



*The Federal Role in  
Science and  
Engineering*  
**Graduate and  
Postdoctoral  
Education**



NATIONAL SCIENCE FOUNDATION

**National Science Board**

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# *The National Science Board*

## **The Federal Role in Science and Engineering Graduate and Postdoctoral Education**

**February 26, 1998**

NSB 97-235

Task Force on  
NSB October 1997 Meeting

Dr. Eamon M. Kelly, *Chairman*

Dr. F. Albert Cotton  
Dr. M.R.C. Greenwood

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# Table of Contents

## **Abstract**

### I. Introduction

Principles of the Federal/University Partnership in Graduate Education

Current Status of the Partnership

    Changes in the Federal/University Relationship

    The Changing Higher Education Context

### II. The Government/University Partnership in Graduate and Postdoctoral Education:

Principles and Practices for the Future

    1. Federal Support to the Enterprise

    2. Breadth vs. Narrowness of Graduate Education

    3. Human Resource Policies

    4. Impact of Federal Regulatory and Funding Practices on the Culture of  
    Institutions

### III. Issues to be Negotiated Between the Partners

## APPENDICES

### I. Current Issues with Regard to the Federal Role in Science and Engineering Graduate/Postdoctoral Education

### II. Agenda of the Convocation on Graduate and Postdoctoral Education: The Federal Role, Houston, Texas, October 9, 1997

## *The National Science Board*

### **The Federal Role in Science and Engineering Graduate and Postdoctoral Education<sup>1</sup>**

#### **Abstract**

In response to the request from the President's Science Advisor, John Gibbons, for a National Science Board contribution to the Presidential Review Directive on the Government/ University Partnership (GUPPRD), the Board offered to provide its views on the role of the Federal government in graduate and postdoctoral education. In this paper, the Board examines the general framework of the partnership in graduate education established after World War II, affirms that the partnership has been highly successful for the Nation, and concludes that the Federal role in the partnership remains critical. The Board urges that the general principles of the partnership be maintained, but offers some recommendations on adjustments to increase the effectiveness of Federal policies and programs in advancing the objectives of this partnership.

The Board identifies some troubling issues that have emerged as a result of changes over the last fifty years, and offers recommendations to improve the effectiveness of the partnership for all concerned. The Board suggests new opportunities, particularly those offered by advances in communications technology, to expand the benefits of the partnership to a wider range of institutions in the academic research and engineering ecosystem, and to broaden the options for graduate students to experience environments outside the research university to supplement their core Ph.D. training. In addition, the Board draws attention to serious stresses in the partnership arising from administrative and accounting changes implemented by Federal funding and regulatory agencies. The Board provides recommendations in several areas: Federal support to the enterprise, breadth versus narrowness of graduate education, human resource policies, and impact of Federal regulatory and funding practices on the culture of institutions. Finally, the Board comments on outstanding issues to be negotiated between the Federal and university partners.

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<sup>1</sup> This report was originally prepared as a contribution to the Government/University Partnership Presidential Review Directive (GUPPRD). It has been revised and issued as a report of the National Science Board.

## ***I. Introduction***

The education of graduate and post-doctoral students in a discovery-rich university research environment is at the heart of the post-World War II compact between the Federal government and universities. Federal support of U.S. graduate education in science and engineering has insured the global leadership of the United States in science and engineering and contributed robustly to our country's innovation and economic growth. In a time of extraordinary political and economic changes worldwide since the end of the Cold War, understanding the current status and clarifying the principles of Federal support for graduate education in science and engineering are matters of high priority.

This paper responds to the request of the Assistant to the President for Science and Technology that the National Science Board provide its views on the status of graduate and postdoctoral education and the Federal role. It contributes to the ongoing review of the Federal/university partnership being conducted by the National Science and Technology Council in response to the Presidential Review Directive of September 26, 1996. In developing the views presented in this paper, the Board benefited greatly from a "Convocation on Graduate and Postdoctoral Education: The Federal Role," held at the October 8-10, 1997, NSB meeting in Houston, Texas. This symposium, which included presentations by a number of invited speakers, provided rich insights for the development by the Board of the comments and recommendations that follow.<sup>2</sup>

### **Principles of the Federal/University Partnership in Graduate Education**

At the conclusion of World War II in 1945, Vannevar Bush argued persuasively in his report, *Science--the Endless Frontier*, that the Federal government should continue to support science and engineering research and post-secondary education in peacetime and that this investment would contribute to national security, economic growth, health, and the quality of life. The principal instruments of the Federal investment in research were to be colleges and universities, which would generate new knowledge in an environment of free and open inquiry and at the same time develop science and engineering talent. The proximity and integration of the two functions of research and education would insure a process of continuous mutual enrichment between them.

Bush argued that the Nation could not rely on government agencies, the private sector, or foreign nations to produce the fundamental knowledge necessary for the continued improvement of the quality of life in the United States. Bush approvingly quoted James B. Conant: "We shall have rapid or slow advance on any scientific frontier depending on the number of highly qualified and trained scientists exploring it...So in the last analysis, the future of science in this country will be determined by our basic education policy."<sup>3</sup> In

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<sup>2</sup> The agenda for the Convocation on Graduate and Postdoctoral Education: The Federal Role, is attached as Appendix II.

<sup>3</sup> Vannevar Bush. *Science, the Endless Frontier*, 40<sup>th</sup> Anniversary Edition (Washington DC: National Science Foundation , 1990) 23.

short, Bush's report defined a national education policy for university- and college-trained science and engineering personnel that:

- is based on the national interest in advancement of knowledge in an environment of free and open inquiry, such as that provided by the university sector;
- explicitly integrates fundamental research and advanced training in science<sup>4</sup> in universities and colleges;
- supports students on the basis of their exceptional ability, *i.e.*, student merit;
- is sensitive to the needs of the scientific and technical workforce; and
- is responsive to the needs of society.

The Federal/university partnership in research and graduate education has been an extraordinary success for the United States. Public investment in academic science and engineering research and education in an environment of free and open inquiry has indeed been a major contributor to U.S. economic growth and quality of life.

Therefore:

- ***The National Science Board strongly affirms the fundamental soundness of the principles of the Government/university partnership for the academic science and engineering enterprise established after World War II.***
- ***The Board concludes that the application of those principles in academic science and engineering research and advanced education has enabled the enterprise to lead the world in quality and productivity.***
- ***The Board affirms that the Federal role is critical to advanced science and engineering education at both the graduate and postdoctoral levels. It urges a re-examination of the Federal/university partnership in graduate and postdoctoral education as it has evolved, to identify areas where adjustments may enhance the capacity of the enterprise to serve the national interest in a changing global environment.***

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<sup>4</sup> Bush's proposal was for advancing basic scientific knowledge, which in today's use would include basic research in engineering.



## **Current Status of the Partnership**

Since the Bush report, U.S. society has become larger, more diverse, and more urban and the economy has become increasingly global. With the end of the Cold War, greater national attention can be devoted to other concerns, such as environmental and social needs. Once the privilege of a small elite, post-secondary education responded to a changing marketplace. Market demand for higher-level training and the decline in the value of a high school diploma, both to the employer and high school graduate, have resulted in expansion of the share and diversity of the working age population who pursue college-level and graduate education. The Federal responsibility to insure, in partnership with the universities, “constantly improving quality at every level of scientific activity”<sup>5</sup> has become broader and more varied as science and technology have become more central to the economy and society.

Universities confront stresses that result from increasing demands and associated rises in costs without offsetting increases in revenues. These stresses reflect the impact of more and broader-based demands from an expanding group of stakeholders; budget constraints on traditional sources of funds, including Federal sources; globalization of advanced education; the need to respond to technological changes, especially to advances in communications and information technology; and unintended consequences of Federal policies. The Board has identified several broad areas of concern in the Federal/university partnership in graduate education that deserve special attention.

### *Changes in the Federal/University Relationship*

Agencies of the Federal government support research in universities through a variety of mechanisms, including grants, cooperative agreements, and contracts. Regardless of purpose or mechanism, the research activities serve to enrich the learning environment and expand opportunities for graduate student and postdoctoral participation in frontier research. Some Federal research funding to academic institutions is public investment in the advancement of fundamental knowledge and in the education of the next generation of scientists and engineers. This kind of relationship may be described as an “investigator-initiated” activity performed by the university. Other Federal research funding responds to an objective related to an agency’s mission. This activity, also performed by a university, may be described as “agency-initiated.” Federal funding falls along a continuum between these two poles.

As the research and education enterprise has grown and as the Federal investment has increased, emphasis on accountability for public funds has also increased, resulting at times in unintended but serious stresses on the university partners. The growing Federal focus on accountability tends to emphasize short-term research “products” and to deemphasize benefits to graduate education from engaging in research at the frontiers of knowledge. Increased emphasis on accountability also may result in an increase in the perceived value of postdoctoral researchers compared with graduate students on research

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<sup>5</sup> *Ibid.*, 25.

grants, thus reducing options for cutting-edge research experience during graduate training.

There are also unintended consequences of some of the new cost accounting methodologies and standards which, with the best intentions of fully accounting for taxpayer money, are resulting in serious stresses on the academic research and education enterprise. There is a growing tendency to treat all research activities equally for accounting purposes, whether for an agency-initiated product or for investigator-initiated research that provides cutting-edge research experience for graduate students. This trend has been marked by the adoption of adversarial administrative procedures inconsistent with the trust and cooperation that should characterize the Federal/university partnership in research and education. Moreover, relationships between faculty researchers and the university administration may be adversely affected by such procedures, resulting in stresses within the university community.

In addition to the lack of coherence between objectives of the Federal/university partnership and Federal cost-accounting practices, there is an inconsistency in administrative and regulatory requirements of different Federal funding agencies. This inconsistency results in a mushrooming of paperwork for the administration of federally-funded research. Some portion of the paperwork burden falls on faculty, absorbing time that could otherwise be devoted to teaching, mentoring, and research. Unnecessary costs for administrative overhead may also mean less money available to support valuable research and education activities, equipment, and physical facilities.

### *The Changing Higher Education Context*

Stresses on the universities represent pressures that are a product of growth and change in the research enterprise and its environment over the last fifty years. One area of stress comes from the diversity that is a strength of our system of higher education. The academic science and engineering research and education system is an ecosystem, differentiated along functional lines to meet a wide variety of education and research needs. Within this system, research institutions produce, in addition to a share of science and engineering undergraduate degrees, the great majority of Ph.D.s in science and engineering. Liberal arts colleges, state universities, and two-year colleges that provide undergraduate preparation for scientists and engineers employ as faculty Ph.D.s trained at research institutions.

The Ph.D. is and should remain a research degree. The most important function of a Ph.D. program is to educate talented students to a level of mastery of a chosen discipline and its methods of research and scholarship. Graduates of the Ph.D. program, as members of their disciplinary communities, are prepared to make independent contributions to the store of human knowledge through research, information exchange with colleagues, and educating the next generation of scientists and engineers. Nonetheless it has always been the case that many Ph.D.s who pursue academic careers fill faculty positions that are

primarily teaching positions, often involving little or no research.<sup>6</sup> Moreover, Ph.D.s who pursue research positions in industrial or government laboratories may well move into non-research positions over time. These are by no means inappropriate outcomes of Ph.D. education: Ph.D. recipients have broadly applicable skills; and the problem-solving abilities they acquire enrich their capacities in teaching, research and management positions.

Those who take faculty positions following completion of their education, regardless of the type of institution, have an obligation to remain current in and to contribute to their fields of specialization. The research university offers the greatest opportunities for fundamental research within the field of specialization. Today, however, rapidly advancing communications and information technologies are opening and expanding opportunities for inter-institutional cooperation in research and education within the academic sector, and also between academic institutions and other sectors. These opportunities for expanded collaboration, in addition to increasing faculty opportunities to contribute to fundamental knowledge, promise to enrich graduate and postdoctoral education by broadening options to experience a range of educational and research environments in preparation for a variety of future careers.

## ***II. The Government/University Partnership in Graduate and Postdoctoral Education: Principles and Practices for the Future***

### **1. Federal Support to the Enterprise**

Federal support to research in the academic environment may contribute to fundamental knowledge and enrich the education of the next generation of scientists and engineers, regardless of funding mechanism or agency objective. The Federal role in support of broad-based fundamental research and graduate education in universities, medical schools, research institutes and colleges remains crucial to the national interest. Graduate education is a long-term commitment, requiring substantial investment of time and money by the student, institution, and other funding sources.

A major objective of the Federal/university partnership in research and education historically has been to attract high-ability youth into science and engineering careers by providing significant multiyear financial support that is competitively allocated and based on the student's past achievement and future promise. This policy insures the quality of the science and engineering workforce and offers opportunities for careers in science and engineering to all individuals of high ability.

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<sup>6</sup> Forty-six percent of Ph.D.s were employed in the academic sector in 1995; of those, 59 percent were employed by non-research institutions.

The Board recommends that:

- **The Federal government reward and recognize institutions that initiate model programs for the integration of research and education.**
- **Mission agencies funding agency-initiated research in academic institutions recognize the intimate connection between research and graduate education in universities. They should adopt principles and practices exploiting that interconnection and insure that their funding reaps the dual benefits of simultaneously advancing both research and graduate education.**
- **The Federal government contribute to promoting closer collaboration between faculty in non-research and research institutions. Such collaboration in research offers opportunities for greater exposure to a variety of career options for graduate students. It can also improve the transition from undergraduate to graduate programs across institutions. The improvement of that transition is especially important for reaching minority undergraduates. Federal investments, particularly in communications infrastructure, can expand the scope of these programs.**

## **2. Breadth vs. Narrowness of Graduate Education**

The core training for the Ph.D. requires the candidate to acquire the knowledge base and tools in a chosen area of science and engineering and to make an original contribution to the base of knowledge through an in-depth investigation in a specialized area. With this experience the candidate develops skills as a creative problem solver. In addition to this core training, universities can offer a range of opportunities for the student to consider in preparation for careers outside the research university, including those within the academic sector in primarily teaching institutions, and in government and industry.

The Federal government and universities are responsible for developing relevant experience and training to meet expanding workforce needs and to prepare the student for his or her chosen career. More should be done to inform graduate students of the full range of employment opportunities and careers and to offer a choice of options for expanding career-related training.

The Board recommends that:

- **University programs and Federal support policies continue to encourage exceptionally talented students to pursue Ph.D. programs and to develop their capacities to advance knowledge in their chosen disciplines;**

- **The Federal partner recognize and reward institutions that, in addition to the core Ph.D. education, provide a range of educational and training options to graduate students, options tailored to the career interests of the individual Ph.D. candidate. These might include interdisciplinary emphasis, teamwork, business management skills, and information technologies.**

### **3. Human Resource Policies**

In spite of Federal and university efforts to increase the participation of underrepresented populations in graduate education and academic careers, the participation of these groups in graduate programs and on university faculties remains low, particularly in science and engineering fields.

Also of concern is the status of postdoctoral researchers in academe. After the Ph.D., many students continue their specialized training in postdoctoral appointments. The training they receive substantially enhances their preparation for careers in research in their area of specialization. These researchers are a significant component of the academic research and graduate education system, serving in some programs as an important component of the mentoring system for graduate students. Nonetheless, these researchers' status may be ambiguous during the period they spend in postdoctoral appointments, because they are neither graduate student nor faculty member in the institution where they are performing the research. There is a need for institutions to clarify the status of these important personnel.

The Board recommends that:

- **The Federal and university partners seek more effective ways of promoting diversity and full access to graduate education, guarding against strategies that inadvertently keep underrepresented groups from the mainstream of research and graduate education. Efforts should emphasize identification of high-ability students earlier in the educational experience, including the precollege level, and encouraging them to consider careers in science and engineering.**

The Board recommends the attention of universities to the following areas:

- **To assure access for high ability students, examine the current use and possible misuse of assessment tools for entry to, and financial support for, graduate education, e.g. the Graduate Record Examination scores (GREs); and**
- **Recognize postdoctoral researchers as a significant component of the system of graduate research and education in some areas, and better integrate postdoctoral scholars into the university community.**

#### **4. Impact of Federal Regulatory and Funding Practices on the Culture of Institutions**

Federal rules and regulations for the administration of Federal funds for research and education, and the competitive grant system itself, help shape the culture and working environment in universities. The Federal government must recognize in its policies and administrative requirements that research and education are integrated in the academic environment and insure that accounting requirements for academic research support objectives of the Federal/university partnership in advanced science and engineering education.

Negative impacts on education of some Federal regulations and practices for research administration may be cumulative. For example, the administrative separation of education from research may have a growing, unintended negative impact on the university mission in graduate education. At the same time, emphasis on success in research by Federal funders may encourage a parallel emphasis in faculty reward systems in departments and institutions, in some cases to the detriment of education.

The Board recommends that the Federal government:

- **Support university-initiated efforts to insure in the science and engineering faculty reward systems an appropriate balance between recognition for excellence in research and excellence in teaching, mentoring, and other areas of faculty responsibility;**
- **Examine how it can prevent unnecessary and unintentional interruptions in academic research programs and in associated support to graduate students that may result from the vagaries of the Federal research funding environment;**
- **Review conflicting or confusing treatment of graduate students and postdoctoral researchers--as students or employees--in Federal regulations and policies. The review should entail consideration of both consistency across agencies and coherence between the purposes of regulations and administrative requirements and Federal objectives for supporting and integrating research and education in academic institutions.**

#### ***III. Issues to be Negotiated Between the Partners***

Over the last fifty years, some issues in the partnership have emerged as gray areas, whose resolution is not clearly the responsibility of one partner or the other. An issue of particular concern is the broad impact of current funding patterns and practices on the national science and engineering workforce for the future. This consideration includes the responsibility to support a continued, adequate infusion of talented students from across the population spectrum into graduate programs in the broad range of science and

engineering fields. There is a need to clarify the roles of the partners so that a strategy to address this and other gray areas can be framed.

The Board recommends that the following areas be explored:

- **Strategies to attract and retain talented students from underrepresented groups. These strategies might include consideration, in some cases, of criteria for support on research grants;**
- **The respective Federal and university responsibilities for reducing the administrative burden on faculty researchers/teachers to increase time available for mentoring and other educational and service activities that enrich the learning environment. This reduction in administrative burden needs to be coupled with the alignment of faculty reward systems, as described in Section II.4;**
- **Improved policy data to assess the effectiveness of current Federal support for graduate education including attention to attrition and time-to-degree, and to identify current and emerging national needs for the science and engineering workforce.**

This exploration should include input from a broad range of stakeholders in graduate education and be attentive to maintaining the benefits of graduate and postdoctoral research and education in science and engineering for the Nation.

# APPENDICES

## *The National Science Board*

### **The Federal Role in Science and Engineering Graduate and Postdoctoral Education**

- I. Current Issues with Regard to the Federal Role in Science and Engineering Graduate/Postdoctoral Education**
  
- II. Agenda of the Convocation on Graduate and Postdoctoral Education: The Federal Role, Houston, Texas, October 9, 1997**



## APPENDIX I

### *Current Issues with Regard to the Federal Role in Science and Engineering Graduate/Postdoctoral Education*

Issues that have been raised in other recent discussions of graduate education include:

*What are the principles of Federal support of graduate education today?*<sup>7</sup>

- Is there a common purpose or purposes among Federal agencies in supporting research that involves graduate and postdoctoral students in universities and colleges? In what programs is the impact on science and engineering education an explicit consideration?
- What are the qualifications or requirements for S&E graduate and postdoctoral students to be supported on research grants by Federal agencies? What data are available to measure the impacts of support from research grants? (e.g., student demographics, retention, time to degree, field of degree, career after graduation).
- What programs are expressly directed to graduate/post-doctoral student support? (e.g., fellowships). By which agencies? In which fields? For what purposes? How successful are these programs in comparison with support from research projects?

*Does the Federal role in the current partnership encourage the production of highly able scientists and engineers from the broad spectrum of the U.S. population who, in the aggregate, meet national needs for the S&E workforce?*

- Does Federal support of graduate/postdoctoral students on research grants and/or directly on fellowships and traineeships help to attract and retain talented youth in science and engineering careers across the broad spectrum of the U.S. population?
  - ◇ Are there special barriers to underrepresented groups in graduate/ postdoctoral education in S&E that can be reduced through the Federal/university partnership?
  - ◇ Are the Federal support modes, or mix of those modes, for graduate education effective in achieving Federal objectives for the science and engineering workforce?<sup>8</sup>

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<sup>7</sup> The COSEPUP report, *Reshaping the Graduate Education of Scientists and Engineers* (1995), concluded that there is no coherent national policy that guides the advanced education of S&Es today. It suggested a national discussion group—including representatives of government, universities, industries, and professional organizations—should deliberately examine the goals, policies, conditions, and unresolved issues of graduate-level human resources in S&E.

<sup>8</sup> The NSB Task Force on Graduate and Postdoctoral Education (1995) after careful and thorough review concluded there were insufficient data to support a change in NSF policy on the mix of support

- ◇ Do Federal policies and programs affect or contribute to increasing time to degree?
- What is the national interest/impact of supporting foreign students on Federally-funded research grants?
  - ◇ Is the current reliance on foreign students to meet the personnel needs for certain fields, supported in part by Federal research grants, a viable long-term strategy?
  - ◇ Do foreign students compete with U.S. students for support on Federal research grants?
  - ◇ Do large numbers of foreign students in some programs discourage talented U.S. students from pursuing graduate studies; are underrepresented groups impacted more by this factor?

*Do Federal programs and policies for support of research in universities enrich the learning environment and support free and open inquiry?<sup>9</sup>*

- To what extent does Federal support encourage narrow specialization in areas related to the immediate needs of mission agencies or faculty mentors?
- Does Federal support for graduate/postdoctoral research and education in universities encourage acquisition of skills and knowledge to prepare graduates for a broad range of research and teaching careers?
- Do Federal policies and support methods encourage dissemination of knowledge, and sharing of the benefits of research and graduate education throughout the host institution, and synergy among academic researchers, faculty and students, and researchers in other sectors?
- Is Federal support for graduate and postdoctoral research and education sufficiently sensitive to the important contributions to the national science and engineering research and education enterprise by the comprehensive universities, liberal arts colleges and other institutions not among the major research universities?

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mechanisms for graduate education, i.e., research assistantships, fellowships and traineeships. It therefore recommended limited studies with defined goals and assessment criteria be conducted on alternative modes of graduate support; and that NSF support data collection and/or research on funding mechanisms and various aspects of graduate student education and employment of Ph.D. scientists and engineers.

<sup>9</sup> “The current graduate paradigm can be characterized best as an apprenticeship, in which the dissertation advisor has significant responsibility for not only the content but as well the duration of the program...stressing specialization and depth of investigation [it] is frequently accused of cloning the current cadre of research faculty.” (James Duderstadt, Remarks to the National Science Board, August 1997).

## APPENDIX II

NSB-97-169

(REVISED)

October 7, 1997

### Agenda

## National Science Board

345th Meeting

October 8, 9, 10, 1997

The Hilton Hotel and Conference Center

The University of Houston

Houston, Texas

Thursday, October 9

## Convocation on Graduate and Postdoctoral Education: The Federal Role

8:30 a.m. - 9:45 a.m. *Opening Remarks*

Richard N. Zare, Chairman, NSB

### *Welcome*

Arthur Smith, Chancellor/President, University of Houston,  
Convocation Host

### *Overview*

Eamon Kelly, NSB; Chairman, NSB Task Force on the NSB  
October 1997 Meeting

### *Keynote Address*

Paul Cuneo, Director of Technology, Shell Oil Products Co.  
*Importance of Graduate Education for the Nation*

9:45 a.m. - 10:00 a.m. *Break*

10:00 a.m. - 4:00 p.m. *I. The National Interest and Federal Role in S&E Graduate & Postdoctoral Education*

10:00 a.m.- 12:00 p.m. *A. Federal/University Partnership in Research and Education for the Future*

Chair: MRC Greenwood, NSB

### The Federal View

Neal Lane, Director, National Science Foundation

Marvin Cassman, Director, Institute of General Medicine,  
National Institutes of Health

Robert Trew, Director of Research, DTR&E/Department of  
Defense

James Decker, Deputy Director, Office of Energy Research,  
Department of Energy

Discussion

12:00 p.m.- 1:00 p.m. The University View  
Henry Yang, Chancellor, University of California, Santa Barbara  
Malcom Gillis, President, Rice University

Discussion

1:00 p.m. - 2:30 p.m. *Lunch, Hosted by University of Houston, Conrad Hilton-A  
(by invitation); Guest: Dr. Eduardo Aguirre, Regent,  
University of Houston, representing  
Governor George Bush III*

2:30 p.m. - 4:00 p.m. ***B. Modes of Federal Support for Graduate and Postdoctoral  
Education***

Chair: F. Albert Cotton, NSB

Stuart Rice, Professor of Chemistry, University of Chicago  
Marye Anne Fox, Vice President for Research, University of  
Texas, Austin

Thomas Appelquist, Dean, Graduate School; Professor of  
Physics, Yale University

John Alderete, University of Texas Health Science Center, San  
Antonio; President, Society for the Advancement of  
Chicanos and Native Americans in Science (SACNAS)

Discussion

4:00 p.m. - 4:15 p.m. *Break*

4:15 p.m. - 6:15 p.m. ***II. S&E Graduate/Postdoctoral Education: Needs and Issues***

Chair: Diana Natalicio, NSB

David Sanchez, Department of Mathematics, Texas A&M  
University

Roy Schwitters, The University of Texas, Austin

Brian Schwartz, Brooklyn College, and The Graduate Center,  
CUNY; Sr. Assistant to Executive Officer, American  
Physical Society

Karen Watson, Texas A&M University, Alliance for Minority  
Participation

Discussion

Opening Comments: Richard Tapia, NSB

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