing interconnected computer network ~~that we~~ referred to as INTERNET. The overall goal here is to achieve a 100-fold increase in

communication speed. We want to take this up to the level of gigabytes per second.

In addition, as you have noted many times, one of our major goals here is to develop a vastly greater number of on and off ramps ~~on~~ to this information superhighway. There are too many isolated institutions and areas in our country ~~for a modern civilization.~~

~~And~~ I hope that in the not-too-distant future our public will look on this network as commonplace and as little-to-be-feared as the telephone system. ~~This is a~~ That goal ~~that I think~~ is quite within our reach.

If we have such a network, ~~I think we have the possibility of~~ it could have a catalytic effect on just about every component of our society ~~:~~ on our industries, both small and large and I appreciate the reference to small industries, because I believe that ~~perhaps there is~~ this could be one of the ~~very~~ major potential impacts; universities and research organizations; ~~but~~ and perhaps even more important the elementary and secondary schools of the Nation where the real deficiencies in our educational system are most apparent.

Finally, I think that no plan is better than its execution. ~~And~~ the execution of this initiative is going to depend very critically on the synergy that has been developed among the agencies that are participating in it. What we have tried to do is to develop the plans so that each agency does

what it does best, and does it in a coherent way to amplify the effects of its sister agencies in this overall program. And each of the agencies, as you well know, has ~~national~~ natural constituencies, and ~~has~~ historical strengths. ~~I think that~~ as has been noted before, ~~that~~ this ~~particular~~ initiative has the promise of very high payback in economic terms and in social terms ~~and~~ as I indicated at the outset, I find it very difficult to think of any other initiative that has the potential of a higher payback to the American taxpayer.

The high-performance end of the computer market, ~~as we all know,~~ is relatively small. But its influence far transcends it size. ~~That~~ is where the leading-edge technologies and ~~the~~ leading-edge applications are developed ~~and~~ a Federal investment in leading-edge computer technology will speed the growth of the overall computer market and can catalyze, ~~I believe,~~ investments on the part of U.S. industry.

But I would again come back to the matter of synergy. ~~I mentioned earlier~~. I would not want this to be thought of as only a supercomputer initiative. It is much more important than that. Supercomputers play a role, and a very important one, but by no means the only role.

~~I think also that~~ the initiative that we bring before you today also has the potential to be a major contributor to meeting a number of other very important national needs -- national security, health, transportation, education, energy,

environment -- all of these are areas where the availability of a new generation of high-performance information handling, and information transfer will be essential. ~~And~~ the dependence, ~~I believe,~~ will, in fact, only grow.

If we are to realize the full potential of this initiative, it is not enough that it reach its technology goals. It is equally important, ~~in my view,~~ that that technology be deployed by the private sector in a timely fashion. ~~And~~ the continued development and use of Government-funded, high-performance computing and communication prototypes can certainly have an important, positive impact on the commercialization of these technologies. ~~And,~~ in fact, we can make available to a great many institutions in this country ~~that~~ which cannot themselves justify the hardware investment, the power that will be available through the proposed networks.

This diffusion, however, ~~I would submit, Mr. Chairman,~~ is not possible by Federal action alone. The administration's initiative will serve the Nation best as a catalyst for private action.

(Noted) Some analysts have suggested that the initiative can spur several hundred billion dollars of GNP growth. If so, it will be because American companies, both small and large, have been able to deploy these technologies in the production of high-quality goods and services.

I think also that ~~as some have predicted, that~~ the

National Research and Education Network will lead to the establishment -- and I hope quickly -- of a truly national, high-speed network that really does connect essentially every home and office in the Nation. ~~And~~ if that happens it will be because the private investments that make it possible have been stimulated by the initiatives taken here.

~~Now,~~ the legislative proposals pending before the Congress, I would suggest, Senator, perhaps do not fully recognize the comprehensive inter-agency effort that has been achieved through the years of collaboration that have led to this particular activity.

(Off the record.)

When I testified last year before the corresponding hearing, I noted one concern and I would simply ~~only~~ reiterate that concern ~~sir.~~ ~~And that is that~~ in a field of technology that is moving as rapidly as is the case here, as you illustrated with the automotive analogy, I am somewhat concerned that by freezing the program in legislation we may have given up some flexibility that we may want in order to be able to adjust this program, and the agency participation, on an ongoing basis.

I would emphasize that the FCCSET activity should still be viewed as partly experimental. This is the first year that we have really had it working as I had hoped it might. ~~And~~ we will certainly move forward next year to do a better job in these areas than we have been able to this year.

That was one concern. The other concern I have, sir, reflects a fact that you, ~~yourself~~ mentioned. ~~And that is that~~ we have worked long and hard to bring about this total integration of the agency programs. ~~And~~ my concern, which I believe ~~is one that~~ you, ~~yourself~~ share, is that in the subsequent actions ~~here in~~ of the Congress, it would be a great pity if that coordination and integration were not carried forward as the various ~~pieces and~~ players in the program present their programs to your sister subcommittees.

~~And~~ I ~~would~~ very much look forward to working with you, sir, and ask for your assistance in making sure that we ~~do~~ retain the coordination that is now a hallmark of this activity.

~~Now,~~ I think, sir, that ~~I would,~~ at that point, ~~simply say that~~ I would conclude my prepared remarks. The full testimony will be in the record, ~~and~~ I ~~would~~ welcome your questions, ~~sir.~~

[The prepared statement of Dr. Bromley follows:]

Senator Gore: Well, thank you very much. I know my colleagues will have questions also.

Let me begin by thanking you very much for your statement. I thought it was very well put. And I, too, look forward to the private investment which will be stimulated by this initiative and the passage of this bill. In fact, I know you are aware of the Merit proposal, with IBM and MCI and MErit, announcing a massive not-for-profit venture designed solely to quickly expand and proliferate the network as soon as the Federal backbone network is in place.

I want to see a day when a school child in Tennessee can come home after class and sit down, and instead of playing Nintendo, use something that looks like a Nintendo apparatus and plug into the Library of Congress; and read just not words, but look at pictures and moving graphics presented artfully and imaginatively in a way that captures and holds that child's attention; responds to the child's curiosity so the child can navigate through an ocean of information according to what he or she wishes to explore at the moment.

We know how to do that. The technologies are here, available, today. We ought to be empowering -- to use the buzz-word of the day -- not just one or two or a few individuals, but we ought to be empowering the whole country to make better use of the information that is out there.

I also agreed with your emphasis on the level of

cooperation that is so necessary to making this successful. And, I could not agree more when you say do not freeze it. We are interested in passing this and getting it moving, authorizing it for the number of years necessary to complete it -- sending those clear signals to the private sector that it is there, it is going to be there, and it will be completed, not just started, and then reevaluating every year the ways to improve it and make it even better.

I also would like to identify with your statements about the coordination of these efforts.

Let me start with my questions on that one. We are agreed that the goals of the administration's initiative and S. 272 are very, very similar, and that S. 272 is consistent with what the administration is proposing.

Last year, as I had mentioned, the precursor, S. 1067, passed the Senate unanimously. And then its passage was delayed by a difference of opinion with the House, and among different committees in the Senate.

In particular, the Department of Energy was pushing to have DOE coordinate the whole program, and run the National Research and Education Network. That was at-odds with the administration's plan, and at-odds with the legislation.

I know that DOE labs like Oak Ridge and Los Alamos have a critical role to play in this initiative. But I also know that the best program is one that uses the strengths and

resources of all relevant Federal agencies.

Luckily, many busy people within the administration have spent the last couple of years designing just such a balanced program as we have. However, last year, personnel from DOE and elsewhere actively lobbied against the OSTP approach and bad-mouthed some of the other agencies in the program, saying that they were unable to accomplish the missions that you laid out for them.

Should we expect to see more of such bureaucratic in-fighting? Or is everybody on your team on-board this year?

Dr. Bromley: I would devoutly hope not, Mr. Chairman. I have spoken with --

Senator Gore: You would hope we would not see more in-fighting.

Dr. Bromley: No more in-fighting.

[Laughter.]

Senator Gore: Okay, I just wanted to clarify that.

Dr. Bromley: That is important.

I have spoken with the senior officials of both the Department of Energy and the Department of Defense during the formulation of this plan, and as we went through the FCCSET process. ~~And~~ I have been assured by them that they are full players and full participants in the program that we have presented to you. We recognize that many of the agencies will have a need for their own independent, mission-related

activities. But we agree completely that in order for this to be a truly national program, it requires management as a national program. And we have identified NSF as the appropriate agency for that. I believe that to the best of my knowledge, that everyone who is represented in the report that you have before you is committed to moving forward with the program and plan laid out in that report.

Senator Gore: Well, that is good news. And I welcome that assessment. And, along with you, I devoutly hope that it is the case. And I believe that it is.

Now, I appreciate your kind words and your statement of support for the principles involved in the bill. And I fully understand why any administration, given its druthers, would like to have the money but no requirements on how the money is spent.

And I take it that you -- your basic position is you like the legislation. But your basic position is that you would like to recommend that the Congress appropriate all of the money that you have requested, but to give you no formal instructions on how to spend it. Is that basically --

Dr. Bromley: I would phrase it somewhat differently, sir.

[Laughter.]

Dr. Bromley: I would perhaps put it that we look forward to working with you.

[Laughter.]

Senator Gore: Well, we look forward to working with you too, Doctor.

Does the administration's initiative represent more than just a 1-year commitment? Do you have a commitment from OMB for the entire 5-year program or just for the first year?

Dr. Bromley: We have held, as you understand, detailed discussions with not only the agencies, but with OMB. And the program that is before you in the 1992 budget is the one that we agreed on with OMB based on a 5-year plan. But you also understand, sir, that the OMB, in its normal activities, focuses on ~~the~~ so particular years. ~~And~~ So we will go back and ~~we will~~ have to make our case again in the following year. But I am convinced from our activities this year that there is a full recognition that what we are talking about ~~here~~ is an important initiative, ~~It is~~ a presidential initiative. And ~~that~~ we are talking about a 5-year program to achieve what is involved.

So, although I cannot guarantee to you anything about the years beyond this, my best judgment, and that of my colleagues, is that this administration is fully committed to this as a very important ~~and a~~ presidential initiative.

Senator Gore: Of course, things change, and budgets change, pressures build, lips get red, circumstances alter. But formally, you have a commitment for 1 year?

Dr. Bromley: That is correct, sir.

Senator Gore: And you look forward to working with OMB for the other 4 years -- just as you look forward to working with us for the 5 years.

Dr. Bromley: I look forward to working with anyone who will push this initiative forward, sir.

Senator Gore: All right.

Dr. Bromley: But let me say that I have a very reasonable degree of confidence that OMB understands fully that this objective is a very important one, and that it is certainly the intent of everyone involved at the present time to move this forward expeditiously.

Senator Gore: Well, I think that is a very important signal to send out. I am making the point, of course, that the legislation is needed, even though any administration would like to have all the money for everything, each year, simply appropriated and not authorized.

But I do not want my efforts to make that point obscure the very clear signal that you are sending to the private sector, to all of the agencies involved. This is going to happen. This is going to happen. And everybody needs to get with the program and make certain that it does happen.

I just have a couple more questions before deferring to my colleagues. I want to explore the relationship between this and other OSTP initiatives.

Last month when the budget was released, you presented two other multi-agency initiatives -- a new math and science education initiative, and -- and, as it has for the past 2 years, the budget also included a coordinated and integrated U.S. Global Change Research program involving nine different agencies.

Is it fair to say, as I regularly do, that this program will contribute greatly to these other initiatives, enhancing our Nation's ability to pursue them productively. I do not want to lead you on. I suspect you agree. But since these other two initiatives are yours, I would like you to flesh that out just a little.

Dr. Bromley: Well, first of all, let me say that it is ~~im~~eminently fair to make that statement. ~~That, in fact, not only will~~ the high-performance computing initiative have a very important impact on the other two that you have just mentioned, but, indeed, on a great many other of the activities we have under way.

The most obvious connection has to do with the global change arena ~~where~~, as you noted earlier, ~~sir,~~ we have a Mission to Planet Earth that I consider very important under consideration. And ~~as was noted earlier this afternoon,~~ once we have the EOS A platform up, which will be a unique part of that program, ~~because~~ it ~~would~~ will allow observation of individual points on the earth's surface through 14 to 15 instruments,

simultaneously. ~~And~~ that is critically important, because from those simultaneous data one can ~~then~~ extract vastly more than one can from just 14 or 15 individual sensors flying independently. ~~Because~~ there is no air column correction, no cloud correction, nothing of that sort.

However, ~~But~~ as was indicated, the data flow from that particular remote-sensing complement alone will send us the equivalent of the Library of Congress in less than 5 days ~~in fact. And so,~~ unless we have the kind of speed, capacity, and information transfer capability that we are talking about in the high computing and communications performance initiative, we simply cannot cope with the flood of information that will be coming to us from the sensors ~~that we have in action.~~

~~And~~ perhaps even more importantly, ~~I think,~~ is a point that you touched on earlier. ~~And that is that~~ the human brain is substantially limited with what it can do ~~with~~ in whacking through great stacks of computer print-out. ~~But~~ on the other hand, it is almost miraculously able to form hypotheses and sense patterns in those same data if presented in a graphical fashion. That, I ~~think,~~ is probably the largest qualitative difference that high-performance computing can make in any area. ~~Because~~ it will allow us to take this flood of data and actually do something with it -- make decisions, understand phenomena that would ~~simply~~ be beyond us otherwise. ~~So~~ in that area, the question has a very obvious answer.

In education and mathematics, I think that the impact probably is going to be greater in the long run than even on global change. ~~But it~~ This is not yet as obvious. But the fact that impresses me enormously ~~in this area~~ is that with a single fiber optic going into a classroom, every student in that classroom can have self-paced, individualized instruction in any subject -- repetition where repetition is necessary, positive reinforcement where that has been earned, ~~and~~ I cannot think of anything that will improve the quality of our education, particularly at the elementary and secondary school levels, where our greatest weakness now lies, more than the introduction of this kind of technology into the education field.

~~So,~~ No? In the long-run, I think the impact may be even greater there, although it will take a little longer to bring it into place.

Senator Gore: I welcome that response. Just briefly, I heard a presentation in one of the early hearings on this, I do not know how many years ago, where someone said, and I have repeated it often since then, that if one analyzes the human brain in computer terms, you could say that we have a low bit rate, but very high resolution.

The telephone company decided years ago that seven numbers were the most we could remember, then they added three. And yet, when we see a trillion bits of data arrayed

in a mosaic pattern where each has a meaning in context related to all of the others, we can comprehend them all almost instantaneously.

What the new supercomputers allow us to do is to configure data in shapes and patterns over time, which enable us to absorb very large quantities of it conveniently and quickly. Secondly, they allow us to search through vast oceans of data and instantly retrieve those particular bits which are necessary to make up the particular pattern that we are looking for in order to understand the problem that we are trying to solve.

In any event, I will come to questions later. Let me recognize Senator Pressler.

STATEMENT OF HON. LARRY PRESSLER, U.S. SENATOR FROM SOUTH DAKOTA

Senator Pressler: Thank you very much.

Dr. Bromley, I am fascinated with page 26 and 27 of the report which show all the agencies that have to be coordinated that are involved in the program, and the agency responsibilities. It is amazing to me how many of the agencies -- and I am sure they are all filled with highly trained scientists and highly trained people.

When I was in the Army in Vietnam, I was at one point on detail to -- we called it ARPA then; it is now DARPA. But I know the difficulty of getting highly trained people to work together. You would probably have the classic job in public administration or an administration in coordinating all these people and getting them to work together. What is the number one problem in keeping all these agencies working together on this program?

Dr. Bromley: I would have to say, sir, that probably the number one ~~program~~ problem is information transfer.

Senator Pressler: The number one problem?

Dr. Bromley: Yes, because there are, as you say, a very large number of people involved here, and they will work to maximum effectiveness if we can be sure that everyone understands what everyone else is doing, and that they are really part of a coherent program. ~~So~~ We are devoting a very

large amount of our activity to trying to make sure that this is the case.

~~And~~ I must say that I want to pay tribute ~~here~~ to the people who have been involved, the people who prepared this document, because they have managed what is really a remarkable feat ~~in bringing~~ They have brought about a fusion of what started out as separate programs in each of the agencies you see listed on these pages, sir. ~~And~~ these folk have spent many long hours sitting and looking at each program and asking how ~~does~~ it fits as part of a national program, and then adjusting wherever the overlap, the duplication, the gaps were to make it actually fit. ~~And so~~ we already have developed a level of personal communication among the members of the community involved in all these agencies that ~~I think~~ will ~~service~~ serve us extraordinarily well in the years ahead.

Senator Pressler: Now, as I understand the general difference -- and I am not advocating either one here necessarily, because last year in one of my statements I called on the administration to come forward with a plan.

As I understand, the basic difference is that these various agencies, we would depend on you to coordinate them as you saw fit; whereas, you feel the Gore-Pressler-Kasten, et cetera, bill would codify too much the relationships on the HPCC program regarding all these agencies. Is that a general statement?

Dr. Bromley: I would have to modify that just a little if I might, sir, because we in OSTP do not force anybody in any agency to do anything ~~but we do,~~ when we are successful, we persuade them that they have the opportunity to become part of a much larger entity, ~~the~~ a national program. ~~And so~~ to that extent, everyone here already is involved. The responsibility is the agency's, but if the coordination fails, then the blame is ultimately mine.

Senator Pressler: But basically, these are all administration-appointed -- well, they are all -- the heads of all these agencies are appointed by the President, usually with the advice and consent of the Senate. So therefore, the White House could order them to do something.

Dr. Bromley: In principle, yes.

[Laughter.]

Dr. Bromley: There is a famous quote that springs to mind, sir. I can summon spirits from the vast deep, but will they come.

[Laughter.]

Senator Pressler: Well, I know back from my days as a second lieutenant in the Army listening in on meetings, to get the attention of an assistant secretary was hard on some of these things. If you could do that, you could accomplish something, but there is great competition.

Dr. Bromley: May I add one word of clarification, sir?

One of the important things that perhaps I should have emphasized is that this has been a concern within the administration and within my office. ~~And in order~~ to address that concern, during this past year I have restructured the FCCSET committee so that its members now comprise the cabinet secretaries, or deputy secretaries, and the heads of the independent agencies that are responsible for all these activities. ~~so that~~ As a result, once the FCCSET group makes ~~the~~ a decision, ~~that then is a~~ that decision ~~that~~ will stick from there on in because it has been made by the senior officer of the agency involved. ~~and~~ That is a key part.

Although ~~that group~~ FCCSET is not involved in the actual construction of the initiative, it receives the initiative, approves the initiative, and gives the initiative its blessing before it moves forward as part of the budget process.

Senator Pressler: I am glad to hear that, because that is really key. As a point of view of public administration, many of these activities require the input of highly trained people, and frequently the very top people administratively in these agencies are so preoccupied with the war in the Gulf or with other matters that what happens, as a practical matter, is that you start having these decisions made -- you have assistant secretaries battling it out, so to speak, for turf.

And I am glad to hear that the administration has gotten the very top people involved on this. I think that is key,

and I hope you are able to continue that level of interest. And I just point that out because I am fascinated with all these agencies here. This chart is an amazing Washington chart, and to make all this work together with these highly skilled people who perhaps do not submit to traditional administrative discipline quite as much as some others, you have a big job.

Now, let me ask a couple of questions here. Do you foresee the development, at some point, of a system of user fees so the supercomputer network will pay for itself partially? And how would that system be structured so that user fees do not deny access to users with limited resources, such as small schools and individual researchers?

Dr. Bromley: ~~Well~~, in the long term, sir, as I touched on ~~just briefly~~ earlier, I look on the National Research and Education Network as a pilot, if you like, a precursor for what, as fast as we can, will become a national service that is provided by the private sector as a utility service just like the telephone.

~~And~~ under those circumstances, it would seem to me that we would function much as we do at the present time, ~~namely that~~ small schools, for example, or people who wanted access to this utility would make application as part of their normal process of receiving support for their research activities to an appropriate agency, ~~and that~~ just as we now provide part of

grants and contracts to support the use of telephones, copying machines, and whatnot, ~~I think~~ we would also be more than happy to include in that list of necessary tools, ~~if you will,~~ the charges that might be levied by those public utilities for access to the computer net.

Senator Pressler: Now, as you know, we have EPSCOR legislation to ensure that the smaller institutions are not unfairly left out when Federal research grants are made. What steps can be taken to ensure that the computer research and development called for here in S. 272 and your proposal will include small institutions? Or to put it more specifically, how can we be sure an EPSCOR professor working on deep drilling at the South Dakota School of Mines will be included?

Dr. Bromley: ~~Well,~~ I think perhaps the first and most important answer ~~that~~ I can give to that is simply to tell you that this is the President's wish transmitted directly to me. ~~that~~ if this is going to be his initiative, he wants it to be broadly available to institutions large and small, both in the educational and in the industrial sector. ~~And so that,~~ I look on that as an instruction, and we will do everything we possibly can to make sure it happens. Frankly, I do not think that we will achieve anything like the potential of this system unless we do just what you suggest.

Senator Pressler: Thank you.

I have some additional questions for the record, Mr.

Chairman.

Senator Gore: Thank you very much, Senator Pressler.

Senator Robb.

STATEMENT OF HON. CHARLES S. ROBB, U.S. SENATOR FROM VIRGINIA

Senator Robb: Thank you, Mr. Chairman. I am pleased to join you and Senator Pressler and other of our colleagues on this committee again as a cosponsor of this legislation, and I am delighted to have a chance to be with Dr. Bromley again. We have coconspired in previous incarnations on other scientific projects, and it is always a pleasure to work with him.

I did have a very brief statement that you may have already included in the record. In any event, I would ask unanimous consent to include it without delivering it just on this particular topic.

Senator Gore: Without objection.

[The prepared statement of Senator Robb follows:]

[COMMITTEE INSERT]

Senator Robb: I just tell you, Mr. Chairman, I was struck when you made mention of the fact that you would like to find a way to be able to let a child at home tune in to the Library of Congress. I could not help but think last night when I came home, I have a child who was trying desperately to do just that. She had just lost about an hour's worth of work that she had done on her own PC. It had gobbled it up, and she was looking for some recourse to higher authority, which I was unable to provide at the moment.

And then when I heard Dr. Bromley say something to the effect that the entire Library of Congress could be transmitted in 5 days, it occurred to me that if any of these children had a printer and some sort of an arrangement to simply put it on automatic pilot, that we could incur costs that are beyond the ability of even Congress to take care of.

[Laughter.]

Senator Robb: I have a couple of questions that are more technical in nature that I would like to submit for the record, but I would like to ask Dr. Bromley just in a very sense, since this is presented again in a cost-conscious environment, and several of the lighter remarks and exchanges took place with respect to future funding and the coincidence of intent, and what have you, with respect to others here and at OMB and elsewhere.

But I wonder if you could just talk a little bit about

ways that those who believe that this would be a very good investment for our country, for our individual States, for our industrial sector, for others, how we could attempt to provide what would be traditional cost benefit analysis. How could be grapple with the basic question of justifying the kinds of expenditures that we are proposing here, or that are implicit here, and in the long term to realize the full potential that I believe and others believe this has in terms of the costs, so that we could make some comparison to the costs that other competing interests for the finite Government dollar might be justified or evaluated.

Dr. Bromley: That, Senator, is an excellent question, and I wish I had a better answer for you than I am going to give you. ~~We have~~ back in 1989, ~~for example,~~ we entered into a contract with a group ~~on~~ from Los Alamos to try to do just what you have asked, namely to try to come up with an economic cost-benefit analysis of this initiative, and it has been under way since that time.

Frankly, I would have to say that I do not put too much credence in the numbers that we have at the moment, ~~because~~ the sort of range that people are talking about is that if we were to implement the initiative that we have presented to you, ~~that~~ the payback would be somewhere between $170 billion and $500 billion over a period of the next 10 years. The range in itself tells you a lot about how good the actual

calculation is, and frankly, sir, I think that it is a little premature.

Senator Gore: Even so, Dr. Bromley, it might be good to have that on the record.

Dr. Bromley: It is not bad.

[Laughter.]

Senator Gore: It might be good to look at. I do not want to interrupt Senator Robb's question, but those are intriguing numbers. I mean, we can deal with a range.

[Laughter.]

Senator Robb: That is right. Regrettably, very little justification is frequently required around this institution. If you want to believe, you do believe.

Dr. Bromley: Let me, then, sirs, tell you that the only numbers -- concrete numbers that I have available to me at the moment are those that came from a Gardner study that, in fact, was requested back a number of years ago, and it is that range of $170 billion to $500 billion over 10 years. And that is a very impressive payback. But I also would caution you, sir, that like you being familiar with a great many cost-benefit analyses, that there are many potential pitfalls. And I give it to you only as an indication in support of my personal belief that the payoff here is probably one of the best in terms of an investment viewpoint of anything that I can conceive of us doing. We just recently, for example, had

the study of Professor Edwin Mansfield of the University of Pennsylvania, which focused on ~~what is~~ the rate of return on Federal investment in academic research, ~~and~~ he came out with a figure of 28 percent.

~~Now,~~ that is a marvelous figure, because it was created by a first-rank economist. ~~And~~ we scientists love figures of that kind because our economist friends cannot argue with us about them. But I would submit, sir, that if that is the return across the board on Federal investments in fundamental research, then I would be prepared to wager rather heavily that the return on this initiative would be higher by substantial factors.

Senator Robb: Dr. Bromley, I cannot tell you that that is encouraging news. I would only warn you that having given a figure like that, you may find that in an off-set within the current caps on budget, somebody will pencil in this program and then spend those savings for some other program which may be equally worthy.

[Laughter.]

Senator Robb: But I do appreciate it, and I think that the fact that there is, at the very least, a very substantial benefit in hard dollars that could saved ought to be cranked into the equation sometimes. And there are occasions when we spend money to get even more money back. It does not happen often in government, but there are occasions when it does, and

in the private sector as well.

As I said, the other questions are really more technical, and I will submit those in writing. But again, I thank you.

And Mr. Chairman, I thank you for not only again sponsoring the legislation, but for another hearing, and hopefully more understanding of the importance of this particular possibility on the horizon.

Senator Gore: Well, Senator Robb, thank you, and thank you for your early and vigorous support of the initiative in the last Congress as well. And as one of the former Governors who took a leading role in stimulating high-tech research and development in your State, I do not know if that is the reason why you were such an early cosponsor of this, but I appreciate your --

Senator Robb: Mr. Chairman, if I could, let me just say that had the economy not soured a little bit just south of the Potomac, I had some proposals that we were going to use our Center of Innovative Technology to house a supercomputer, but got into some of the costs involved and recognized the fact that the economy, in least in terms of available expendable dollars, was going sour too rapidly to push it very hard.

But I hope when we recover, that -- I actually made a presentation on this bill and the purposes of it to an appropriations subcommittee that was taking a look at it, and I hope at some point that we may be able to get back in as a

part of this overall highway that you hope to create.

Senator Gore: Well, thank you again for your early and vigorous support. I wanted to follow up on the figures that you had Dr. Bromley comment on, and I accept the caveats on why models like these are not reliable. But the numbers are quite significant, and they include estimates not only related to GNP, but also reductions in the deficit. So your thing about the offset there I know was in jest, partly in jest anyway, but this --

Senator Robb: No, Mr. Chairman, I have learned in this institution you do not jest about things like that.

[Laughter.]

Senator Gore: But this does project, as unreliable as such figures are, very significant reductions in the Federal budget deficit because of this. To use a more reliable way of estimating its benefits, you could say that the total expenditure on this program represents about 1 percent of the Federal R&D budget.

If, therefore, the improvements in the productivity of even a tiny fraction of the other 99 percent of the Federal R&D budget results from this, and you know it will, then we are ahead right there in terms of value saved for the taxpayers before you even consider the benefits for the economy.

It took only a tiny leap of faith to embolden those who

created the interstate highway program to allow them to assume that it would be used when it was built. They could really see that it would be used, and it was; it has been. And it has vastly improved our economy. It takes an even smaller leap of faith to assume that when this network is built it will be used.

The utilization rate for the network which now exists, one one-thousandth of this capacity, is growing by -- I cannot remember the exact figures, but they are measured not annually, but monthly. The increase is just phenomenal. And so it may be hard to put reliance in specific numbers, but it is easy indeed to assume that it is going to make a tremendous difference for our economy.

I have just a few other questions, and then we will let you move on. Your initiative, Dr. Bromley, places a great deal of emphasis on massively parallel supercomputers. Clearly massive parallelism is the only way we are going to soon achieve the 1,000-fold improvements in computing power needed to solve many of the grand challenges. Yet, there is still a good deal of good science being done on so-called conventional supercomputers.

And I am wondering, will the administration's initiative focus solely on massively paralleled supercomputers, or will funding also be provided for purchasing supercomputers that are now on the market and developing new and improved software

for them.

Dr. Bromley: It is certainly, Mr. Chairman, not our intention to in any way suggest that the only way to go is the massively parallel route. The important thing is that, given a problem in either science or technology, it usually turns out that either the parallel or the mainframe has major advantages in the solution of that particular problem, ~~and so that~~ the goal ~~here~~ is to have both facilities on the network, ~~and~~ so that you have essentially a transparent system.

~~So the~~ individual working in Senator Pressler's laboratory would simply use his work station and have access through the network to whichever is most suitable to the problem ~~that~~ happens to be addressed at the time. We in no way are suggesting that we want to eliminate one of these approaches in favor of the other. We do, however, ~~simply~~ note ~~here~~ that if we are to reach the increase in speed in the time that we project here, ~~that~~ the only way to do it is through ~~the~~ scaleable massively parallel architectures.

Senator Gore: Well, I am a big fan of massive parallelism as you know, because you and I have talked about it. But I also recognize the kind of balance in the program that you have just indicated with your response and how important that is.

One other question, and it involves education. In the administration's proposal, the primary justification for the

initiative is research and development. Frankly, I was a little bit surprised that more attention was not given to the educational applications of this technology. There are hundreds if not thousands of ways that a national network in supercomputing can help students in colleges, high schools, junior highs, and even elementary schools.

For instance, in January I attended the annual meeting of the American Library Association in Chicago, and saw a demonstration of how librarians are using the NSFNET to provide students with information from databases all over the United States. Yet, in the administration's proposal, there is almost no mention of the role that libraries will play in providing information resources to other users of the NREN.

Was this an unintentional oversight, or does the administration intend to focus almost exclusively on research? And how would you personally like to see existing networks and the NREN used to improve the American education system?

Dr. Bromley: I am in complete agreement with you, Senator. ~~And~~ the fact that this does not appear in this particular ~~issue~~ report reflects ~~back on~~ my earlier comment that this is the first year and the first attempt was done under immense time pressure, ~~and~~ it ~~was~~ essentially ~~building~~ built on activities in which the agencies are currently involved.

No one in the group that developed this initiative questions for a moment the tremendous importance that it will

have for education. ~~And~~ I think I can promise you that when you see the report of this group next year, you will see a much greater expansion of areas like education ~~which are~~ They are not included this year because, as I say, we were working to get this report to you, and there was a natural tendency to build on those familiar areas in which the agencies are currently involved.

Senator Gore: So you would not object if in our authorization this year we included the educational components?

Dr. Bromley: I believe that education is going to be a very important part of this initiative, sir.

Senator Robb: The tough questions have got to stop.

Senator Gore: Yes, I know, I know. I am going to relent soon, Doctor.

[Laughter.]

Senator Gore: All right. Well, I have other questions like Senator Robb and Senator Pressler which I will supply for the record. Is it okay if we move on now? We have had you here a long time, Dr. Bromley, Dr. Wong. You have our admiration for the job you are doing, and you may get tired of me bragging on the good work you do in so many areas. Maybe it makes up for the few --

Dr. Bromley: I never tire of that, Senator.

[Laughter.]

Senator Gore: Maybe it will make up for the few where we disagree. But thank you so much for your leadership in this area in particular. It has been a joy to work with you publicly and privately, to get to know you better and, in the process, help mutually to move this matter along. And we look forward to continuing that working relationship.

Dr. Bromley: I would welcome the opportunity to work with you, sir.

Senator Gore: Thank you very much, and thank you, Dr. Wong. We will now call our panel. We have five more witnesses in a panel, and then we will conclude the hearing.

First, Dr. Donald Langenberg, Chancellor of the University of Maryland System at Adelphi, Maryland; Dr. Melvin Kalos, Director of the Cornell National Supercomputer Facility in Ithaca; Mr. Tracey Gray, Vice President of Marketing for Government Systems with U.S. Sprint, based in Herndon, Virginia; Dr. David Nagel, Vice President of Advance Technology with Apple Computer, Inc.; Dr. John Wold, Executive Director of the Lilly Research Laboratory, Eli Lilly & Company in Indianapolis, who is accompanied by Dr. Riaz Abdulla, Head of Supercomputer Applications and Molecular Design with Eli Lilly.

Without objection, the full prepared statements of all our witnesses will be included in the record. We invite you to summarize what you have to present to the committee today.

Dr. Langenberg, we will begin with you. I would like to thank all of you for coming. I know that some of you have traveled great distances. We really appreciate the time and effort you have put into making the hearing today a useful and productive one, and we will hear all of you before going to questions.

Dr. Langenberg, please begin.

STATEMENT OF DONALD LANGENBERG, CHANCELLOR OF THE UNIVERSITY OF MARYLAND SYSTEM AT ADELPHI, MARYLAND

Dr. Langenberg: Thank you, Mr. Chairman. Most of my biases on the issues before you stem from my service as chair of a national research council panel that 2 years ago wrote a report entitled Information Technology and the Conduct of Research: The User's View. I will come back to that subtitle in a bit.

I would like to make just a few points related to the work of that panel and the issues before you in S. 272. The panel found that there exists significant technical, financial, behavioral, and infrastructural impediments to the widespread use of information technology in research. And though the panel's charge was confined to research, I believe the same impediments exist with respect to education.

We made three main recommendations and a host of subrecommendations. S. 272 responds to most of them, and responds very well. One of the panel's principal recommendations was that, and I quote, "The institutions supporting the Nation's researchers led by the Federal Government should develop an interconnected national information technology network for use by all qualified researches."

The National Research and Education Network responds directly to the need reflected in this recommendation, and

also, I believe, to the very important collateral need of the education sector. In my judgment, NREN, if that is the correct pronunciation, will revolutionize both research and education, though, of course, in a evolutionary way.

My third point is that when one thinks of what NREN might do for education, one thinks first of the education of scientists and engineers, and then perhaps of the incredible potential inherent in linking NREN to every elementary school, every secondary school, every public library, and every museum in the country.

There is another educational need of utmost importance. I believe that part of the challenge we face is the creation of an entirely new kind of institutional infrastructure for managing the new information technology, led and supported by a new breed of information professionals. These may bear some resemblance to librarians or to computer scientists or to publishers. And whatever they might be, we need to create schools for training them and institutions within which they can function. And that means educational and institutional innovation of a kind that S. 272 appears well designed to foster.

My fourth point is that the most important words in the title of our panel report reflect the panel's most important observation. And those words are "the user's view." In simple terms, the panel concluded that the development of

information technology and its applications in the conduct of research -- and here I would say education, as well -- are far too important to be left to the experts. The panel cautioned that planning and development should be guided by users of information technology, both current and prospective, not by information specialists, information scientists, information technologists, or local national and international policymakers.

It may not invariably be true that the customer is always right, but institutions that create technology or make policy without a clear understanding and appreciation of the real needs of their clients and constituents risk making serious and expensive blunders. S. 272 calls for the advice of users in the development of a national research and education network, and I especially applaud this provision.

My fifth point is a very strongly held view. In my preface to our panel's report I wrote, and I quote, "I share with many researchers the strong belief that much of the power of science whether practice by scientists, engineers, or clinical researchers derives from the steadfast commitment to free and unfettered communication of information and knowledge." This principle has been part of the ethos of the global research community for centuries, and has served it and the rest humanity well.

If asked to distill one key insight from my service on

this panel I would respond with the assertion that information technology is of truly enormous importance to the research community, and hence to all humanity, precisely because it has the potential to enhance communication of information and knowledge within that community by orders of magnitude. We can only now dimly perceive what the consequences of that fact may be.

That there is a revolution occurring in the creation and dissemination of information, knowledge, and ultimately, understanding, is clear to me. It is also clear to me that it is critically important to maintain our commitment to free and unfettered communication as we explore the uses of information technology in the conduct of research.

Now, what I asserted there about research, I would assert now about education. And if I am right, and by far the most profoundly important consequence of the creation of NREN will not be the expedition of research or the improvement of next year's balance of trade. It will be the fundamental democratization of all the world's knowledge. And this means placing the accumulated intellectual wealth of centuries at the beck and call of every man, woman, and child.

What that might mean ultimately can only be guessed, but let me reminisce for a moment. I grew up in a small town on the Great Plains, and in that town was a Carnegie library; one of hundreds Andrew Carnegie endowed across the Nation. In

that modest building in the modest collection of books that it housed opened the world to me, and I have been grateful to that Pittsburgh steel maker ever since.

What if I had had direct personal access to the Library of Congress, the British museum, the Louvre, and the Deutsches Museum all in the course of a summer afternoon in North Dakota? Just imagine. Now, my point here is that there is an overriding public interest in NREN and in the rest of the provisions of S. 272, an interest that transcends research and its industrial applications or issues of governance and the timetable for commercialization. I truly believe we have an opportunity here for an American achievement of truly Jeffersonian proportions. Let us not blow it.

Finally, for my sixth point, I note with approval that S. 272 identifies the National Science Foundation as the lead agency for the development of NREN. The choice is wise, I think. NSF has a demonstrated capacity to manage large, complex, technical operations. Unlike other S&T agencies, NSF's focus is not on some mission, but on its users, that is to say, its client science and engineering communities.

And perhaps most important, alone among Federal agencies NSF bears responsibility for the support of research across the full spectrum of science and engineering disciplines and for the training of those who perform the research and for the general education in science and technology of everybody else.

Now, Mr. Chairman, you will have gathered that I have a considerable enthusiasm for S. 272; I do. I urge you and your colleagues to enact it into law.

Thank you.

[The prepared statement of Dr. Langenberg follows:]

Senator Gore: Thank you very much. We certainly appreciate your forceful statement and the way you delivered it.

Dr. Kalos, from Cornell, welcome. Swing that microphone around there so we can hear you. Thank you very much for coming.

STATEMENT OF MALVIN H. KALOS, DIRECTOR, CORNELL THEORY CENTER

Dr. Kalos: I am sitting on the end to give me ready access to the computer terminal, because I am going to demonstrate some.

Senator Gore: Very good.

Dr. Kalos: Mr. Chairman, it is a privilege to be invited to comment on S. 272, the High Performance Computing Act of 1991; however, being asked to follow Dr. Bromley and others makes me feel like the man who survived the Johnstown Flood.

The Cornell Theory Center, which is dedicated to the advancement and exploitation of high-performance computing and networking for science, engineering, and industrial productivity, is one of the National Science Foundation Supercomputer Centers. We are part of the transformation of our science and engineering culture brought about by the advent and adoption of high-performance computing and communications in our technological society.

Senator Gore, Senator Pressler, Senator Robb, and the other cosponsors of this bill, and the President, understand the deep and positive implications for our future. Dr. Bromley has done essential work in translating these ideas into effective policy. FCCSET for the first time has unified the Federal approach to high-performance computing. Theirs is a well-designed, well-integrated program that shows good

balance between the need to exploit advancing supercomputing technology, the need for very high-performance networking, and the need to bring these new tools to the widest possible community through research and education.

The aim of fundamental science is to connect all our knowledge in a seamless webb of quantitative understanding. This is now harder to do, because we probe into more and more complex phenomena that defy analysis by the mathematical tools we have. Computational modeling is essential to fill this need. Many areas of science involve systematic connection among different phenomena at different scales of length or energy. Chemistry, biology, medicine, science of materials, astrophysics, are very good examples.

Computation is also an essential tool in experimental science. The most advanced instruments, optical and radio telescopes, particle accelerators, and computers themselves, are studied, designed, optimized, and verified with the help of computer simulation. Data collection is automated. The reduction to comprehensible data sets involves enormous computations in some cases. The exchange of large data sets will require very heavy use of high-capacity data networks.

An important step in modern science, I believe, was the creation by the Congress and the National Science Foundation of the National Supercomputer Centers. That was the mark of the entry by the mainstream of American research into this new

era of computational science. The entire scientific and engineering community of the Nation has the opportunity to exploit these new tools. Students and young scientists, always the very heart of any important scientific change, are now involved. They will carry the message to the rest of our society and to the future.

I would like also to comment that the present program includes attention to education. The NSF program, the supercomputer programs include for example at Cornell the Superquest program which is bringing knowledge and training of supercomputing to high schools around the Country.

I will show some videos showing significant scientific advances made possible by supercomputing, and I would like to comment to Senator Pressler, in particular, that some of the advances that I have in my written testimony are those that come from small schools. So these centers provide this power to large institutions and small, primarily research institutions, primarily undergraduate institutions, and this is a very important balance.

Another vital role of computational science is that of permitting quantitative connections among different disciplines. Every one of the large problems that confront our society, and to whose solutions we expect science to contribute, is in some sense a multidisciplinary problem. Issues of the environment and medicine, to site only two,

involve many sciences working together; chemistry, physics, engineering, fluid flow, biology, understand of materials.

Bringing the knowledge from these fields together to make quantitative predictions about the effect of some technological or regulatory proposal would be utterly impossible without the use of high-performance computational modeling, which is the natural language, the indispensable lingua franca of quantitative multidisciplinary research. The supercomputing community will soon find itself at a major crossroads where the increases in performance needed for our scientific mandate will demand parallel architectures.

To exploit these new machines, a major retooling of software and algorithms will have to take place. This must be started very soon if we are to make progress on the grand challenge problems in the mid-1990's. The high-performance computing and communications program will offer us an essential opportunity to bridge the gap between today's high-performance vector machines and tomorrow's highly parallel systems.

I have emphasized how science and its application to societal problems involve the national scientific community. Bringing to bear this transformation of computational science in the most complete and positive way requires that its techniques and strategies be learned, used, and shared by the widest possible group of researchers and educators. All of

these are necessary, and the appropriate level and balance among them is essential. The High Performance Computing Act of 1991 ~~is~~ a vital step in that direction.

And now I will move to the screen and I am going to show three videos with different scientific themes, and each has a different theme to bear on the application of science to industry or medicine.

[First videotape shown.]

Dr. Kalos: The first one shows the investigation, which involves some important algorithmic advance by Mike Teeter, who is a professor of Cornell and an engineering fellow of Corning Glass.

We are going to see -- please start it. We are going to see a model, first a simple ball and stick model, of a quartz crystal. Then, the silicon and oxygen atoms will be dressed in fields that represent the electron fields at various densities. There are three of them, and the lowest of level of electron density is shown in blue.

Now we see the blue level only, and we see the ramified electron field that permeates the entire crystal and gives it its structure. The importance of this for Corning is that understanding the physics of quartz means understand the physics of glass, and this was translated into making better optical fibers and an important competitive advantage for Corning.

[Second videotape shown.]

Dr. Kalos: The next movie is going to show something you have talked about. The composition of a set of data representing a sedimentary oil field in the Gulf of Mexico assembled by a team of 19 organizations, 11 petroleum and 8 academic institutions.

We see a 30 by 10 mile area of the floor of the Gulf of Mexico. The green zones show places where oil or gas has been seen. This is a set of salt domes. They are 6 miles high under the ocean. And what we are going to see -- well, now we see sand and shale zones. But more important, we are going to see patterns of heat-flow throughout these salt domes. And the patters of heat-flow are correlated with the presence of petroleum.

Now, this is simply the assembling for the first time of disparate data from all of the partners in this. Assembling it, producing this video, has presented new insights for the geologists. They think they understand better than ever before how to improve the recovery of petroleum from existing sources worldwide. They are also going on to do serious, very heavy computational modeling to try to understand in a still more fundamental way the processes that are going on.

We are flying through the data; we are understanding what is really happening.

Senator Gore: This is an example of what they mean when

they say that computational science has now joined inductive reasoning and deductive reasoning as a third new branch of knowledge creation.

Dr. Kalos: Absolutely. Yes. Incidently, these partners are also far apart geographically and will need to exchange these data through high-capacity networks as they work.

The third video has to do with the uses of ultrasound, low-intensity and high-intensity ultrasound in probing the human eye.

[Third videotape shown.]

Dr. Kalos: First, we will see how low-intensity ultrasound is used to survey the existence of tumors in a human eye. A data set is being built up, reduced to a form understandable by the computer. The location of the tumor is indicated. Incidently, this is the retina, which is so distorted by the tumor that it is torn away from its usual position in the eye. A data set is being sliced off and assembled into a three-dimensional data set that the computer can understand.

And we see in animation how this is done. We see the retina there, the distorted retina. And here a computer-usable model has been assembled. And now we see the tumor in three dimensions as it rotates. Now the model is used in a mathematical way to understand how the illumination by high-intensity ultrasound would affect that tumor. And we

see the simulation of the effects of heating by a focused, high-intensity ultrasound beam.

You see, of course, the high temperature at the center of the focus. In therapy, that focus would be steered around the tumor and would literally cook it into oblivion.

Thank you.

[The prepared statement of Dr. Kalos follows:]

Senator Gore: Boy, that was really impressive. Well, we will save our questions, but thank you so much for your presentation. Very impressive.

Our third witness on this panel is Mr. Tracey Gray, vice president for marketing with the Government Systems Division of US Sprint. Mr. Gray, thank you so much for joining us today, and please proceed.

STATEMENT OF TRACEY GRAY, VICE PRESIDENT OF MARKETING, GOVERNMENT SYSTEMS DIVISION, US SPRINT COMMUNICATIONS COMPANY LIMITED PARTNERSHIP

Mr. Gray: Thank you, Mr. Chairman, and Members of the subcommittee. Now, these are two tough acts to follow, and I do not even have my video to support me. I would like to give you some comments from the perspective of the -- of a business poised to take advantage and to offer to the Government and to the many users of academia and industry in this country, the kind of capabilities that you have designed this bill to support.

First of all, we endorse and support this bill. I would like to reference my comments, really, along the lines of how we as a business in the industry see fulfilling and participating in the objectives of this legislation and initiative, and how we believe that we can bring some of those objectives to bear.

I would like to depart just briefly, though, to remind everybody of the power of the private sector to bring to bear resources, capability, technology, and the business resources and energy to meet goals of this type, providing the incentives and the understanding and the perceptions are properly put in place. And I think that is what this bill is all about.

I would like to remind everybody here that just about 6

years ago, this country saw one of the most significant economic realignments in the industry that we have ever had. That was the divestiture of AT&T. US Sprint was an outgrowth of that.

US Sprint today has a network that is just a little under 4 years old. It is a fully deployed, fiber-optic network that transcends the Nation. It has 23,000 miles of fiber in it. We support millions of residential, business, large corporations and Government customers. We support 500,000 or more Government customers today on that network, supporting them with voice, data, video, imaging, high-speed facsimile, electronic messages, packet services, and a vast array of private line services.

Indirectly we support hundreds of thousands of other Government services through inter-operability of our networks with others. We are also deploying at this time -- bear in mind, this is a network slightly less than 4 years old -- we are deploying at this time the capability to support sonic technology.

What that really means is very wide band high-speed network and data transmission capability within the network. Bear in mind, again, this is a network slightly over 3 years old. We have well over $3.5 billion invested in this network.

We support this bill from the standpoint that it provides the seed money, the initial stimuli that we think is necessary

to develop the next level of applications and to bring about the incentives in the private sector to make the next step, which could be a quantum leap, in the deployment and the investment of technology that will support the multi-gigabyte transmission paths that are necessary to achieve the objectives you are talking about.

We are very heartened to hear and see the recognition of the importance of the communications link, the superhighway network. We believe that the National Research Education Network objectives can be achieved with this initiative, with this measure.

I would like to bring two issues to the fore that, to give us, if not some concern, some reason to watch what you are doing and look at what you are doing and participate in it, to ensure that these issues are dealt with. And I believe Senator Pressler articulated one of those very well. And that is to ensure that the funding and the development and the participation is broad enough to encourage and to support the users of something other than supercomputers and the users who may only have to rely on multi-gigabyte networks.

A reason for believing this, and promoting this, is we know from experience that the cost benefits and the likelihood of seeing timely development, timely deployment, of the types of technology you are talking about is very dependent upon a broad base of users. The more fully cost can be allocated and

distributed along many users, the better off everybody will be, and the faster and the more timely development of these technologies will take in the private sector.

I think an example I would like to cite where we have had the technology, we have had the capability for some time, and yet we have not seen the full benefits and the full optimization of the technology and the applications in the area of integrated services digital networks, this thing called ISDN.

Certainly the technology and the capability is there, but the applications are not. And Dr. Bromley spoke eloquently about the need for software and the development of basic applications to drive and to take advantage of the technology of that type.

So we encourage the planners and the architects of this legislation to ensure that there is a broad participation in the academic, educational, and industrial community, beyond those that just rely on supercomputers. Secondly, we encourage and we will do all we can through our participation to ensure that the development of the network itself is a development and a plan that will permit the utilization of public networks to support these services and to support the capabilities.

We do not believe that it requires a private network development or application to support your objectives. We do

believe, and our experience tells us, that the maximum cost benefits, the long-term interest of the users of a network can be found with shared network applications. We have seen time and again the problems that develop with private networks, where you have a group of users stranded with a set technology.

We also believe that public services and the commercialization of these applications and products will ensure that the Government, the need for the infusion of Government money, will cease over time, will minimize over time.

I thank you, Mr. Chairman, and members of the subcommittee. That is a business perspective that differs slightly from my panel members. I welcome this opportunity to have spoken to you. Thank you very much.

[The prepared statement of Mr. Gray follows.]

Senator Gore: Thank you very much. Extremely valuable statement. And may I say, in echoing the words of Dr. Bromley, that the real-life perspectives or reality checks, if you will, which we have gained from our dialogue with your company and others, have been invaluable in shaping this legislation. We really appreciate your statement here today as well.

Next, Dr. David Nagel, vice president for advanced technology with Apple Computers. You are invited to proceed at this time. Welcome.

STATEMENT OF DAVID C. NAGEL, VICE PRESIDENT, ADVANCED TECHNOLOGY, APPLE COMPUTER, INC.

Dr. Nagel: Thank you, Mr. Chairman. I am appearing today not only on behalf of Apple Computer but also on the behalf of the other members of the Computer Systems Policy Project. We are very appreciate of the opportunity to appear for the subcommittee on a favorite topic of high-performance computing and networking.

In the fall of 1989, the 11 largest computer systems companies in the U.S. formed the Computer Systems Policy Project to address what we felt were some fundamental problems facing our industry. It was a measure of the importance of this activity that the CSPP is an association of the chief executives of our companies; the CEO's are supported by the chief technologist for each company, like myself, and by a permanent professional staff in Washington.

We began our study more than a year ago with an internal look at the health of our industry. We assessed technologies that we believe are critical to our industry. We assessed how the U.S. is doing relative to other countries and our foreign competitors in those technologies, and we developed a prognosis for U.S. industry performance into the future.

While by almost any measure, our industry is still the strongest in the world, our lead appears to be diminishing rapidly by almost all of the measures that we examined. In

1983, for example, U.S. companies held an 83 percent share in the world market of computer systems, including software. Between 1983 and 1989, our share of the world market declined by more than 20 percent, from 83 percent to about 61 percent. During the same period, Japan's share rose from 8 percent to 22 percent and our European colleagues' share grew from 10 percent to 15 percent.

More troubling, the computer systems industry went from a significantly positive contribution to the U.S. trade balance all throughout the 1980's to a position in 1990 where our imports almost exactly balance our exports. While the U.S. ratio of computer exports to imports moved steadily downward over the last decade, Japan even more dramatically increased its export-import ratio from about 2 in 1980 to more than 6 at the end of the 1980's.

While these findings are clearly troubling to us, the members of CSPP recognize that the primary burden for staying competitive in the global marketplace rests squarely with our own industry. So we began with an internal assessment. We examined our own investment levels and competitive positions in the key technologies which we think are critical to success. We identified, for example, 16 critical pre-competitive generic technologies, and concluded that the U.S. still leads the world in half of these. And most of these are software intensive.

We also concluded that the U.S., once leading the remainder, now lags the world in several critical technologies, and is losing a lead in the remainder. And most of these, and in contrast to the technologies for which we hold a lead, the lagging technologies are mostly capital-intensive ones. We also believe that, without further positive action, the U.S. position will erode further in all of these 16 technology areas over the next few years.

The computer systems industry spends 21 percent of the private sector R&D, or about 10 percent of the total national investment, in research and development. The investment of the computer industry in 1989, more than $18 billion, is more than that of any other industrial sector, and represents a 26 percent increase over the amount we spent in 1988, a period when many other industrial sectors were reducing their R&D spending.

In contrast to the level of investment in private industry, the U.S. Government only invested about 2 percent of its R&D portfolio in generic technologies related to our industry.

Taken as a whole, we conclude that the Federal R&D budget in computing is not today focused or managed in ways that are needed to preserve and enhance our economic competitiveness, given the rapid pace of innovation and the R&D practices of other countries. In short, we believe the Federal R&D has not

been as helpful to the computer industry as it might be.

Based on our analysis and this conclusion, we have outlined an initial set of technology policy recommendations. These provide a strategy, we believe, for better focusing the Federal R&D investment in these pre-competitive generic technologies, and will help us meet very stiff international competition.

We believe that the Government and industry must work together, and jointly must take the following first steps to improve the effectiveness of the spending in the U.S. First, we think that there should be an improvement in the mechanisms within OMB for reviewing the Federal R&D spending program. In many cases, these have become so complex, it is very difficult to actually figure out what is being spent.

Number two, we need to increase the industry input, we believe, in setting Federal R&D priorities and to better manage the Federal R&D budget. Number three, we think industry should work with the Federal labs and with Government agencies to improve, to set Federal laboratory priorities and improve the return on the national investment made in these labs.

And fourth, we look forward to working with the Government in implementing high-performance computing industries, including a national network capability of bringing the benefits of computing to every institution,

household, business, and school in the Nation.

We have created three CEO-level working groups to address our industry's participation in the Federal R&D priority setting. And we are looking here at structural and legal impediments of which there appear to be a variety. We are increasing the degree of interaction between industry and the programs in the Federal labs. And finally, we are looking at ways in which we can better participate in implementing the high-performance computing and communication initiatives.

We fully support and recommend full funding for the national high-performance computing and communication programs, including a National Research and Education Network. We recognize and applaud the pioneering role that this subcommittee and its chairman have played in recognizing the importance of the development of a national information infrastructure and an effective, high-performance computing program.

We believe this efforts are critical in providing the research infrastructure in maintaining our Nation's leadership in basic computer and information research. The CSPP believes that the high-performance computing and communication initiatives will be instrumental achievement of the national education in work force training goals.

Now, much has been written and said about the benefits of high-speed networking at the institutional level, of higher

education levels. While we agree with and support these uses, high-speed networks will allow the rate of scientific and engineering progress a major grand challenge problems to accelerate significantly.

But we also believe the benefits of high-speed networking and high-performance computing should ultimately find their way beyond institutions and become available to the rest of us. And I am echoing this, both what my colleagues have already said and what have been said by the senators.

I would like to briefly touch on some other benefits of what we believe are a truly universal high-speed network, benefits that will eventually impact a much larger number of our citizens.

Actually, we are beginning to see the precursors of the benefits of networking and distributive computing, even with the overly complex low-speed network systems currently in place in the U.S. Apple Computer, for example, in a project called Apple Global Education, or AGE, has made our own internal slow-speed electronic mail system available so that school children all over the world can communicate and exchange ideas.

For example, recently on Earth Day, 12 schools from around the world collaborated and prepared and produced local newspapers that featured environmental issues using this network. On other networks, we have begun to see a variety of

education applications develop. We have seen collaborations between teachers in the preparation of educational materials. We have seen collaborations between students conducting scientific investigations. We have seen networks allow students in elementary and high school to benefit from access and experts in universities. And we have seen a variety of on-line courses and instructional materials being prepared and disseminated electronically every day.

Both students and teachers have access to a widening range of information, databases and computing resources, all remote to their physical locations. We believe these applications are springing up everywhere, even though there are many impediments, because our educational system is discovering the value of electronic information delivery, even with the very slow speed networks available today.

With the arrival of data exchange capabilities like those that will be provided by the NREN, capabilities that will allow graphics and images to be transmitted as easily as text, we should see an explosion in new uses of high-speed networking and education, uses which we think will fundamentally transform the whole process of education.

Teachers and students who are in remote, rural areas -- in some cases, remote urban areas -- far from major libraries and universities, will have access to information and expertise every bit the same as their counterparts in the most

favored settings. Physical separation will no longer matter when on-line video conferencing and other high-speed network supported applications are available to every school in the U.S.

We believe also that U.s. business will benefit from high-speed networking. Apple, for example, has greatly benefited from our own internal electronic mail system, as have many other companies; in our case, an information exchange system called Apple Link. Using Apple Link, individual contributors exchange ideas and documents with one another, with their managers, and with the executives of the organization. From time to time, they exchange insults with one another.

Some of the fundamental administrative activities within Apple, activities that were used to generate large piles of paper, now are done almost entirely electronically. The advanced technology group which I head uses a video conferencing network to tie together our four separate physical labs in the U.S. Without this system, it is clear we would all have to do a great deal more traveling and generate waste along a variety of dimensions.

Finally, Apple uses high-performance computing to great advantage both in the development of technology for products and in the development of products themselves. Over the past year, for example, we have used our Cray to develop advanced

algorithms for data compression, high-performance graphics, and speech recognition, among other applications.

Once we prove to our satisfaction that these algorithms work on our Cray, we can design special circuits, again using the Cray, which makes Cray levels performance for specialized applications available on our advanced personal computers at a tiny fraction of the cost of a supercomputer.

So high-performance computing helps us both in the product sense and in the technology sense.

In conclusion, we recognize that improving U.S. technology policy is a long-term process, cannot be addressed by any one organization, any single set of recommendations or any given piece of legislation. Improvement of U.S. technology is, nonetheless, an essential process that will require the cooperative R&D investments and partnership of both the private sector and the Government. We believe that improving U.S. technology requires a long-term commitment and a series of changes by both industry and Government over time. Whether as independent CEO's or as an industry, the members of CSPP are committed and will remain involved in this process.

Thank you very much.

[The prepared statement of Dr. Nagel follows.]

Senator Gore: Thank you, Dr. Nagel, and my thanks to CSPP for the input. Your company, your member companies have provided throughout this project -- and I now you are representing the project, but please convey my personal gratitude to John Sculley for his personal support and encouragement of this legislation as it has gone along.

Dr. Nagel: I will be happy to do just that. Thank you.

Senator Gore: I have many questions, as I know Senator Pressler does. But we have one more witness, and it is one we have been looking forward to hearing: Dr. John Wold, executive director with the Lilly Research Lab at Eli Lilly. And you are accompanied, Dr. Wold, by Dr. Riaz Abdulla, head of supercomputer applications and molecular design at Lilly.

Dr. Wold, please proceed.

STATEMENT OF JOHN S. WOLD, EXECUTIVE DIRECTOR, LILLY RESEARCH LABORATORIES, ELI LILLY AND COMPANY; ACCOMPANIED BY RIAZ ABDULLA, MANAGER, HIGH-PERFORMANCE COMPUTING PROGRAM, ELI LILLY AND COMPANY.

Dr. Wold: Thank you, Mr. Chairman. Eli Lilly and Company is a global corporation based in Indianapolis, Indiana, that applies advancement in science to basic human needs, health care, and nutrition. We compete in the pharmaceutical, medical devices, diagnostic product, and animal health products industries.

My responsibilities at Lilly include the company's high-performance computing program. And with me, as you just alluded to, is my colleague, Dr. Riaz Abdulla, who manages this program on a day-to-day basis, and is himself a practicing supercomputer user.

I would be pleased to have this opportunity to present my company's views about the importance of a national commitment to high-performance computing and to high-capacity network. I am sure that this subcommittee has heard -- it will hear much more in the future -- about the underlying technology required to support the evolution of supercomputers and high-capacity networks.

It is important that you share our computering technologists' excitement about their visions of supercomputing systems. But I think it is also important that

you share the visions of a research-based institution like ours which have motivated us to invest in supercomputers.

Long-term success in the research-based pharmaceutical industry depends on one factor: innovation. We must discover and develop cost-effective new products that improve the quality of life and offer economic benefits to patients, payors and society as a whole.

Pharmaceutical R&D has traditionally been a high-risk, complex, time-consuming, and costly enterprise. Over the past half-decade, the research-based pharmaceutical industry has experienced major changes. The rapid escalation of R&D costs has helped precipitate major structural changes in the sector of the global economy in which the U.S. is an established leader.

An unprecedented wave of mergers, acquisitions, joint ventures, has led to fewer, larger competitors. Competition in the research-based pharmaceutical industry will only become more challenging during the 1990's and beyond. Consequently, my company, Lilly, has evaluated many opportunities to reinforce its capacity to innovate, to enhance its capacity to compete. Supercomputing is a case in point.

Our supercomputing experience was initiated through our partnership with the National Center for Supercomputing Applications at the University of Illinois, the NCSA. The NCSA has prepared a video segment that describes our

involvement in their program. If we can run the video, I will conclude my remarks after the video.

[A video was shown.]

Dr. Wold: Mr. Chairman, as you pointed out earlier, supercomputing has created a new common language for research. In recent years, scientists have developed mathematical methods describing the realistic shape and motion of atoms in large molecules, such as receptors or enzymes that exist in the human body. These models are now emerging as important tools for scientists probing new investigations into how potential drug candidates would likely affect these molecular targets.

These mathematical descriptions are based on equations involving billions of numbers. Conventional computers take days or weeks to perform these calculations, but supercomputers can do this work in minutes or hours and permit previously impossible calculations.

Graphic representations of the data serve as a new communications medium, a new language for scientists. Teams of scientists can share the same visualized image of how a specific chemical agent would likely affect the receptor in question. They can quickly evaluate the probable effects of modifications in a chemical. They can focus the painfully slow efforts required to synthesize and test new agents on those compounds that appear to have the greatest potential.

Our experience to date suggests three interrelated advantages high-performance computing to our industry. These systems will speed up the identification of promising drug candidates. Supercomputing will enable our scientists to design new drug candidates that they otherwise would not have even considered.

These systems will foster greater collaboration among scientists from various disciplines who are involved in pharmaceutical research and development. Supercomputer-generated graphic simulations help scientists with diverse academic training to share the same vision of crucial data.

And thirdly, these systems will encourage truly visionary exploration. Now, supercomputers are motivating our scientists to ask "what if" more boldly than ever before in helping them to quickly consider many possible answers to their questions.

I want to stress that supercomputing is only a tool. But it is a very powerful scientific tool, a tool that will become all the more powerful with networking capabilities. A high-capacity network will greatly facilitate the dynamic collaboration among scientists at different locations and often different institutions. The network will help us optimize scarce scientific talent during a period when we are almost certain to experience major shortfalls in availability of highly trained scientists.

Finally, a high-capacity network will help scientists raise questions that they could never seriously ask before. In conclusion, I want to stress two points. We believe that supercomputers in a national, high-capacity network are important to our company, to our industry, and to the medical professionals and patients we serve. And we believe that high-performance computing will play a crucial role in the many technology-based industries and in the growth of national economies that depend on these industries.

We strongly recommend the enactment of the High Performance Computing Act of 1991 and thank you for this opportunity to share our thoughts with the committee.

[The prepared statement of Dr. Wold follows.]

Senator Gore: Thank you very much.

Senator Pressler will have to depart for another committee hearing, and I want to recognize him first.

Senator Pressler: Thank you very much, Mr. Chairman. I am going to ask most of my questions for the record. I just want to ask one question of the panel, if I may. And that is, is the current fiber-optic infrastructure sufficient to handle supercomputer network envisaged in S. 272 or envisaged in the administration's proposal?

I do not think it is. But the question is how do we get the fiber-optic infrastructure? How do we accomplish that? Some people say we let the telephone companies, the regional telephone companies into cable TV, and they will do it, so they say. Others say we require the cable TV companies to start laying fiber optics rather than copper.

And I guess a second question to that, and might be addressed to Mr. Gray, is what type of user or consumer demand needs to occur before private companies like yours will begin to connect homes and small businesses with fiber optics to the supercomputer network?

So, in other words, the underlying question, and some of you want to think about it a little bit more, but I think that is a basic question. I am working on that in the communications subcommittee and some other legislation that is related to this. How do we get the fiber-optic infrastructure

to support this?

Mr. Gray: I will try a first shot at some of that. It certainly will not be all inclusive. But certainly we as a carrier, as well as our competitors, the more evident it becomes to us and the greater the probability there is for applications of the type that we are talking about here, and a large user base to be established.

And frankly, that is what I see this initiative really precipitating. It becomes a coalescing force to bring those things together. We as individual members of the industry cannot bring all that together; we cannot get the computer industry, the users, academia, we cannot pull them together.

What you are proposing here does begin to coalesce those forces and bring some focus, and at least provide some, some perspective on our part that this could happen, as a private industry. Therefore it gives us the incentive to divert and to reorganize priorities to shift our investment toward these kind of capabilities.

And within the industry, we have worked with the exchange carriers; we are very dependent on them to extending the capabilities of our network to their users. And more and more competitive forces are at work there, because we do have options other than the exchange carriers to get to our customers.

So there are fairly powerful marketing influences that

can drive this, providing there is a, the infrastructure provided by the Government to fund and seed some of this, and provide the stimuli to make those things happen.

Dr. Nagel: It may well be that the, that the political regulatory and problems of that category far outweigh the difficulties of getting the technical infrastructure in place. I think even from the limited look we have taken at this so far, the technical problems are very minimal relative to the problems that we have just talked about, getting people together to work on something like this.

Dr. Abdulla: Senator Pressler, as a user, I would like to very directly state that the answer to your first question is no, the existing infrastructure is not sufficient. And what the proposals that we have heard today really tell us about is a paradigm shift.

You are talking about the difference between a teleprinter and a telephone, is how different we are talking about. It is going to completely change the way we do things.

Senator Pressler: I think we have got a big job to get that fiber-optic infrastructure built somehow. It is like wiring the Nation, and we have to find a way to do it. The big telephone companies say they can do it, but they will only do it if we let them get in the cable TV business, stuff like that.

We have to find a way, and then we have to find a way

that everybody has access to use, it is kind of like a gas pipeline; people will have a right to have access to that fiber-optics cable somehow. And if one company controls it or something, or does not let other people use it, the whole -- it is a very difficult problem, as I see it.

So this whole supercomputing thing is great. But I see this fiber-optic infrastructure thing as a very great problem we have to solve. And I do not really have all the answers; I am working on some legislation that I hope will solve part of it. But any of you, if you think of any great ideas as you ride the train home, tell me.

Senator Gore: If I could supplement this for the record, let me just offer my 2 cents' worth on this. I have supported the entry of telephone companies into the cable television business, but that is an extremely controversial proposal which may not finally pass.

I do believe that the measures included in this legislation will result in the unleashing of forces which will inevitably lead to the wiring of the Nation. In fact, the fiber-optic capacity which is already in place is adequate for the long distance links, provided we make available the new switches, the new software, and the new algorithms, which will upgrade the capacity of the existing fibers without requiring the placement of new fibers in the ground or on the poles.

The inadequacy of the present fiber network, leaving

aside the software switches and algorithms, the inadequacy of the fiber itself is mainly in what is called the last mile, from the last switching station to the home. It is for that reason that I have supported the Telco entry into cable.

But let us assume that that does not happen in the near term. I believe very deeply that once the backbone network is in place, we will witness the emergence of a new generation of information services, a new generation of ways to configure information to make it understandable to people, that we will unleash enormous demand for access to that backbone network.

There will be a new set of financial incentives to encourage people to provide that last mile. There will also be the ongoing efforts of merit; just to name one, I know that that is not a -- it is not universally participated in by everybody, but it is a not-for-profit corporation, perhaps one of several that will be active in rapidly expanding the reach of the backbone network.

Just as the interstate highway system led to initiatives by States and cities and even private turnpike authorities to connect to the interstate highway system with new, four-lane limited-access roads that were not part of the federal system, as it was initially designed. So this backbone network will quickly, in some cases even simultaneously, lead to the completion of access links, which will themselves encourage access links.

Just as arteries and capillaries are related on down, I think there will be a growing network, a growing network, with lines going to more and more people.

What we have now is a chicken-and-egg problem. The market place is not perceiving the demand for these new information services because the network is not there to deliver them. The market is not perceiving the demand for the network to deliver them because the new services are not yet there. Once that chicken-and-egg conundrum is overcome, then the, we will be in a new system of supply, we will be in a new reality. And the demand for these new services, I think, will drive the forces that will encourage the market to complete the national network.

Now, I believe that is a realistic vision. But just in case, I also support the Telco entry into CATV, and I will look forward to working on any other proposals that people have to address that.

Dr. Langenberg: Mr. Chairman, I might be able to provide some support for that view on a relatively small scale. There is a generic type of community that tends to run from 20,000, perhaps to 40,000 population, that contains an unusually high proportion of serious users of computing facilities. It is called a university.

And one after another over the past decade or so, I have watched universities all across the country, fiber-optic

backbone -- provide fiber-optic backbones for themselves. It is a very complex kind of drive for that effort, but it is partly demand, it is partly based on leadership of university officials who can see the future coming and who want to be prepared to hook into it, once it is there, as a part of maintaining that institution's competitive edge. And it is partly push, partly pull, but it does work.

Senator Gore: To use another example, the state of Tennessee Public Service Commission has already embarked on a very ambitious plan to provide high-performance networking to virtually the entire State in anticipation of the completion of the backbone network.

I know that there are some other states that are doing the same thing. So I think that it will happen, once the network is there.

But let me say that we have a statement for the record from the U.S. General Accounting Office on supercomputing in industry -- thank you very much, Senator Pressler -- and we will include this for the record.

[The material referred to follows.]

Senator Gore: We also have statements for the record from the American Library Association, the Computer Research Association, the Association of Research Libraries, and there are other associations that have also provided statements for the record. Without objection, they will be included.

[The material referred to follows:]

[SUBCOMMITTEE INSERT]

Senator Gore: Most, if not all -- the GAO was not asked to provide a statement of support or opinion one way or another on this; it is a factual recounting, accounting of some of the questions we addressed to them. These other statements, or most, if not all, are extremely supportive of the legislation.

Just to pick up where I left off in my last comments. Dr. Nagel, you talked about making this available to the rest of us, beyond the institutions. I was thinking of the supply and demand forces that will be unleashed when I heard your statement there, and I wanted to refer back to that.

Dr. Kalos, I enjoyed the videos that you showed there. How many industrial partners use the Cornell facility?

Dr. Kalos: We have about 15 industrial partners.

Senator Gore: Are they concentrated in a few industries?

Dr. Kalos: No, they span many industries. I should also mention that our major industrial partner is IBM, which is a well-known manufacturer of computers of all kinds.

Senator Gore: I have heard of them.

[Laughter.]

Dr. Kalos: And when IBM decided to reenter the high-performance computing arena, they did it in partnership with Cornell University. We have been pioneers with IBM in conceiving, testing, shaking down certain aspects of their supercomputing, and especially their parallel computing

effort. And that is a partnership that will continue as IBM enters the highly parallel computing arena.

Senator Gore: Now, I understand that Cornell runs a program called Superquest to give high school students access to supercomputers. How does that work?

Dr. Kalos: Well, we run a national competition; we announce to schools around the Nation that this program is available. Teams at high schools submit ideas for original research that requires supercomputing for its accomplishment. The proposals are evaluating by a group of independent reviewers, and the winners come to Cornell. Their prize is 2 weeks in Ithaca --

[Laughter.]

Dr. Kalos: -- where they are provided with pizza, softball, and access to high-performance computing, among other essential parts of life.

[Laughter.]

Dr. Kalos: And the winners are chosen on the basis of the originality of the research. Some have done videos, and so on. I myself had the privilege of introducing the two winners in Gainesville, Florida, and each gave a research talk about research that I found interesting and original.

One had to do with surgical treatment for strabismus, crossed eyes. And I thought it was quite original. And another, in fact, was research in my own area, which is

stochastic simulation. And I found that extremely interesting. So I was a little overwhelmed by the quality of these students. And this program continues, and in fact is being broadened this year with the participation of other of the national centers.

Senator Gore: Am I wrong that relatively few U.S. companies seem to be using supercomputers compared to what the potential would appear to be?

Dr. Kalos: Compared to the potential, yes, I think that is absolutely correct.

Senator Gore: Why is that?

Dr. Kalos: Well, I think that is, there are a number of issues; perhaps our colleagues from Lilly could speak better to this. I think first of all, the role of computational modeling in science is a relatively new development. The recognition by scientists is complementary to what they have learned --

Senator Gore: Inductive and deductive reasoning.

Dr. Kalos: Exactly so. The idea that this is another way of doing science that sheds valuable information, it is a way of connecting to the knowledge they already have. This is relatively new. In addition, of course, new techniques have to be learned.

First of all, the basic techniques of mathematical representation of the problems at hand, the translation of

that into correct and efficient computer algorithms, the realization and testing on computers of all kinds, and the realization and testing especially on supercomputers.

So these are a number of new challenges that scientists face everywhere, and I think that, as the applications grow throughout the country, as our young scientists are trained in computational scientists almost as a matter of course, that industry will very naturally take this up.

Senator Gore: Dr. Wold.

Dr. Wold: I can say that, certainly in our case, our entry into supercomputing would have been clearly impossible without the national center at the University of Illinois. That was our introduction. We felt it was quite a leap of faith to get involved even to that level; I had not even considered at that time purchasing our own supercomputer.

Our usage of supercomputing time at the national center, as well as our own usage after we finally got our supercomputer, has just in every case exceeded our expectations; in fact, it exceeded our ability to plan for it.

So once the tool was there, the utilization just increased dramatically. The key is to get that first opportunity into any researcher's hands to see what can be done.

Senator Gore: Do you work with Larry Smarr at Champaign-Urbana?

Dr. Wold: We certainly do, yes.

Senator Gore: Now, geographically, you are about, what, 50 to 100 miles from there?

Dr. Wold: It is about 120 miles, yes.

Senator Gore: 120 miles. Do you have to go to his center still? Or do you have a link?

Dr. Wold: We do have a link. But perhaps I could have Dr. Abdulla address that, since he drove that 140 miles many times.

Dr. Abdulla: Senator Gore, we have, and continue to have an important program at the National Center for Supercomputing Applications. When we started off, obviously our people had to go to the center where they learned all of the different kinds of technologies that Larry Smarr had over there. There was a tremendous commitment to new hardware, to work stations, to networks, to software, and to new algorithms.

We had educational programs that are ongoing, even to this day. We call them FOCUS; obviously we focus on chemistry and the -- it stands for Focus on Chemistry Using Supercomputers. So we expose, in very tight-knit workshops, the latest in supercomputing technology. Our staff goes through all these training sessions, comes back to an environment which is very similar to what we have at the NCSA, and continues in collaboration with consultants that we have in our shop, and expand and grow.

And you know, if you remember Jack Walton's talk in Washington, D.C., when he talked about the stages of change, one of the things he said was that until somebody establishes a gate post, there is not going to be any diffusion.

So we are at that state now; we have establishes gate posts. And people are saying, gosh, if it works for scientists, let me try it with my problem. And then it diffuses, until finally you bring about a complete revolution in the way you do things. So it is a process.

Senator Gore: In parallel.

Dr. Abdulla: Yes. It is a process rather than an event. And it is happening because of all of these infrastructure-related items that we talked about.

Senator Gore: Am I wrong that Japanese companies seem to be relatively more willing to explore the potential of supercomputing?

Dr. Nagel: Well, I was going to comment. I think -- and I do not necessarily have the data to support this assertion -- but I think that what, one of the things that you will find is that the use of high-performance computing in industry is jointly, is really a function of how competitive the industry is, or how competitive the people in the industry are.

And one of the things that we know about the Japanese is that they are very, very competitive, and effectively so. So I think even in the U.S., you will find those industries which

are the most competitive, and are, you know, frantically searching for ways of getting a sustainable competitive advantage, will be using advanced techniques like supercomputers and high-performance computing networks and so forth, because they will give that advantage and they will, you know, make that initial threshold jump to get over the difficulties.

Senator Gore: I think the testimony of a witness from Cray last year indicated that one-third of U.S. supercomputers are in industry; two-thirds of Japanese supercomputers are in industry. That does not clash with the impressions that you all have, does it? All right.

Mr. Gray: Mr. Chairman, could I elaborate on that point just for a moment?

Senator Gore: Please.

Mr. Gray: We happen to be well aware, through all of our international negotiations and dealings, that your Japanese have got very ambitious programs for upgrading their networks for deploying fiber in a very ubiquitous fashion.

They are currently purchasing advanced technological switching capability that would support multi-gigabyte networks and this kind of thing, and have every evidence they will be deploying this technology and is capable of, within the next 2 to 3 years.

Senator Gore: Well, there is no question about that. We

have by most estimates about an 18-month lead over the Japanese in network technology. But if we choose not to exploit it, we will lose it in about 18 months because they are not standing still at all.

Dr. Nagel: I would like to make, if I might, just one more comment on this business of networking, going beyond just institutional support. I think one of the sometimes unappreciated consequences of setting a goal that we are going to move beyond sophisticated users, as Dr. Langenberg mentioned you find in the universities, to people that are not necessary sophisticated in the use of networking and computers, is that it will force us to make them easier to use, and therefore the barriers to use in industry and in education and everywhere else, will be, you know, reduced greatly.

And that is really one of the, you know, it is still a fairly arcane business to use high-performance computing and to use our Internet and the various range of networks that we have available in this country.

Senator Gore: And not only with the user interface, as they call it, become a lot friendlier, as they say, the cost is coming down dramatically. One estimate given to the subcommittee -- I do not know whether it is accurate or not -- but the estimate was that a supercomputer which costs between $10 million and $20 million today will almost

certainly with 5 years be in the $400,000 to $500,000 range.

If that is the case, then, and if simultaneously the ease of use improves dramatically, we will see a sudden sharpening of this conflict between data processing capability, demand for data processing, all on the one hand, and our ability as a nation to communicate over our existing communications lines, the information visualizations and packages of data that we need to convey in order to communicate with each other.

Dr. Kalos?

Dr. Kalos: Mr. Chairman, I would like to amplify somewhat on the issue of the contribution, in particular of high-performance networking to industrial productivity. I would like to call your attention to a joint program of the Xerox Corporation and Cornell, Cornell Theory Center, which they call the Xerox Design Research Institute.

That is a very broad-based program which is concerned with what it takes to bring better products more quickly to market. And it concerns simulation and modeling on the supercomputers, but much more than that. For example, one of the issues is the product history and how one learns from previous products how to design better products.

Another issue is that Xerox, like many other companies, is spread all over the country. And for people in Park, in Palo Alto, to collaborate with people in Webster, near Rochester, to collaborate with people in their laboratory in

Tarrytown, New York, and design better products that are more manufacturable, that are more maintainable requires a collaboration at great length.

And they are very concerned about their ability to communicate, not only the results of supercomputer calculations, but the results of many other ideas and records. I consider that also important, and I believe that the present bill will contribute to productivity very much.

Senator Gore: In what Bill Wolf again has called a "co-laboratory."

Dr. Kalos: Exactly.

Senator Gore: And I might just note for the record, while we are talking about industry, that until quite recently, Toyota had more supercomputers than Ford, GM and Chrysler combined. That has now barely changed, but it is significant.

Dr. Wold, could you name any products for which, that Lilly has been able to develop that might not have been possible in this time frame without supercomputing?

Dr. Wold: Well, I certainly wish I could. But our business is a very long-term business in terms of research. It takes 10 years after the discovery. The supercomputer impacts the discovery phase of research, so if and when we have a compound, a new drug that can be linked to the supercomputer, it is a number of years in the future.

I feel, however, though, that when that day does come, we probably will not remember or notice that it was discovered by the supercomputer, that computational sciences will have been woven into the fabric of research such that it will no longer be remarkable such that we would notice that.

Senator Gore: I have a number of questions which I may have to ask for the record because we are running out of time. But Mr. Gray, one of the goals of S. 272 is to provide a catalyst for development of the extensions of the network by the private sector, as I was saying earlier.

We want the technology developed under this bill put to use by commercial network providers so that every office and home will have access to the information resources available on the NREN. It is my view that because of the unique nature of this challenge, namely, adding to fiber already in place new switches and software and algorithms which will vastly upgrade the capacity of the fiber.

And since other fiber not dedicated to this national network is also there, the discovery of the new switches, et cetera, will present the possibility of making them quickly available for private fiber, so that the network can be very, very quickly expanded. It will also serve as a sort of national demonstration project, showing what is possible with a national gigabyte network, and providing that a commercial market exists for such services.

One thing that might clearly hinder development of commercial, high-speed networks would be if the federal government ran the NREN in a way that competed directly with the private sector, and set up an unnecessary conflict.

S. 272 states clearly that the NREN will be phased into, and I am quoting here from the bill, "will be phased into commercial operation as commercial networks can meet the networking needs of American researchers and educators."

Is that consistent with your vision of where the NREN plan ought to be headed?

Mr. Gray: Well, that is not, not totally clear to us. The objectives as articulated in the legislation are clear; what is a little unclear at the moment is how we, how that path will evolve and how that plan will play itself out.

And the point I raise is that we would like to feel certain we have a role to play in our participation to ensure that the initial plan on the road map that is ultimately put in place and followed will assure some evolution or some, at least not exclude public network opportunities to support and provide those services.

Senator Gore: Well, I raise this question now, so as to reassert for the record of this hearing, as I have in other hearings, the clear intent of the sponsors of the bill and the advocates of the whole project, to make that work.

And even, we, like you, do not yet know how to dot every

I or cross very T. I want you to know that that is clearly our intention and that is the way it is going to happen.

NSF seems now to be able to let the private sector provide networking services when that makes sense. They have contracted with your company, with companies like MCI and ANS and regional networks to run NSFNET. Do you think that NSF is presently taking the right approach?

Mr. Gray: From what we see and what our experience has been, yes.

Senator Gore: Okay. Well, at least we have a model to work with. It may need refinement; it may need modification. But we have the intent, we have the model, we have the working relationship with the companies involved. So that is a good place to start.

Suppose we did not pass S. 272. Suppose the money was not appropriated. Suppose there was no Federal leadership in gigabyte networking. How long would it take for the private sector to start providing gigabyte networking services on its own?

Mr. Gray: Well, I could only speculate on that. I would certainly think it is in the 5-year time frame or beyond. And I think the more serious issue is whether or not the process would optimize the capability. I think what you are suggesting there would probably create a scenario where there would be test bids developed or individual applications

develop one by one, and directed and designed and participated in by a variety of participants.

And while you were setting down, you would probably have a piecework of applications and standards, and you would have a number of potential network services out there that could possibly never inter-operate with one another. I think that is the bigger danger over time.

Senator Gore: Can you estimate what the U.S. would use if we do not build a gigabyte network? Or if we do not have one, that can be used in a coherent fashion?

Mr. Gray: It would be kind of hard to estimate something like that. I would not even want to take a stab at that after te kind of figures that Dr. Bromley threw around.

[Laughter.]

Senator Gore: Yeah. We could just say, maybe we could just agree that it would be a lot. I really wish that we had more time to explore each of these questions with follow-ups. I was looking for this number earlier about the increase in the amount of traffic growing in NSFNET. It has been growing at between 20 percent and 30 percent per month. That is a pretty rapid rate of increase.

Voice: Have you calculated that out to an annual increase?

Senator Gore: About 600 percent per year. That is a pretty good growth rate, I would say. And with the new

information services, of course, it would expand dramatically beyond that.

Because of the pressures of time, I am going to ask each one of you if you would be willing to respond to further questions in writing. I appreciate that very much. We are going to proceed expeditiously this year.

[The information referred to follows;]

[SUBCOMMITTEE INSERT.]

Senator Gore: I want to express my gratitude to Chairman Hollings of the full committee and Senator Danforth for their support and encouragement on this whole matter. And I appreciate all our witnesses here today. And I think I speak for most of my colleagues on the committee in saying that -- most, if not all, because it passed unanimously last time -- in saying that we are going to move expeditiously and get this done. We appreciate your help today. Thank you.

[Whereupon, at 5:05 p.m., the hearing was adjourned.]

Enclosure D

High Performance Computing and Communications
FY 1992 Budget
(dollars in millions)

	1991	1992	1993	1994	1995	1996
DARPA						
BA	183.0	232.2	283	353	399	447
OL	157.5	210.1	258	320	374	423
DOE						
BA	65.0	93.0	110	138	157	169
OL	54.6	78.7	97	121	143	153
EPA						
BA	1.4	5.2	5	5	5	5
OL	1.0	2.7	4	4	4	4
NASA						
BA	54.0	72.4	107	134	151	145
OL	49.1	62.9	89	118	140	148
HHS/NLM						
BA	13.5	17.1	17	17	17	17
OL	12.0	15.2	17	17	17	17
NIST						
BA	2.1	2.9	3	3	3	3
OL	1.8	2.7	3	3	3	3
NSF						
BA	169.0	213.6	262	305	354	413
OL	150.4	190.0	234	280	326	380
NOAA						
BA	1.4	2.5	3	3	3	3
OL	1.2	2.1	2	2	3	3
TOTAL						
BA	489.4	638.3	789	956	1,087	1,202
OL	427.7	564.6	704	865	1,009	1,129

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U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUITE 2320 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-6371

March 11, 1991

The Honorable D. Allan Bromley
Assistant to the President for
Science and Technology
New Executive Office Building
Washington, D.C. 20506

Dear Dr. Bromley:

Thank you for your testimony last week outlining the President's High Performance Computing and Communications Program and your views on H.R. 656. I appreciate your contribution to the discussion of the future of high performance computing in this country.

Several questions remain, however, on the Administration's position on this issue. I have attached several additional questions for your consideration. Your expeditious reply will greatly assist us in incorporating your views into relevant legislation considered by the Committee.

Thank you for your attention to this matter.

Cordially,

Robert S. Walker
Republican Chairman

RSW/am
Enclosure

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

WASHINGTON, D.C. 20515

QUESTIONS FOR THE WRITTEN RECORD

HEARING ON HIGH PERFORMANCE COMPUTING

1. Please provide the Subcommittee with both the incremental and total run-outs for each of the agencies participating in the President's High Performance Computing and Communications Program (DOE, NASA, NSF, NIST, NOAA, EPA, NIH, and DARPA) over each of the next five years.

2. Does the President's initiative envision the government buying and owning supercomputers, high end switches, fiber optical cable, and other hardware? Is there any reason why the network cannot be established commercially from its inception? Is it necessary for the federal government to do more than fund research and development and contract for services from the network?

3. What specific and detailed changes would you like to