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13. ABSTRACT (Maximum 200 words) The 1991 SSSC Forum was conducted under the auspices of the Board on Physics and Astronomy's Solid State Sciences Committee (SSSC) and cosponsored with the National Materials Advisory Board (NMAB). The Forum was the culmination of a year-long dissemination effort following up the NCR study Materials Science and Engineering for the 1990s that was released in September of 1989 and successfully brought together experts and policy makers in the field of advanced materials processing to discuss issues pertinent to the field. Support for the Forum was provided by the Air Force Office of Scientific Research (AFOSR), the Department of Energy (DOE), the National Science Foundation (NSF), and the Office of Naval Research (ONR).				
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NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS
Board on Physics and Astronomy
Solid State Sciences Committee

FINAL REPORT
to the
Air Force Office of Scientific Research
on the

1991 SOLID STATE SCIENCES COMMITTEE FORUM

Activities for March 1, 1991 to February 29, 1992
Award No. AFOSR-91-0185

May 1992

SUMMARY

The 1991 SSSC Forum was conducted under the auspices of the Board on Physics and Astronomy's Solid State Sciences Committee (SSSC) and cosponsored with the National Materials Advisory Board (NMAB). The Forum was the culmination of a year-long dissemination effort following up the NRC study *Materials Science and Engineering for the 1990s* that was released in September of 1989 and successfully brought together experts and policy makers in the field of advanced materials processing to discuss issues pertinent to the field. Support for the Forum was provided by the Air Force Office of Scientific Research (AFOSR), the Department of Energy (DOE), the National Science Foundation (NSF), and the Office of Naval Research (ONR).

ORIGIN AND BACKGROUND

The Solid State Sciences Committee (see attached roster) has a long history of annual forums spanning more than a decade. The 1985 Spring Forum was jointly sponsored by the SSSC and the National Materials Advisory Board. It was at this Forum that a consensus developed that a new assessment of the field of materials science and engineering would be useful and timely. As a result, a Committee on Materials Science and Engineering was formed under the joint auspices of the SSSC and the NMAB. The Committee's report, *Materials Science and Engineering for the 1990's*, was featured at the 1989 Forum. The intervening forums focused on the progress of the study in addition to specific areas of the study which were of particular interest to the community. Topics treated at those forums included the following: research opportunities in the field of materials science and engineering, materials science and engineering for the year 2000, and superconductivity. The focus of the 1991 Forum was the federal response to the report *A National Agenda in Materials Science and Engineering: Implementing the MS&E Report*. This report was the culminating activity of the regional meeting process that was initiated, at the request of the Office of Science and Technology policy (OSTP), to follow up the MSE study.

The forum process was originally designed to bring together the scientific community and the policy makers in Washington, DC. At these forums, policy makers are asked to address a general theme and to respond to discussion and to questions from the audience. Additionally, there is usually a scientific

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or technical theme on which talks are presented. Invitees to these forums include members of the NMAB, past and current members of the Board on Physics and Astronomy and its committees and panels, heads of materials science and engineering departments, and liaisons from materials-related societies.

HIGHLIGHTS OF THE 1991 FORUM

The 1991 SSSC Forum was convened on Wednesday, February 27, 1991 by Bill R. Appleton, Associate Director of Oak Ridge National Laboratories (ORNL) and Chair of the Solid State Sciences Committee. The Forum, the capstone of the dissemination effort for the materials study, was divided into three sessions. (See attached agenda.)

The first session of the Forum included keynote addresses by Senator Albert Gore (D-TN) and by Dr. D. Allan Bromley, Science Advisor to the President and Director of the Office of Science and Technology Policy. Both keynote speakers were introduced by National Academy of Sciences President Frank Press. Senator Gore discussed the role of the Congress in taking the initiative to spur development of critical technologies. Dr. Bromley described the work of OSTP in developing national initiatives in critical technologies including computing, materials, and biotechnology. He expressed the hope that, with guidance from the materials study and the regional meetings process, a national initiative in materials could begin in 1993. (The Presidential Initiative-Advanced Materials and Processing Program (AMPP)-has since been proposed as part of the FY93 budget.) Bromley praised the efforts of the materials community in providing input to the formulation of the initiative.

The second session of the Forum focused on the results of the regional meetings that had been organized to develop ideas for the implementation of the recommendations of the materials study. Bill Appleton began the session with an overview of the regional meeting process and the resulting recommendations. Following that presentation, Jim Williams, NMAB Chair, moderated a panel discussion that included representatives from each of the regional meetings, the MSE study CoChairs, and OSTP. In particular, the panel responded to questions from the audience.

Finally, Jim Williams led a session on consortia in materials science and engineering. The thrust of this session was on examples of and issues connected with consortia and government-university-industry collaboration. Several leaders in this area spoke, including Siegfried Hecker, Director of Los Alamos National Laboratory; Turner Hasty, COO, Sematech; Edward Miller, President, National Center for Manufacturing Studies; and Kent Bowen, Co-Director, Leaders in Manufacturing.

The Forum was followed by technical sessions organized by the Materials Research Society and cosponsored by the American Ceramic Society, ASM International, the American Physical Society, the American Vacuum Society, the Minerals, Metals, and Materials Society, and the Federation of Materials Societies. The technical sessions focused on high T_c superconducting films for electronic applications and the science behind semiconductor processing.

STATUS OF THE PROJECT

A summary of the Forum highlights, as well as transcriptions of the keynote addresses, was published in the March 1991 issue of the *BPA News*. (A copy is attached.) The SSSC is currently planning the 1992 Forum as a followup to the 1991 Forum and the FY93 AMPP Initiative. The 1992 Forum will serve to acquaint the MSE community with the federal AMPP initiative and involve interested members of Congress in discussions regarding its implementation. A more detailed accounting of the 1991 Forum proceedings will be prepared to distribute prior to the next Forum. The reports resulting from this effort will be prepared in sufficient quantity to ensure their distribution to the sponsors, to committee members, and to other relevant parties in accordance with Academy policy. Proceedings will also be made available to the

public without restriction. As planned, the proceedings are scheduled for completion during the Summer 1992. The support of AFOSR will be acknowledged in the published proceedings.

Attachments

- (1) Roster of the Solid State Sciences Committee
- (2) Agenda of the 1991 SSSC Forum
- (3) March 1991 issue of *BPA News*

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NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS

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NATIONAL RESEARCH COUNCIL
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1991 Solid State Sciences Committee Forum

Solid State Sciences Committee—National Materials Advisory Board
Auditorium
National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Wednesday, February 27, 1991

0830 Registration

0900 CONVENE

Opening Remarks

Bill R. Appleton, Associate Director, ORNL;
Chairman, Solid State Sciences Committee
Frank Press, Chairman, National Research Council

Session I: Keynote Speakers

0915 Keynote Address: Congressional Views
on Science and Technology

Sen. Albert Gore (D-TN)

1000 Keynote Address: Federal Advanced
Materials Program

D. Allan Bromley, Science Advisor to the President

1045 BREAK

Session II: Regional Meetings and National Coordinating Meeting on Materials Science and Engineering

1100 Overview of *A National Agenda in
Materials Science and Engineering —
Implementing the MS&E Report*

Bill R. Appleton, Chair, SSSC

1130 Panel Discussion on the Regional
Meetings and the MS&E Report

Moderator: Jim Williams, Chair, National Materials
Advisory Board
Panel: SSSC and NMAB Regional Meeting
Representatives, OSTP, MSE Cochairs
Northeast: Peter Eisenberger, Princeton; George
Parshall, DuPont
Southeast: Bill R. Appleton, ORNL; Reza
Abbaschian, University of Florida
Midwest: Melvin Bernstein, IIT; Jim Williams, GE
West: Gerd Rosenblatt, LBL; James Langer, UC
Santa Barbara
OSTP: William D. Phillips, Assoc. Dir. for
Industrial Technology
MSE Study: Praveen Chaudhari, IBM; Merton
Flemings, MIT

1991 Solid State Sciences Committee Forum

1230 LUNCH

Session III : Consortia in Materials Science and Engineering
Jim Williams, Chairman, National Materials Advisory Board

1400 The Superconductivity Pilot Center Siegfried Hecker, Director, LANL
Projects at the DOE National
Laboratories

1445 Semiconductor Consortia: SEMATECH Turner Hasty, COO, SEMATECH

1530 The National Center for Manufacturing Edward Miller, President, NCMS
Sciences

1615 University-Industry Manufacturing H. Kent Bowen, Co-Director, Leaders for
Initiative: A University View Manufacturing Program, MIT

1700 Discussion and Final Comments Bill R. Appleton, Chair, SSSC

1715 ADJOURN

1730 Reception

BPA NEWS

Board on Physics and Astronomy • National Research Council • Washington, DC • 202-334-3520 • March 1991

Washington Gives Mixed Reviews to AAAS Report on Funding Crisis

Board on Physics and Astronomy member Leon Lederman led a discussion of the problems of funding for academic science at a recent symposium at the National Academy of Sciences that took place on January 7. The focus of the discussion was a report prepared under the auspices of the American Association for the Advancement of Science (of which Lederman is president).

The AAAS report, seeking to gauge the state of academic research, polled U.S. academic scientists. Lederman characterized the situation, on the basis of poll results, as worse than at any time in his 40-year career. He proposed, in an extrapolation of the effort to double the National Science Foundation budget that has been under discussion for some years, to double the entire annual federal expenditure for basic academic research.

Among the speakers invited to respond to this proposal was Sen. Al Gore (D-Tenn.). Sen. Gore offered the view that "What the public will support will depend on what they will ultimately get out of it." He stressed the need to demonstrate the economic payoff of basic research, expressing concern about the difficulty that we have in this country translating progress in basic research into profitable technology. He cited the perception that the results lead to products that enrich the standard of living in other countries.

There was general skepticism about a plea based on more of the same. D.

Allan Bromley, Science Advisor to the President, Frederick Bernthal, Acting Director of the National Science Foundation, and others poured cold water on the idea that scientists could find solutions to their problems by simply asking for increased funding. House Science, Space, and Technology Committee staff member David Goldston reminded the audience that "The hallmark of any interest group is to first ask for more money. Unless you address specific issues, like the difficulty of funding young scientists and the sorry state of science education, this report is going to be seen as self serving by people on the Hill."

Astronomy Survey Released on March 19

The report of the Astronomy and Astrophysics Survey Committee (AASC), *The Decade of Discovery in Astronomy and Astrophysics*, was released at a public forum on March 19, 1991 at the National Academy of Sciences in Washington. The report, prepared under the auspices of the BPA, assesses priorities for astronomical research in the 1990s.

Professor John Bahcall, AASC chair, proclaimed "The 1990s will be chock-full of astronomical discoveries. New instruments will reveal previously unimagined aspects of the universe and will lead to new questions about objects that we do not yet know exist. There is more in the universe than in any astronomer's notebook." Aware of the need to set priorities for the goals of the field when budgets are tight, the committee made hard choices among hundreds of attractive initiatives that will improve by as much as a factor of a million our ability to search for clues to the origin and evolution of planets, stars, and galaxies. In addition to establishing separate priorities for ground-based and space-based initiatives, and estimating their costs, the committee determined overall scientific priorities for astronomy and astrophysics in the decade of the 1990s.

As its highest-priority recommendation for ground-based research, the committee urged the National Science Foundation to bolster support for "the basic infrastructure of astronomy" by increasing the budgets for individual grants, augmenting the support for theoretical investigations, establishing computer networks and data archives, and providing for the maintenance and refurbishment of major ground-based facilities. Bahcall remarked that "No prudent businessman would run an enterprise with as little investment in infrastructure as has characterized recent federal support for astronomical facilities."

For space astronomy, the report stresses the need for more frequent, smaller missions while a few key large telescopes are developed.

The 200-page report, based on the formal participation of over 300 scientists and significant contributions from hundreds of other astronomers, outlines a balanced plan for research and proposes new educational initiatives that build on the thrill of astronomical discoveries to promote the study of science, mathematics, and engineering. Supported broadly by the National Science

See "Astronomy Survey" on Page 2

In this issue:

•AAAS report gets mixed reviews. Page 1

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•Neutron Scattering Science to be Assessed. Page 3

•Editorial: The Overselling of the University. Page 13

on Physics and Astronomy

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Johns Hopkins University

Dave Arnett
University of Arizona

Howard C. Berg
Harvard University

R. Stephen Berry
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William F. Brinkman
AT&T Bell Laboratories

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achusetts Institute of Technology

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ise spanning the various subfields of
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ard are supported by funds from the
nal Science Foundation, the
lment of Energy, the Department of
se, the National Aeronautics and
Administration, and private and other
s.

Astronomy Survey (from Page 1)

Foundation, the National Aeronautics and Space Administration, the U.S. Department of Energy, the U.S. Navy, and the Smithsonian Institution, the report draws from the work of 15 separate scientific panels that were established to advise the committee.

The report describes how in the coming decade astronomers will use telescopes in space, in aircraft, on the ground, and even underground to address fundamental questions concerning our place in the universe. Do planets orbit nearby stars? What triggers the formation of stars? How do life-giving elements such as carbon and oxygen form and disperse throughout the galaxy? Where can black holes be found, and do they power luminous galaxies and quasars? How and when did galaxies form? Will the universe continue to expand forever, or will it reverse its course and collapse on itself? These and other fundamental questions will be addressed by the four major equipment/instrumentation programs recommended by the committee for construction in the 1990s.

•The Space Infrared Telescope Facility (SIRTF), which would complete NASA's Great Observatory program, would be more than 1,000 times more sensitive than earth-based telescopes operating at infrared wavelengths, that is, at wavelengths between those of visible light and radio. SIRTF, equipped with an 0.9-m liquid-helium-cooled telescope, could locate newly forming stars and galaxies.

•An infrared-optimized 8-meter U.S. telescope operating on Mauna Kea, Hawaii, would provide a unique and powerful instrument for studying the origin, structure, and evolution of planets, stars, and galaxies. With superb angular resolution and high sensitivity, the telescope, which would be available to all qualified U.S. astronomers, would complement SIRTF across the limited range of wavelengths transmitted by the atmosphere.

•The Millimeter Array (MMA), an array of telescopes operating at millimeter wavelengths, would bring planet-forming regions around young stars as well as distant star-burst galaxies into clear view for the first time.

•An 8-meter optical telescope, operating from the Southern Hemisphere, would

give U.S. astronomers access to important objects in southern skies, including those found with orbiting telescopes.

Looking to Space for Answers

The committee pointed out that "the Great Observatories are large facilities that make possible 'small science' at institutions distributed across the country, since typically only a few researchers work on each observing project." The committee reexamined the justification for large-scale space astronomy programs, taking into account both the failure to meet specifications for the Hubble Space Telescope and NASA's record of successes in carrying out other complex missions at the frontiers of science and technology. The committee concluded that "large telescopes are required to answer some of the most fundamental questions in astronomy." However, the committee pointed out that smaller telescopes can be built and launched more quickly to answer specific questions, to respond to technological innovations, and to train future generations of scientists.

The committee made a number of recommendations for moderate-sized programs, including:

A three-phase enhancement of the ongoing Explorer program that allows NASA to fly modest-sized telescopes on a more rapid time scale than its large observatories; the construction of a 2.5-m telescope mounted in a Boeing 747 airplane (SOFIA); a mission to improve a thousand-fold the precision with which the positions of celestial bodies are known and thereby possibly detect the presence of "Jupiter-sized planets around hundreds of stars up to 500 light years away"; support for flying U.S. instruments on the spacecraft of other nations; and technological development activities to lay the groundwork for missions that will start in the next century.

Should the United States place telescopes on the moon? The committee determined that, if a lunar base is established under the proposed Space Exploration Initiative, a small telescope surveying the atmosphere-free skies of the moon would return important scientific results even in the early phases of the program. The committee advocated a "Learn as You Do"

tegy in which potential lunar instruments are first deployed on the ground, then in earth orbit, and finally placed on moon to achieve their ultimate performance, but with important scientific results obtained at each stage.

Arching the Skies from the Ground

The committee made a number of recommendations for moderate-sized programs around-based astronomy, including: Use techniques called **adaptive optics** and **interferometry** to greatly enhance the spatial resolution of astronomical images at optical and infrared wavelengths; additional optical telescopes to provide U.S. astronomers with state-of-the-art instrumentation; an innovative instrument called the **'s Eye telescope** to help determine the characteristics of the most energetic cosmic rays; a **Large Earth-Based Solar Telescope** to provide important information about the sun; improvements in the quality of spatial resolution of radio images with extension to the Very Large Array;

and technological development of improved detectors at optical, radio, and infrared wavelengths, and of instruments to detect neutrinos and dark matter.

Astronomy and Society

The committee recommended the establishment of a national Astronomy Fellowship program to select promising high school students for summer internships at major observatories, an increased educational role for the national observatories, and expanded summer programs for science teachers at astronomical institutions.

The committee stressed that asking questions about the universe not only challenges astronomers, but also "fascinates a broad national audience and inspires many young people to pursue careers in engineering, mathematics and science"

The committee's report, *The Decade of Discovery in Astronomy and Astrophysics* is available for \$24.95 (prepaid) plus shipping from the National Academy press at 2101 Constitution Avenue, Washington, DC 20418; telephone (202) 334-3313 or (800) 624-6242.

Neutron Scattering Science to be Assessed

At its February 27 meeting, the Solid State Sciences Committee heard a proposal for a study of neutron scattering science prepared by a group headed by SSSC member Paul Fleury. The proposal was prepared in response to a request from the Department of Energy for an assessment of the science that could be done on the proposed Advanced Neutron Source, one of the facilities recommended by the Seitz-Eastman study of major materials facilities.

The study would examine the opportunities and needs for neutron science in the United States in light of the proposal to construct an Advanced Neutron Source. Attention would be given to the overall size, composition, and needs of the broad and interdisciplinary scientific community expected to use the ANS and to their involvement in the planning, design, and

See "Neutron Scattering" on Page 12

Solid State Sciences Committee Holds 1991 Forum in Washington

The Solid State Sciences Committee (SSSC), working closely with the National Materials Advisory Board (NMAB), has completed a year-long dissemination effort following up the study *Materials Science Engineering for the 1990s*, released in September of 1989.

Shortly after the release of the report, President's Science Advisor expressed support for a series of regional meetings to be held throughout the United States to develop implementation strategies for the materials study, drawing on local government, university, and industry resources.

Regional meetings, of which four were held throughout the United States in 1990, provided a mechanism for grass-roots participation of the materials community in realizing the broad objectives of the study. In January of this year, the leaders of the regional efforts were convened in Washington at the invitation of the Office of Science and Technology Policy (OSTP), with the SSSC and NMAB acting as hosts, to develop an integrated report of the regional meeting process. That meeting was

successful in developing an overall report that identifies a number of thrusts for the national agenda in materials. William D. Phillips, Associate Director of OSTP for Technology and Industry, described the regional meeting process and the presentation of its results to federal agency leaders as "a precedent-setting step in providing grass-roots participation in the federal R&D policymaking process."

The 1991 SSSC Forum, held on February 27, was the capstone of the dissemination effort for the materials study. At the Forum, National Academy of Sciences President Frank Press introduced President Bush's Science Advisor and Director of OSTP D. Allan Bromley, who described the work of OSTP in developing national initiatives in critical technologies including computing, materials, and biotechnology. He expressed the hope that, with guidance from the materials study and the regional meetings process, a national initiative in materials could begin in 1993. He praised the efforts of the materials community in providing input to the formulation of the na-

tional materials initiative. A transcript of his remarks begins on Page 4.

Sen. Al Gore (D-Tenn) discussed the role of the Congress in taking the initiative to spur development of critical technologies. A transcript of his remarks begins on Page 4.

Bill R. Appleton, Chair of the SSSC, and Jim Williams, Chair of the NMAB, presented the results of the regional meetings. A panel discussion followed with participation of representatives of the regional meetings, OSTP, and the materials study. NMAB Chair Jim Williams led a session on consortia in materials science and engineering.

The Forum was followed by technical sessions organized by the Materials Research Society. Sponsoring societies included the American Ceramic Society, ASM International, the American Physical Society, the American Chemical Society, the American Vacuum Society, the Minerals, Metals and Materials Society, and the

See "Forum" on Page 12

resident's Science Advisor Addresses SSSC Forum

Speech by D. Allan Bromley
1991 Solid State Sciences Committee
Forum

Good morning ladies and gentlemen. It's always a pleasure to be here. It's always a pleasure to follow Sen. Gore. As you know, he is Chairman of the Subcommittee that holds confirmation hearings for all of us at OSTP and, although sometimes those hearings get a little heated, nonetheless, Senator Gore has for a very long time been a very strong and effective supporter of science and technology in this country. Certainly this is the case in the area we're discussing this morning, materials science and engineering, and I would like to really start out by expressing to our Chairman this morning, to Praveen Chaudhari, and to Vernon Flemings, my thanks for the superb job that they have been doing in pulling together this community. I think that, working together with them, we can, in fact, make a very substantial difference in materials science and engineering in the area that lies ahead.

From my point of view, there's little question that materials science and technology has become one of the most exciting, dynamic areas in modern science, modern technology. In a very real sense it seems to me that we have entered, for the first time, the era of tailored materials. By now, probably everyone has seen the famous IBM logo spelled out with individual xenon atoms, and it's worth remembering that that would have been considered flatly impossible even a few years ago, and it is a measure of the kind of progress that we're really making.

These new capabilities allow us to fabricate new solids, surfaces with properties that in the past we were only able to imagine, production of solid superlattices using molecular-beam epitaxy, now well established, and for the first time it's been possible to actually fabricate the quantum wells that used to occupy the first chapter of quantum mechanics textbooks, and actually measure what happens to an electron that finds itself in one of those wells. Diamond films have shown themselves capable of really remarkable performance in a wide

variety of applications, from machine tools to electronics. Ion-beam techniques of one sort or another are being used to produce corrosion and wear-resistant surfaces as well as catalytically active surfaces. And the work of our Chairman, for example, on using ion-beam treatment of prosthetic devices for use in joint replacement has made it possible for literally hundreds of thousands of people world wide to have joints that were not functioning as they should have functioned, replaced when the need arose rather than as in earlier times, when you either had to wait until you were seventy to have the joint replaced or you simply had to face up to the fact that you're going to have to have it replaced several times. That is simply no longer the case and we cannot forget what a tremendous impact materials science and our ability to manipulate surfaces and materials has had on fields all the way from the most applied technology through medicine to our understanding of some of the most fundamental concepts in physics.

But now, despite these developments, many of you have already heard me say that

Senator Al Gore Discusses Science, Technology, and Competitiveness

Keynote Address by Sen. Albert Gore
1991 Solid State Sciences Committee
Forum

Ladies and Gentleman, it's an honor to be with you here. I am Al Gore. I used to be the next President of the United States of America. I was asked recently whether I was going to run again. I responded that I was not really making any such plans right now, but I have made a strategic decision, and since this is one of the groups that have been able to speak to me, I thought I might announce it here. I've decided that if I run again I would run as an older candidate than I was last time.

I know that all of you, like me, have your thoughts and prayers directed at the area of the world called the Persian Gulf as our troops are now in a dangerous but triumphant phase of the conflict we've been engaged in for two months now. The news seems so good for us, but still we have much to occupy our concerns and I know that it's hard for any of us to shift away from that

with all of the news that's coming from the Gulf, but this meeting which you are opening is extremely important to the outcome of another sort of conflict. One which will also be won as the war in the Gulf has been won, by our ability as a nation to make intelligent use of new advances in science and technology.

Many factors have led to our success in the Gulf, but it is not entirely accidental that the real stars in the media have been the smart bombs and, incidentally, "What did the smart bomb say?" This is a dangerous joke. "Cogito, Ergo, Boom!" I hope there is no press out there this morning because it really is a horrible thing to talk about and one of the dangers really is that we develop a kind of Nintendo war way of thinking. There's been much comment about that. I think it's very appropriate.

But as I started to say, it's not an accident that the star of the public perception of this has been the smart bomb, and the Tomahawk Cruise Missile, and the incredible precision, and the material sciences that have contributed

to the stealth fighter and its ability to slip in on the first evening of the war and bomb the key targets, all of which has helped to completely minimize the loss of life for the soldiers we have sent over there. Four killed in action during this ground war phase, about which we were so justly apprehensive, because we made such good use of the new advances in the technologies that can be brought to bear on military problems.

In any event, I'm delighted to see the level of sustained attention you're giving to how our nation can make the best use of new advances in this incredibly exciting field of solid state sciences. I found out about this particular meeting because Oak Ridge National Lab's Bill Appleton, whom many of you know very well, asked me to consider doing it. Actually, he didn't simply ask me to consider doing it, he gave me to understand that the pride and dignity of all east Tennessee was at stake depending on whether I would

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it is my impression that materials science and engineering for a long time, for far too long, has been something of an orphan science here in Washington, and an orphan science in many ways in our universities. Because of its breadth of coverage, its breadth of application, your field doesn't fit comfortably in the traditional academic departments any more than it fits comfortably into the agencies here in Washington. And so it is important to recognize that materials science plays an important role in every one of the federal agencies all the way from the Department of Defense to the National Institutes of Health. The time has come when we have to focus attention on this field and, as has happened already with many of our foreign competitors, make an attempt to get some coherence in our approach so that we can take advantage of the leadership role that we still enjoy in many areas of science and technology that relate to materials.

The materials science and engineering survey report that I've mentioned earlier has really been a watershed document in this whole field. *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials*—it's an excellent title. It's an appropriate title. It's proven to be a landmark document in a number of ways. First of all, it has provided a focus that has in a very real sense unified this field in a way that wasn't present before. The identification of the critical areas of synthesis and processing has been very important in terms of prioritizing our activities and in terms of pulling together your community behind those priorities. One of the things that is very obvious is that this area of synthesis and processing is one where we have a significant gap in our capability. I use this example frequently, because, while we still retain international leadership in the development of new materials, ceramics, composites, you name it, and while we still retain international leadership in our ability to characterize an adequate sample of materials (we can tell you about its structure, its wear and corrosion resistance, its mechanical characteristics, its electrical characteristics, and so on), all too frequently, we find that in order to get an adequate sample of the new materials that we have developed so that we can characterize it we go to Japan, where we have what we would term

technicians or supertechnicians who have great prestige, have appropriate reward structures, and who have spent their careers learning to do a very limited number of things, but to do them superbly well. And I will come back to this question of our need for similar people in the United States in just a few moments.

Now, I would have to say at this point that the federal government has just begun to respond to the shortcomings in our national

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activities that are identified in the MSE Survey Report. In the fiscal year '92 budget that President Bush just submitted to the Congress you will all have noted, for example, that we have put within the National Science Foundation a new \$84 million initiative that emphasizes the whole question of synthesis and processing. The initiative is intended to begin a process of strengthening the competitive position of the United States in developing the next generation of materials and new methods for processing those materials. And in this first year of the program it will extend across three directorates of the National Science Foundation, focusing on electronic and photonic materials and on biomaterials.

There are several other special initiatives in the '92 budget that are going to have an impact on materials science and engineering. One of those is the initiative that was being discussed when I arrived by Sen. Gore on high-performance computing and communications. This was one of the three special initiatives, Presidential initiatives, in the '92 budget that was constructed on an interagency basis under the aegis of the Federal Coordinating Council for Science, Engineering, and Technology—the group that has the unfortunate acronym FCCSET. This group has been reorganized in this past year and its members now comprise the cabinet secretaries and the heads of the independent agencies responsible for science and technology in the federal government,

and this is a very important change, because it means now that decisions made within FCCSET remain made throughout the entire budget process and are not disowned by higher authorities somewhere in the later stages of budget crunch.

As a reflection of the fact that we were able to integrate the programs of the various agencies, 8 in fact, in high-performance computing, we were able to convince not only the Office of Management and Budget, but also the President, to request a 30 percent increase in the funding of this activity, in a year when we have a very stringent budget.

Our goals here are straightforward. We want to double the funding from the federal government in this area over the next four years. A lot of that funding will go to materials science and engineering, because that plays an absolutely critical role in this field and we want to increase by factors between 100 and 1000 the speed, the memory capacity, and the information transfer rates that are available not only in the research environment but in the network Sen. Gore was talking about.

Another new initiative that is going to affect materials science and technology, and again one that was developed under the FCCSET, is that on education and human resources. For the first time in the history of the federal government we have been able to put together an inventory of what the federal government does in science and mathematics education. This was a committee activity led by the Secretary of Energy, the Deputy Secretary of Education, and the Director of the Education Directorate of the NSF, who were the chairman and the co-vice chairmen of this activity, respectively. Again, we were able to put together a coherent national program, and the budget calls for a 13 percent increase overall and a 28 percent increase in the precollege area, which has been identified by the committee as the area of greatest need, and within that area the improvement of teacher competence is the specific area that will receive the lion's share of this increased funding.

I think that in general we have to recognize that the goals that have been established by the President and the governors, particularly in science and mathematics, are very ambitious goals. The specific goal, which I think you will all agree is something of a

stretch goal, is one that says that by the year 2000 American students in science and mathematics will be second to none in the world. Given the distance behind scratch from which we are starting this is a very ambitious goal, but, nonetheless, is one that I believe that we can meet.

There are other areas of importance that I should emphasize. I mentioned the question of the technical people, the people who take care of our production lines, the people who operate our high-technology systems, and let me emphasize, the people who have been operating our high-technology military systems that have served us so well in recent days and weeks in Desert Storm. We in this country, unfortunately, have not treated that particular group (it's sort of a forgotten middle in the educational system) particularly well. The assumption has been frequently made, and openly made, that such persons either fell or were kicked off the academic ladder prematurely. If they were really all that good they would have gone on to higher degrees. And we have forgotten how much we depend on people who may not be at the top professional level in a particular area, but nonetheless, have developed very high-level personal skills. I believe that we have to recognize the need to train many more people at that level, to reward them more effectively, and to give them the recognition that is their due in this country or we will not succeed as a competitive player in the international marketplace. It is important to recognize, for example, that only 2.4 percent of federal support in this country goes to two-year colleges, where most of these people, in fact, receive their training.

And let me also comment here on a somewhat related issue, it's one that you all have heard about, and that is the plight, particularly of the young person in the academic structure in terms of receiving adequate funding for research activities, the plight of the individual investigator, and of the small groups of investigators. It is sometimes cast as big science versus little science and that is a specious distinction because at the great many large facilities, particularly in your field at the National Light Source, for example, most of the work is done by single professors, with a post-doc and a few graduate students, and so there is no sharp dividing line between big science and little science. That argument

is certainly counterproductive.

Even more counterproductive, however, in my view, is the discussion that has been going on in the country in the last few months, in particular, but also over the last year, that focuses on the fact that young people are not receiving the funding, nor are older people receiving the funding, that they would like to receive in support of their research activities. I agree that this is true and in the '92 budget we have made determined efforts both in the National Science Foundation and in the National Institutes of Health that support more than 75 percent of academic research in this country to improve this situation and to improve it substantially.

But at the same time, I would plead with you and with all the members of the scientific community, that in making this case, for heaven's sake, focus on the fact that there are untold opportunities out there that if followed up could have tremendous payback for the American taxpayer, for our entire system. Focus on the fact that we're not, because of a shortage of funding, following up on these opportunities, and these possible great benefits to our society, rather than casting the argument in a form that is interpreted by the great many of the people in the Congress as an entitlement for scientists and engineers, because that one is very counterproductive.

And I think that you must remember that although the budget we've sent up this year is a very good one for science and technology, it is a request to the Congress and to the U.S. taxpayer, it is a proposal, and it is the Congress that, in fact, appropriates and makes these things really happen. Your help is going to be needed, this year more than it has ever been needed before, to convince the Congress that what we've asked of it is realistic, is a reasonable investment for the taxpayer to make, particularly at a time when we are really playing a zero-sum game in constant dollars. We have had to remove funding from some very attractive programs with strong constituencies to get the additional funding to apply to science and technology. So we need your help in making that case with the Congress.

But, I assure you that any argument that says "because I've defined myself to be a scientist or engineer, I have some sort of

right to federal funding" will not fly well in the Congress. On the other hand, I'm happy to be able to tell you that the Congress in general shares our belief that we as a nation are underinvesting seriously in science and technology and what they need are some compelling arguments about the opportunities that will not be followed up. The marvelous new avenues, new frontiers, new areas, where we have the talent and we are simply unable to unleash it because we cannot provide the support for that talent. I would urge you to really consider that as a serious charge in the year ahead.

Now let me turn back to the MSE Survey Report. Excellent as that report is, like all other reports, unless there is an effective follow-up, it can disappear without a ripple. Happily, this will not happen with the MSE Report. As you know, the publication of the report was followed by a series of four regional meetings held throughout the nation. All of them were held outside of Washington in an effort to involve a broader range of persons in the discussion and to recognize two facts. One, it is widely recognized that Washington is the only place on the planet where sound travels faster than light and, second, when viewed dispassionately, Washington is in fact 69.2 square miles surrounded by reality. When I heard about these meetings, I called Frank Press and urged him that these meetings should be used insofar as possible to identify initiatives that would be appropriate at the national level, even though the regional characteristic of the meetings was important. In my view, that process has been extremely successful, and I think you will agree with that when you receive the summary report of the regional meetings [available from the Materials Research Society] that I believe is scheduled for presentation later this morning. This report establishes a strategic planning process for materials science and engineering that involves industry, universities, and the federal government. It is organized around areas of national need, information and communication technologies, transportation, energy, health, the environment, and future materials.

And it contains some very important recommendations about ways to increase the cooperation among the three players that I just mentioned. In the past we have talked a great deal about partnerships, but in

fact have seen very little of it. I believe that with the initiative we have underway here in materials science and engineering we have the possibility of showing the way toward a shortening of the innovation cycle and leveraging of scarce resources, to a very important end.

Now in parallel with this private sector activity, the federal government has also been moving forward in its planning for materials science. Most important, the FCCSET mechanism is now tooling-up for an intensive crosscut of agency activity. It's the kind of planning that has led to the presidential initiatives in this year's budget, in education and human resources, high-performance computing, global change, and although we have not yet run this through the full FCCSET committee for its blessing and cleaned up all the detailed negotiations with the Office of Management and Budget, I'm very confident that in fact next year materials science and technology will be one of the issues that will receive this special consideration and coordination. And if this proceeds, as I believe it will, it will be carried out in major part by a materials steering group operating under the subcommittee on materials in FCCSET's committee on industry and technology.

The kind of program that we would have in mind is one that would build very heavily on the work that has been done in these regional meetings and here in the Academy in preparation of the MSE Report in the first place. A preliminary analysis, carried out in this past year, to get a feeling for the baseline involved, shows that in fiscal year 1990 the federal government spent about \$1.4 billion for materials R&D, with about 85 percent of that being spent on a category that is roughly characterized as advanced materials. In that same fiscal year, about \$185 million was spent on research and development for superconducting materials. These are the kinds of numbers that will be used for the foundation of the study on the integrated request that I expect we will be able to prepare on behalf of materials science next year.

In addition to this whole question of direct federal funding there are many other issues that could affect materials science and engineering. These include the standardization of new materials, the evaluation of materials characteristics,

management of databases containing materials information, and perhaps the most exciting of all is the possibility of beginning to use a whole new generation of computer power to do theoretical work in materials science that up to now has simply been impossible to carry this whole question of the design of materials several steps farther than has been possible in the past.

And of course there are a whole series of other generic issues relevant to materials. These include the matter of technology transfer and support for generic precompetitive research and development, which is an area which this administration believes is one that fits very appropriately within its responsibility. There are new environmental considerations, the environmental regulations, and new tax policies.

Many of these issues are now being taken up by an organization closely related to my office. In fact, it is a new organization which I now chair, and that is the National Critical Materials Council. The President asked me to chair the Council last year and it has two other members, W. Henson Moore, who's the Deputy Secretary of Energy, and TS Ary, who is director of the Bureau of Mines.

By mandate, this council has special responsibility from the Congress for three areas of importance to you, namely advanced materials, critical materials, and superconducting materials. More broadly, what we are doing is to work within the council to integrate the various activities going on within OSTP and within FCCSET to strengthen the nation's overall materials effort. We're in the process of producing the advanced materials plan that is required by the Congress, that will be delivered later this year, and it will detail many of the policy and technical steps being taken throughout the federal government to bring greater cohesion and coherence to materials science and engineering.

It will draw also on a number of other activities within my office. Many of you here have seen the report we issued this last September entitled *U.S. Technology Policy*. This report should not be viewed as the last word on anything. It represents instead a first attempt on our part to pull together a statement on which all of us in the administration could agree on what our technology policy was. The fact that we had

never articulated such a policy in the past was a very real impediment to a lot of the things that we wanted to do in the area of technology and I think that we have begun a process that can have some important consequences.

We are just about to release to the President, and thirty days later to the Congress, the report of our National Critical Technologies Panel. It has identified a number of technologies that it believes are critical to our future. I used to think that economic competitiveness and national security could be considered as separate areas. That is no longer the case. It is certainly true that in the future economic strength maybe a greater determinant of security than military strength, so the two must be considered together.

With this panel report behind us we are also in the process of setting up out of my office the new national Critical Technologies Institute and it has as one of its major functions the followup on this Critical Technologies Report. For the first time, it will give us in OSTP the resources and personnel to do the kind of strategic planning in the long-term that this field deserves. And it will allow us also to bring together the kind of partnerships I've discussed involving the universities, the national laboratories, and the federal government.

And finally, I would mention the President's Council of Advisors on Science and Technology. This is the private sector group that now meets on a monthly basis with the President and provides input directly to him. The chemistry within that group and between that group and the President has developed over the past year and is excellent at this point, so that private sector input goes into the very highest level of decision making in this administration. And that fills what would otherwise be an important gap in FCCSET activity, because by law FCCSET members and the members of all FCCSET committees must be federal employees. With PCAST working with FCCSET we can in fact calibrate our activities against private sector opinion. For example, next week the FCCSET and the PCAST groups will be meeting jointly to get to know one another better and since I have the privilege of chairing both groups, I also have the responsibility of making sure that the appropriate information transfer takes

place between the two.

And so, just let me just simply conclude by saying that, as I hope I've convinced you, we have identified your field as a very important one from the national point of view, one deserving the kind of integration and coherence that we have been able to bring to some other critical areas and I look forward very much to working with you as we move ahead. The fact that you have done so much of the spade work already makes our task for the coming year just that much easier and hopefully will result in our turning out just that much better a product. I think I can guarantee you that through these efforts materials science and engineering will end up with a much higher profile within the federal government than it has had in the past. I believe that such emphasis is long overdue. Benjamin Franklin once said that "the greatest inventions are those inquiries which tend to increase the power of man over matter," and I would only say that that observation is vastly truer today than when Franklin first made it.

So I commend you for what you have done already, I look forward to working with you as we move ahead together, and I believe we have an exciting time ahead. There are tremendous opportunities out there and a great adventure, and all of us are fortunate to have the possibility of playing a role in it.

Questions from the Forum

Q: Joel DuBow, University of Utah. In addition to the entitlements argument that you mentioned was a sensitive issue with a number of representatives, there is another argument based upon the fact that U.S. science and technology is a commercial asset and why should our government fund it when everybody else in other governments, particularly the Japanese, have direct access to it. Is the executive branch thinking about addressing that problem?

A: Yes, we have thought about that problem and I think I can tell you, without any hesitation at all, what the bottom line is. The bottom line is that we believe very strongly that in basic science and in basic technology we gain much more by maintaining a completely open system than we could possibly through trying to build

barriers. There's no question that other nations are building on our basic research, our basic technology, but it is important to remember that up until World War II that is precisely what we did. We drew on the basic activities in Europe. I think what we have to do is to be much more sharply focused than we've been in the past. There's no point in trying to protect a whole broad range of technologies when we know perfectly well that there are ways in which anyone who's really interested can gain access to those technologies.

What we have to do is focus on the particular technologies, and in particular on the know-how we have in systems integration, the integration of technologies that really is of importance to us, and protect those things as firmly as we possibly can. We have to be much more vigorous in enforcing intellectual property rights than we've been in the past. I think it's worth emphasizing that two of three sectors of American industry that have been most successful in the international marketplace, the pharmaceutical industry and the chemical industry, not accidentally happen to be those that have by far the strongest IPR protection and I think there is a message there.

But, in general, our goal is not to try to protect our research and our technology, but rather to try to identify much earlier than we have in the past what we want to get in return for our technology. All too frequently in the past in negotiations on an international basis we have tended to send what can only be characterized as amateurs to represent the United States and we have negotiated with real professionals who knew exactly what they wanted to get, knew exactly what they were prepared to give, and not surprisingly, we have sometimes come out of those negotiations less well than we might have. So, it is my intent that we are not going to let that happen again.

Q: How much has industrial investment into research gone down over the years, and their reluctant to invest into it. What is the federal government going to do? Or is there any plan to encourage or reverse the trend?

A: I think there are several answers to that. First of all, I think you have all heard President Bush state quite clearly on a number of occasions that this administration

is accepting a very real responsibility to work with industry to develop, on a collaborative basis with the federal government and agencies involved, the generic technologies up through the precompetitive stage and that's an important difference from past practice. But much more important, I think, in the long run, is a request we would make to the various industrial sectors to focus on some strategic goals, some particular actions that they would wish the federal government to take that might be of particular benefit to them. I'll give you a specific example. The semiconductor industry has been in a difficult competitive situation. We not long ago had a meeting with a number of the major industrial leaders in that field with Darman, Sununu, Boskin, and myself, at about a four-and-a-half hour meeting which was educational in the best possible sense on both sides. We asked the group to do some homework, to identify what would be the most important thing that we in the federal government could do and, of course, among the spectrum of things was the whole question of patent, long-term capital, the adjustment of capital gains taxes, the research and experimentation tax credit, the whole thing. What emerged from the study, however, was that the single change that would do, by far, the greatest good for the semiconductor industry was a very simple one. And that is allowing them to amortize their production line equipment on a three-year instead of a five-year basis, because that in today's world is the effective lifetime of that equipment. And that's something that we can do within the administration. It doesn't even require legislative change. And so we are encouraging other groups with whom we've talked not to simply come and tell us, "We're in trouble." When we say, "OK, what do you want?", "Money!" is the all-too-frequent answer. Under today's conditions, that's really not something to which we can respond effectively. So, I urge you to do the strategic thinking first, then come to see us and tell us what would be most effective for us to do. We're prepared to take any of those suggestions on their merits and to work with you.

Q: In making the case for basic science funding, also new investigators, universities, and societies who should provide this

ument to Congress?

All of the above. The important thing to remember, though, and I'm very serious about this, is that we have a terrible reputation in the Congress, and by this I mean by the scientific community, technical community, because we have tended never to show up in the halls of Congress unless we wanted something personally. That is not going to be very effective.

What we need is some statesmanship. We need people like you in the audience this morning to talk to your representatives and our senators and tell them about your concern for the strength of our science and technology base and for the fact that we are derinvesting in that base as an investment in our national future. That kind of input. First of all, it would surprise them, because they will be sitting on the edge of their chair waiting for the other shoe to drop while you tell them what you personally really came for, and if you leave without saying that they will really remember you.

I think the societies have a major role to

play, as well, and we're trying to work with them. A number of the societies, the APS, the ACS, FASEB, a number of the professional societies have already made major progress in organizing the kind of grassroots communication channels that are ones that you can't simply depend on to build and activate when you feel there's a crisis. They have to be cultivated over a period of time so that your representative, your senator, trusts you as a source of information, knows who you are, and is prepared to listen to you. So we all have a role to play to the extent that you can convince your friendly industrialist to make some statements of this kind on your behalf. They carry particular weight, because for obvious reasons, everyone in Congress is used to having people request funds for their own constituency. If you can have someone who is viewed as being a little outside that constituency speak on your behalf, they speak with greater credibility.

Q: Paul Horn, IBM. As you know, as part of the budget reconciliation act, DOE has

been asked to review the effectiveness of users' fees for basic research at the DOE major research facilities. Have you taken a position on those users' fees and what is it?

A: I've not yet had an opportunity to take a formal position on it, but I'll tell you right now what my position is on it and that is, I think it is a mistake. We have over the years had a remarkably open system where the access to our major facilities was determined not on the ability to pay, but rather on the quality of science that was being proposed. I would very much hope that we can retain that as a basic principle. I have held discussions recently with some of my colleagues in the senior administration in Europe and in Japan and we've agreed that, to the extent that we can influence these matters, we will try to keep them as open as possible, because it again goes back to my feeling that in the long run we have benefitted from the openness that we have prided ourselves on in the past and I am convinced that we will continue to benefit from that in the future.

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now the flag at this conference. But I accepted your invitation, even granting my respect for Bill and my affection for the Oak Ridge National Lab, because I do understand how important the field of solid state sciences is for the future of the United States.

We have built our industrial civilization exploiting the properties of matter. If the scientific revolution had a beginning, it wasn't really with the discovery by Ptolemy and Galileo that the earth moved and was not the center of the universe. It probably began on November 10th, 19, when the then 23-year-old Randa scartes had a startling vision on the banks of the Danube river in Neuburg, Germany—a vision of matter whirling in constant motion according to mathematical laws which it is possible for the human intellect to discern and then apply. Since that time, the scientific revolution, during the last 372 years, has been characterized by an increasingly frenetic and relentless search for the information which explains how that matter moves, what makes up its constituent parts, how it might be manipulated for our

advantage, and how we might work together to further the entire process.

Increasingly, our ability to progress, however, depends upon discovering and learning how to manipulate properties of matter that are not entirely evident to the senses and whose very existence in nature is difficult to establish with certainty. The age of serendipity, of trial and error and fortunate discovery, is giving way to the age of massive, organized search. We require materials now with transcendent characteristics that can only be obtained by bringing to bear the most advanced disciplines in mathematics and computational science, in physics, and in chemistry. The creation of new materials with tailor-made qualities demands, as well, new manufacturing techniques for securing these materials in practical quantities and fabricating them into useful forms. These capabilities in turn are the foundations for the new products and the new industries of the next century.

Every advanced country realizes that solid state sciences represents an important front in the battle in competitiveness in the newly emerging global economy. Global well-being, taken as a whole, will reflect the progress made in your field, and we

often stop to realize that we are a global civilization with global well-being which is advanced by progress on the part of any scientist in any nation.

But I am here as well because I know that our nation's well-being as distinguished from that of our friends and competitors will be strongly influenced by whether the scientists and engineers of this country can remain at the forefront of their disciplines. We have one foot in two worlds. Look toward the future and imagine a time when it may not matter so much where the struggles are made or where they are applied.

But we also have a foot firmly planted in the present, in this world, which is still characterized by national competition featuring, among other things, unique sets of national values, and we live in a country with a set of values we deem to be especially important not only for us, but this world civilization toward which we look. It can be, by no means, taken for granted that the advances important to this country's future will occur in this country.

In the past we took American leadership in pure and applied sciences and in engineering as a given. We developed our own mythology that superior performance in these fields

was almost an ingrained part of our national character. Certainly we believed that this superiority, at the least, was the result of a unique and unduplicatable combination involving the American sense of enterprise and pioneering adventure together with the American natural endowment.

We also assumed that our particular approach to free enterprise was a further guarantee of assured technical superiority in the factory and then in the market place.

Other nations, however, witnessed our success and knew unless they made concerted efforts involving the massed energy of their entire societies, it would not be possible for them to emerge from behind our shadow. We have now seen how countries with an extremely poor natural endowment have converted human capital into extraordinary wealth, and while they have advanced we have receded not merely in relative but sometimes in absolute terms. Today there are many areas of advanced applied science and engineering, and certainly manufacturing, where we have either lost our lead or stand in jeopardy, given the continuation of present trends, of losing it in the near future.

Earlier this week in another speech I tried to draw my audience's attention to the alarming decline of American educational attainments in mathematics and the sciences, an issue quite familiar to you here, to the National Research Council and the National Academy, as well, both of which have addressed this problem in great detail. We face a shortage of trained people in the 1990s because we have failed to attract enough of our best young people in these fields. At a much more fundamental and more disturbing level, national performance scores in the mathematics and sciences show a general long-term decline at every level of our educational system.

But let me bring the discussion close to home. In the solid state sciences, those of you who are working on superconductivity, for example, do not need me to remind you how tough the competition is from abroad and how much in danger we are of having others exploit new developments in this field by bringing products to the market based upon it before we do. Those of you with an interest in ceramics know that if not now, then soon, we will have to look abroad to find the most advanced science in this field, the most advanced developments, and

the most advanced applications. And those of you who are concerned with semiconductors probably know better than anyone else how steep the odds are now getting.

Some recent advances here have been evident, but if I have to pick one field upon whose future the destiny of our country rides, it would be semiconductors. This global civilization, which I referred to earlier, is now emerging and is based on shared knowledge in the form of digital code. Binary code is now the *lingua franca* of global civilization. Those nations best able to deal with knowledge in this form will be the nations most competitive in the balance of this century and the next. Our ability to process data, whether in the form of complex equations, masses of statistics, or cultural expression, will determine how well we succeed in any comparison with other nations.

Increasingly, all human knowledge is digitized. Our ability to handle it depends on computers and our computerized culture at once depends upon continual improvement in semiconductors and stimulates those improvements. Our ability to remain a

Democracy is a form of massive parallelism.

factor in world semiconductor manufacturing is at risk and riding on the fate of that industry and, in turn, is the fate of the U.S. computer industry, which itself is under siege from every direction. Riding upon the fate of our computer industry is our standing in the next century. Ask those who are here from Sematech to talk about what they see on the horizon.

Of course the solid state sciences is not the only field where American leadership is on the line. Far from it. An overview of the state of American science shows that it is powerfully challenged in virtually every direction. Under such circumstances it would be wise to reexamine our methods and perhaps we will have to be doing some soul searching, as well.

Our approach to the free market system based upon the premise that wide-open competition is always best, that benign neglect is superior to regulation, that government is the enemy of quality. . . well, that system has been taking some hard knocks from other approaches to the free

market and the characteristics of these other approaches involve, among other things, a belief in a greater degree of orchestration of resources in very long-term planning...in an intimate fusion of industry, finance, and government, to spread risk and focus effort. We cannot and should not abandon what reflects our fundamental character as a people, but neither can we ignore the successes enjoyed by systems whose approach to the free market is rather different from our own. If we cannot mimic them, and we should not, then we can certainly find ways to adapt what is unique about our approach to the new realities we must now recognize. In my opinion the most important instrument in our society for facilitating our ability as a people to work together on priorities of our own choosing is government.

That of course brings us to one of the great philosophical and political boundaries in our society. We are often paralyzed by the opposed and often equal forces representing, on the one side, those who believe in government intervention and, on the other side, those who vigorously resist it. We squabble about something called industrial policy and lose track in the intensity of our debate of how rapidly we are being overtaken by countries that pick their goals and plan their tactics. It seems to me time for us to put ideology aside and join in a search for practical ways to improve the nation's performance in science and engineering and manufacturing. Sematech is an example of what can be done.

Another example, and one upon which I've been working for more than a dozen years, is for a federal government effort to push the state of the art in high-performance computing and create a nationwide high-capacity fiberoptic network. Scientists in solid state sciences, like your colleagues in other fields, now turn increasingly to the use of high-performance computing because it has opened up a third branch of knowledge creation.

One of my rules of thumb is that when there are two items on an important list, and a third is added, that's a big deal. We've had inductive reasoning, and deductive reasoning for quite a long time. Computational science now joins that list as a third basic form of knowledge creation.

But, in order to use the most advanced machines of today you almost have to be in

the same building with it. It is unfortunately true that many teams of scientists and researchers who wish to share latest results of their ongoing work with teams widely distant from them have to physically download their models and programs into a storage medium, and then take them with their physical bodies onto an airplane and travel to another location where they upload the model or program into the advanced computer of the team they're visiting, and then have a conversation about it.

How different it would be if scientists and engineers using supercomputers could share in real time in the work of a true collaborator without going through the impractical steps now required to collaborate with computational science on supercomputers. We're used to thinking about infrastructure in the United States in terms of transportation, water lines, and sewer lines. In the last century we found our ability to compete successfully depended in part on whether or not we had deep water ports, railroads linking our major cities, highways, and then airport facilities. But, transportation, and transportation advantages, now have less leverage over the future than a nation's ability to deal swiftly and skillfully with digitized knowledge and binary code. We need to change the definition of infrastructure and create a nation-wide network of information superhighways.

I believe there are other areas where government can provide the seed money to do things of basic importance for our nation's future. There are basic investments that government must make in your field, for example, an advanced neutron source is absolutely essential. The nation needs to back demonstrations of certain kinds of promising new technologies, again in your field, a single-stage-to-orbit aircraft whose future is, unfortunately, in ~~such~~ doubt can be an extremely powerful focus for new materials and fabrication technologies.

Government planning and investment would be needed in order to help redirect the mission of the national laboratory system, so as to make it more the contributing partner than it is now to the stream of American science and engineering for civilian purposes. Government support for high-precision machining initiatives designed to transfer technology developed for the military to the civilian sector is another area where

the payoff can be high. And above all, government stimulus is needed to help find and implement creative programs and incentives to turn around the decline in the performance of our educational system in mathematics and science.

In conclusion, the war in which we are engaged now, in which we are completing in Kuwait, does remind us graphically that our military security rests upon scientific and industrial skills. So too does long-term strength of the American civilian economy, and with it the moral and political health of our country and our country's ability to continue sustaining a world order based on the free commerce of goods, of peoples, and of ideas.

Questions from the Forum

Q: Bill Holton, Semiconductor Research Corporation. I dare say that everyone in this room and in the scientific community understands and empathizes with the points you made. How would you propose to educate the nonscientific community so that more rapid action can happen?

A: I think that task can be performed in part by a successful effort to redirect the attention and effort in our schools to math and science and engineering. I think it has to start at the grassroots level. I think we need to give a great deal of attention to attracting the best teachers into those fields. Teaching a good appreciation of mathematics and science to the future electorate is fundamental to maintaining an intelligent democratic dialog in this country. This is a problem that can't be adequately addressed in a few short remarks. Many committees and commissions have spent a lot of time, some of them have come up with excellent agendas for addressing that problem. I will tell you that in the governmental community that's begun to sink in. Some steps have already been taken, we're beginning to see some results, but much more needs to be done and I confess not to know the full answer to your question, but I'm comforted by the fact that there is a full agenda of answers that we are already working on.

Q: Ron Egginton, British Embassy. Could you briefly review where you stand with your end-run proposals of fiberoptics and what you hope to achieve this year?

A: The high-capacity fiberoptic network has a better chance than ever of being adopted this year. Last year we began the funding for it. The legislation authorizing all the detailed measures necessary passed the Senate, but passed in a different form at the House of Representatives and in the final days of the session could not be resolved. But, there was a general and shared commitment in both the Senate and the House to pass it early this year, and in fact, the principal House sponsor, who agreed to introduce it over there this year, is the new chairman of the House Science and Technology Committee, Congressman George Brown, a long-time friend, with a sudden increase in his ability and power to get things done. Many of you know what a friend to science he has been over the years.

There is one other change that has taken place, and I'm glad to be able to say this right after Dr. Bromley has arrived for his remarks in just a few minutes. Allan Bromley has been doing a superb job in his role in the White House. In this particular instance he has this year succeeded where he had not succeeded last year because he hadn't had enough time to get it done. But, this year he has succeeded in persuading the President to endorse the idea of a fiberoptic network. The money is in the budget with the money appropriated by Congress last year, the work that began will now be continued at an accelerated pace. So this is going to happen. Moreover, three private companies, IBM, MCI, and Merit, have, as some of you know, already established a nonprofit corporation for the express purpose of quickly expanding the reach of the national backbone network as rapidly as it can be established. So, legislation will pass this year. The work that has started will continue, and this will be a reality.

Q: Renee Ford, Materials and Processing Report. With the possible exception of the aircraft industry, it is becoming less likely that military technology is going to have important spinoffs in the commercial sector. What effort is being made to develop an agency similar to DARPA for funneling some of the funds that are now going purely to military research for research that will benefit the commercial sector in the long run, which I think is very important for the future of this country?

A: Well I agree with you and I support the idea of a civilian DARPA. We used to have a civilian DARPA in DARPA, but unfortunately he was fired. Not everyone is willing on that one, I think. I do think that makes sense and I read from your excellent report your first conclusion that what we need is "goal oriented planning and implementation, a strategic goal oriented planning process, intimately involving participants from," and here I'm contracting a little bit, "industry, universities, and government laboratories in the selection and implementation of new initiatives." That makes a lot of sense. I think we should do it. Our strength has been our understanding that the greatest resource available to humankind is the unused creativity and manpower of the individual citizen. Our birth as a nation rested on the realization of that truth in the political realm. The evolutionary idea that the average citizen had sufficient creativity to become the best guide for the nation's destiny was a startling new departure in the world.

To take a scientific example, why is it that massive parallelism in advanced computing is being recognized by so many as the probably superior route for future development in computing? It rests on the same theoretical principle. When you have a field of information in a computer memory, at some point it becomes fundamentally inefficient to have a central processor, to send a task way out into a memory field and get the bits, bring them back, and process them, and then take the results back out. The process capacity when spread throughout the memory field allows the illumination of these steps and it works a lot better.

Democracy is a form of massive parallelism. We process political information in the minds and hearts of individuals. Capitalism has just routed Communism in the philosophical wars of the last half century, because of its exploitation of the same principle. Capitalism is a means of massive parallelism in the calculation of all the information necessary to establish efficient formulas for supply and demand. Communism has collapsed philosophically because it relied on central processing of economic information. It doesn't work.

So we instinctively understand why we should rely on the widely disparate creativity of individuals and we resist instinctively a reliance on central processing, or statism,

or government planning. But, ladies and gentlemen, a massive parallel supercomputer involves more than just distributed processing capacity. It involves the foresight, and planning and software, and algorithms, necessary to coordinate the uses to which that capacity is put.

Similarly, democracy is not pure democracy, but representative democracy and has an executive function, as well. We have to realize that fundamentally what the Japanese, and now others applying their model, have accomplished is that they have found a way to tap into the creative energy that can come from distributing the ability to participate and yet they have given a little more thought to how they can coordinate the collective output of that process. We don't want to mimic them, but we have to find a way consistent with our values and traditions to come up with a better coordinating mechanism for setting priorities, for spreading risk, and for focusing effort on those things that we determine through dialogue are the most important tasks to address.

Whether that turns out to be a civilian DARPA, I think that has some role to play, but it has to involve more, as well. It has to involve a different sort of dialogue between scientists and politicians and it has to involve a greater level of confidence on the part of politicians that we as a country can set priorities and go about pursuing them in an intelligent and sustained way.

Forum (from Page 3)

Federation of Materials Societies. The MRS Forum included talks on industrial competitiveness and consortia, high T_c superconducting films for electronic applications, and the science behind semiconductor processing.

The SSSC Forum was supported by the National Science Foundation, the Department of Energy, and the Office of Naval Research, and the Air Force Office of Scientific Research. Proceedings will be distributed to registrants in the Forum and will also be available from the Board on Physics and Astronomy at the headline address. The report of the regional meetings has been published by the Materials Research Society and is available from the MRS Office of Public Affairs at 2000 Florida Avenue, NW, Washington, DC 20009.

Neutron Scattering (from Page 3)

utilization of both the source and its associated instrumentation.

The Solid State Sciences Committee has identified a number of opportunities and concerns for neutron science in the United States in view of the scientific and technological advances since the comprehensive studies of the early 1980's, the changes in the worldwide array of sources and instrumental capabilities in the field, and the trends in the U.S. competitive position. These opportunities are outlined in the proposal with the expectation that they will serve as a point of departure for a panel to conduct the proposed study.

The proposed Advanced Neutron Source was given high priority in a number of earlier studies addressing major DOE facilities needed to ensure U.S. leadership in materials and energy-related research. Since the completion of these studies, the economic impact of technologies based on such research has grown even faster than projected. But relative to other nations, the U.S. participation in these technologies has diminished over the same period.

The size, scope, and nature of the neutron-scattering user community has changed significantly since the early 1980's. Physics and chemistry users have grown more in sophistication than in numbers, but continue to represent the major scientific driving forces. Polymer and materials science and biology have grown dramatically in the utilization of neutrons. Besides the evolution in the disciplinary makeup of the user community, there is potential for significantly increased participation by users from industry. Broader use of neutrons by industry for both characterization and modification of materials could well contribute to U.S. industrial competitiveness.

Given the 10 to 15-year leadtime required before ANS operation could begin and the 30-year life of the new source, the proposed study could influence substantially this country's facility policy well into the next century.

On the basis of these considerations, the SSSC decided to recommend to the BPA that a formal study be undertaken. The matter will be taken up at the April 28 meeting of the Board.

The Editorial Page

The Overselling of the University

by Lester C. Krogh

The ivy-covered walls are growing a different kind of green these days. Increasingly, American universities are selling their wares.

Corporations are making arrangements with universities for patentable ideas and trained workers. Federal and state governments are turning to them for extension services and to develop new ideas for industry. Foreign governments and companies are reaching out to our campuses for early access to research findings and for training their students.

Many universities, in turn, are aggressively marketing an ever-broader range of services. The Georgia Institute of Technology advises local businesses through its Industrial Extension Service. Worcester Polytechnic Institute's Manufacturing Engineering Applications Center develops products for subscribers. Stanford University and the University of California at Berkeley maintain active industrial affiliate programs. Similar examples abound.

Many of these arrangements provide valuable educational opportunities for college students. Yet if universities become too eager in their pursuit of new revenues, they could lose sight of their main mission—the training of the next generation. That would be disastrous, not only for universities and students, but for all of us.

As Princeton University president Harold Shapiro has pointed out, universities only recently have been expected to make a dollars-and-cents contribution to economic growth. Over the past eight centuries, their main product has been their graduates, who go on to influence the economy through

their daily working lives, reshaping society without fanfare. The day-to-day job of education is less glamorous than campus research that wins Nobel Prizes, but it represents technology transfer at its most profound and lasting.

There are many reasons why university administrators have begun looking beyond this traditional mission and marketing new services. They are struggling with post-baby boom enrollment declines, rapidly rising administrative and facilities costs, and shrinking pools of government support. Most universities also sincerely want to help government and business make better use of good ideas developed on campus.

Nonetheless, at least some universities are now in danger of becoming victims of their own sales pitches. They endlessly cite a few notable successes—Silicon Valley in California, Boston's Route 128, and Research Triangle Park in North Carolina—as evidence of the economic leverage of their own proposals. These marketers risk becoming mercenaries if they advertise too direct a relationship between higher education and higher profits.

For professors, the pursuit of new sources of research funding may be the inevitable outgrowth of a "justify your existence" mentality. The vicious academic cycle of "publish or perish" puts pressure on them to constantly write new research proposals—or write up their résumés. This mindset has helped make teaching careers so unattractive that U.S.-born professors are now a rarity in some disciplines, particularly in science and engineering. Teaching has taken a back seat to research, because it

simply doesn't pay for universities or professors. This shift away from teaching threatens to prevent our daughters, sons, employees, and other students from getting full value from their education—and from our education dollars.

Make no mistake; university research is essential for generating new ideas, discoveries, and technologies. But it is not a sure-fire ticket to prosperity. The openness of our university system is essential to intellectual vitality. Yet it also ensures that research findings, in many cases funded by our government, can be picked up easily by foreign companies. There is no guarantee that the benefits of university research will remain in the United States. We can be much more certain that our students—the real product of our colleges and universities—will invest their careers in our country's economy.

So, as they seek to meet rising expectations with declining resources, universities should be temperate in their promises of economic return. And companies and governments must avoid raiding universities for their intellectual breakup value. We can enhance our national industrial competitiveness only with careful planning, patient effort, and hard work. We should expect no magic potions from campus labs.

The real return on our personal and collective investments in universities is the career-long contributions of our graduates. We cannot put too high a value on their training, and we must not forget that the university's focus should be on people, not profit.