MAKING POLICY FOR MAKING SELVES
IN SCIENCE AND ENGINEERING:
From Sputnik to Global Competition

by

Juan C. Lucena

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APPROVED:

Gary Downey, Chair

Richard Hirsh

Ellsworth Fuhrman

Steve Fuller

Langdon Winner

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ABSTRACT

This dissertation is a cultural history of the making of policy for education
and human resources in science and engineering for the American nation. The
main thesis of this work is that national narratives, mostly made up by images
of nation, its problems and solutions, as defined by powerful social actors and
groups, have significantly shaped policies and programs for education and
training of scientists and engineers since World War II. Nowhere is this cultural
relationship between nation and policy more evident than around the programs
in education and human resources at the National Science Foundation (NSF).
This dissertation analyzes the emergence of four national narratives, their
influence on the redefining the national mission of the NSF, and their impact on
the policies that NSF has implemented to educate and train scientists and
engineers in the last four decades. The four narratives explored here are: a
nation under threat by Soviet science in the 1960's, a nation plagued by its own
social and environmental problems in the 1970's, a nation challenged by the
technological successes of Japan in the 1980's, and a nation facing uncertain
and ambiguous threats under global competition in the 1990's.
After locating these national narratives, this dissertation traces the trajectories of cultural models of the nation into the struggles among different actors that over the past 40 years have defined NSF's mission. Narratives about the nation and actors struggling to define national problems and solutions shape federal policies and programs in education and human resources in science and engineering. In turn, policies and programs come to define, to a large extent, stereotypic images of scientists and engineers, and in doing so contribute to shaping our understanding of what it means to be a scientist and an engineer in the U.S.
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As a Colombian, I found that writing a dissertation about the American nation, its policy making, scientists and engineers, was not an easy task. I struggled every step of the way not only feeling insecure about my knowledge of American culture, history, and institutions but about my command of the English language as well. From beginning to end, the unconditional support and guidance of the people around me made the completion of this dissertation possible. I acknowledge and thank all of them but there are eight individuals that deserve my utmost sincere appreciation.

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LIST OF ABBREVIATIONS

ABET - Accreditation Board for Engineering and Technology

DoE - U.S. Department of Education

EHR - Directorate for Education and Human Resources

GUIRR - Government-University-Industry Research Roundtable

HBCU - Historically Black Colleges and Universities

HEW - U.S. Office of Health, Education and Welfare

MITI - Ministry of International Trade and Industry

NAE - National Academy of Engineering

NAMEPA - National Association of Minority Engineering Program Administrators

NDEA - National Defense Education Act of 1958

NEAC - National Engineering Action Conference

NIH - National Institutes of Health

NRC - National Research Council

NSB - National Science Board

NTF - National Technology Foundation

OSTP - Office of Science and Technology Policy of the President

OTA - Office of Technology Assessment of the U.S. Congress

PRA - Policy Research Analysis Division at NSF

PSAC - President’s Science Advisory Committee

SPE - Division of Scientific Personnel and Education at NSF

SRS - Division of Science Resources Studies at NSF

USHR - U.S. House of Representatives

USS - U.S. Senate
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CHAPTER 1
Introduction

This dissertation is a cultural history of the making of policy for education and human resources in science and engineering for the American nation. The main thesis of this work is that national narratives, mostly made up by images of nation, its problems and solutions, as defined by powerful social actors and groups, have significantly shaped policies and programs for education and training of scientists and engineers since World War II. Nowhere is this cultural relationship between nation and policy more evident than around the programs in education and human resources at the National Science Foundation (NSF). The NSF has emerged as the leading voice in science and engineering issues in the United States, especially the education and development of human resources for specific national needs. Given the increasing importance of scientists and engineers in the fulfillment of national missions, such as the space race after Sputnik or the current global competition, educating, training, and having knowledge about them have become important activities for federal involvement. NSF has become the main instrument of the federal government to help achieve these responsibilities. However, the creation and implementation of policies and programs in education and human resources occurs with resistances and struggles from different actors involved in the education and training of scientists and engineers. This dissertation explores how different
actors have struggled over the past 40 years to shape NSF’s missions in education and training and in doing so have come to define, to a large extent, what it means to be a scientist and an engineer in the U.S.

The increasing importance of the NSF, particularly in the last 10 years, in making knowledge about and policy for education and human resources in science and engineering make it a unique site to study how what we understand for nation at any particular time comes to define also the meaning of scientist and engineer in the U.S. Since the launching of Sputnik in 1957, changes in national priorities have been motivated by perceptions of new threats to the American nation, both foreign and domestic, bringing redefinitions of what we understand as America. New threats bring new ways to talk about the nation. As new narratives emerge, actors struggle to appropriate them and translate them into descriptions and prescriptions of what and how NSF should do to help save the nation. I refer to actors as not only individual humans but also as organizations (e.g., governmental, academic, private) and groups of individuals who share similar beliefs and have similar purposes (e.g., scientific academism). In this dissertation, one of the main characteristic of actor is how he/she/they relate(s) to the narratives about the nation. I am most interested in how actors have appropriated and translated external and internal threats to the American nation in the last 40 years, from the Soviet threat of the fifties and sixties to the economic threats of the eighties and nineties, to shape the policies
and programs to educate and train scientists and engineers. To analyze this process, this dissertation traces the trajectories of cultural models of the nation, from the communist threat of the Cold War to the economic challenge of the Japanese, into policies and programs to educate and train scientists and engineers in the U.S.. It focuses on the power struggles by actors around and within NSF to define national problems and consequent solutions in terms of scientists and engineers, both in the appropriate numbers and characteristics. It pays particular attention to official statements made by groups and actors in their attempts to shape federal policies and programs in education and human resources in science and engineering. As different claims earn and lose legitimation according to their use of the narrative about the nation and the power location of the groups and actors making these claims, lawmakers recognize certain claims as more valid than others. The claims that come to influence policies and programs for education and human resources is what I call official knowledge. Furthermore, during the power struggle to establish their claims as official knowledge, groups and actors not only shape policies and programs, but also produce stereotypic images of scientists and engineers. I refer to the entire process as the making of policy for making selves in science and engineering.

As a source of certified knowledge about U.S. scientists and engineers, NSF has gone from playing a reactive role to having the leading voice to inform
the American nation about its needs for scientists and engineers. Forty years ago, as a young federal agency, NSF rarely pronounced public statements about the state of American science and technology. After the Soviet Union launched Sputnik in 1957, headlines describing a national crisis in science and education did not rely on representations made by NSF.¹ At that time, top-rank military officials, politicians, businessmen, and elite scientists depicted the latest Soviet threat as something to be dealt with by science and scientists.² They defined the problem and the solution, instructing federal agencies what to do.³

Today, NSF has come to define national crises, maybe not as visible as Sputnik, but those perceived equally threatening to the nation such as the Japanese challenge. "The New Global Workforce: High Tech Skills All Over the Map", "Shortage of Scientists Approaches a Crisis...", and "Wanted: 675,000 Future Scientists and Engineers" are just few of the most recent national headlines that rely primarily on claims made by the National Science Foundation (NSF) about the nation's needs for scientists and engineers to compete in a post-Cold War global economy.⁴ In contrast with its past passive


² See for example, "Air Force and Scientists Isolate Themselves to Map the Future"(Life 1957a), and "Top Businessmen and Scientists Teamed Up to Produce Missiles"(Life 1957b)

³ See for example, "World War of Science...How We're Mobilizing to Win It." (Newsweek 1957)

role, through these statements, NSF informs the nation on what to do about policy and programs to educate and train its scientists and engineers. However, NSF’s statements about the needs for scientists and engineers, whether published in the media or not, do not reveal complex policy processes among different groups that struggle to define the statements in their own terms. Whoever ends up defining these national realities gains power in allocating federal resources and shaping the education and training of scientists and engineers in the U.S.. Also, there are resistances from those groups and actors who do not have privileged positions with respect to political and economic power but who are influenced by the outcome of policies, programs, and stereotypic images. We will see how during the last 40 years different groups have used a variety of strategies, both successfully and unsuccessfully, in their attempts to participate in the policy- and image-making processes which determine, to a large extent, both their access to science and engineering education and their acceptance as scientists and engineers. This dissertation is a history of how these struggles and resistances result in policies and programs at NSF to make scientists and engineers in appropriate ways, where what is appropriate changes over time, particularly in the context of national crises. As such, this dissertation is not about how NSF functions as a bureaucracy to ensure its survival by serving national needs. It is about cultural and social making of policies and selves in science and engineering at and through NSF.
NSF and the American Nation

The National Science Foundation (NSF) is the federal agency in charge of funding science and engineering research and education in the U.S. that is both basic and non-military. NSF is currently organized around seven directorates, six of which fund disciplinary research and one which funds education and human resources programs in the sciences and engineering (see figure 1). As we will see, this configuration has changed throughout NSF's history as national priorities change.

Figure 1. Organizational Structure of NSF
The chief executive officer of NSF is a director nominated by the President and confirmed by the U.S. Senate. The National Science Board (NSB), nominated and confirmed by the U.S. Senate, is a body of representatives of different sectors of American society who set policy for NSF. NSF’s relationship with Congress is very complex with jurisdictions over NSF’s matters being divided, and sometimes shared, among different congressional committees. Generally speaking, the U.S. Senate Labor and Human Resources Committee looks over NSF’s legislative matters, the U.S. House Science, Space and Technology Committee has jurisdiction over NSF’s yearly authorization, and Appropriation Committees of both the Senate and the House decide on NSF’s budget.

Other authors have written in more detail about NSF’s relationship with the executive and legislative branches of the federal government. (e.g., Schaffer 1969) My interest here is to locate NSF’s origins within the American nation so that we have a point of reference to understand its emergence as the leading voice in the status of the nation’s science and engineering.

**Origins and Mission**

The original visions and goals of the NSF can be traced to Vannevar Bush’s *Science -- The Endless Frontier.* (Bush [1945] 1960) Published as a blueprint for postwar research policy requested by President Roosevelt in 1945,
this report embodies the perspective of American industry and the scientific elite on the federal government’s role in supporting scientific research. (Kleinman 1995) The report calls for a federal agency, to be called the National Research Foundation, to support basic scientific research. According to Bush’s original vision, this support was to be "free from political influence, free from the influence of pressure groups..." (Bush [1945] 1960). Bush intended for support of basic research to provide the Nation with the foundations of scientific knowledge upon which all other forms of knowledge rest. Basic scientific knowledge, not intended to produce immediate practical results, would eventually benefit national industry, in the form of "new products and processes," as well as American society with "more jobs, higher wages, shorter hours..." (Ibid) With an elitist conception of who was to carry out this research, Bush’s report proposed the "renewal of our scientific talent" by means of scholarships and fellowships based on merit. This meant that only the best and brightest could ensure the health and growth of basic research. Even after his proposal underwent close scrutiny by President Truman, Bush’s visions for scientific research and education, and the role of the federal government in them, continued into the signing of the NSF Act of 1950.  

President Truman commissioned a task force to revise Bush’s proposal. The four volume analysis, Science and Public Policy, A Report to the President, directed by John Steelman, also recognizes that scientific manpower is the “limiting resource” for scientific progress.
research and science education through NSF.

Between 1945 and 1950, the legislative process that ultimately resulted in the NSF Act of 1950 was marked by a struggle between scientific elitism, led by Vannevar Bush, and populism, led by Senator Harley Kilgore (D-WVa) (England 1982; Kleinman 1995:chapter 4). The Bush-led scientific elite advocated a science policy to give scientists maximum autonomy in their government-funded basic research effort. Kilgore and his supporters, on the other hand, advocated a New Deal agenda for science where the public controlled federal research support (Kleinman 1995:75). At the end of this debate, Bush's vision for a basic research agenda prevailed and materialized in the NSF Act of 1950. As Daniel Kleinman (1995:99) tells us, "scientists' war work had further enhanced their symbolic capital and Bush's and his colleagues' social capital. Bush's intimate relationship with President Roosevelt provided the opportunity and institutional location from which elite scientists and their business allies could contribute substantially to defining the terms of debate and later influence the further course of debate." Signed into law on May 10, 1950, by President Truman, the NSF Act of 1950 authorized and directed the new Foundation "[t]o promote the progress of science, to advance the national health, prosperity and welfare, to secure the national defense, and for other purposes." (Public Law 81-507) Although Congress did not intend for NSF to be a "mission-oriented" agency, like the Department of Agriculture or NASA, the
Act of 1950 implicitly defined a national mission for NSF. Congress, NSF officials, and interest groups have used the Act of 1950 as the legislative mechanism to reinterpret the new missions of the NSF throughout its 45-year history, redefining its research, education, and manpower programs according to emerging needs of the nation. For example, today congressional committees invite groups to discuss how "new opportunities and challenges [which] have been created by the end of the cold war, the rise of multilateral economic competition from abroad, and the emergence of global environmental problems" might redirect the national mission of NSF. (USHR 1993). These groups still justify their demands for new budget appropriations based on "the social contract between government and the research community" established by the Act of 1950. (Ibid: 1) The legislative mechanism by itself, however, is not enough to shape NSF's national mission every time new national needs emerge. Throughout this dissertation we will see how a socio-cultural process, what I call the construction of official knowledge, is what shapes NSF's mission. Power struggles among groups, within a cultural space defined by a discourse about the nation, redefine the national problems for NSF to solve. As new notions of nation emerge, groups struggle to define the meaning of "national health", "national prosperity and welfare", and "national defense" and seek to propose solutions through NSF. Actors that have remained marginalized from political and economic power have resisted definitions of "nation" and "national"
since these greatly influence their participation in science and engineering education. Most of the time, their resistance takes place through an alliance with a powerful actor who grants them access to the legislative process. Once there, marginal actors attempt to define "nation" so that it includes their interests.

Nowhere have these struggles been more visible than in NSF's education and manpower programs. NSF has become, in the last four decades, the most important, and in some respects the only, federal agency in charge of developing and promoting science and engineering education and human resources. From the launching of Sputnik (1957) to the present, NSF has responded to different needs for scientists and engineers brought upon by national crises that follow the appearance of each new threat in two ways: its manpower programs (National Register and Manpower Studies) and its education programs. Defined in national terms, these programs are the mechanisms through which NSF helps supply and educate the required scientists and engineers that the Nation requires. For example, the National Register program, whose aim is to "make possible the location and identification

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6 There are two other major federal agencies with appropriations for education larger than those of NSF: the U.S. Department of Education, whose programs are not specifically targeted to science and engineering, and the National Institutes of Health, whose education programs are targeted specifically to the biomedical sciences.

7 This are the titles of the programs in the 1960's. Today we find most of the education programs under the Directorate for Education and Human Resources (EHR) and the manpower programs under the Division of Scientific Resource Studies (SRS).
of individuals with specialized skills when needed for Governmental purposes, including mobilization," has served to locate and identify scientists and engineers according to time-specific national needs. Similarly, the Manpower Studies activity, as "the central program in the federal government for the provision of data on the supply, demand, education, and characteristics of the Nation's scientific and technical personnel resources," has produced projections for time-specific supply and demand national scenarios. In the last 40 years, as new threats redefine what we understand as the American nation, these programs have changed names, and even location within NSF, but not their broad objective: to locate and project scientists and engineers according to emerging notions of the Nation and national needs.

Locating, identifying, projecting, and hence (re)defining population categories of scientists and engineers is only one side of NSF's role in the making of selves for science and engineering. The other side is the implementation of science education programs aimed at producing the kind of scientists and engineers the "nation needs to survive." Since NSF's early years, whether in the form of Fellowships, Teacher Training, or Curriculum Improvement, these programs have been aimed at the "development of the individual scientist" while ensuring the "production" of adequate numbers of young scientists and engineers qualified to do the things our national goals require."(NSF 1960; USHR 1966:8) As the notion of nation changes so do the
national goals and the aim of NSF science education programs. During the last 40 years, political struggles have redefined the scope and budget of NSF's education programs to help produce the scientists and engineers that the Nation requires.

NSF data and projections have become the most legitimate source of information regarding the state of science and engineering in the U.S., including education. As NSF historian, J. Merton England, reports, "[already] by late 1950s more and more graphs, charts, and tables in books and articles carried the notation 'Source: National Science Foundation,' a designation that was becoming a stamp of authenticity. However shaky NSF's figures on scientific personnel... might be, and they were largely estimates. they were far more accurate than those available before and were becoming steadily better."

(England 1982) Nowadays when threats to the nation are not as visible as Sputnik or the environmental problems of the 1970's, media, both popular and academic, educators, policymakers, etc. depend heavily on NSF's descriptions of the health of American science and engineering, particularly as it fares with that of other industrialized countries. An interesting outcome of NSF's information and projections is that they have guided policies and subsequent budget allocations to NSF programs, thereby creating a conflict of interest. Through these projections, NSF has informed, recommended, and shaped the policymaking process in science and engineering. Legislators, NSF officials, and
other interested parties, have been using NSF projections during appropriation and authorization hearings for NSF programs, legitimizing NSF as the source of knowledge that shapes its own policies. But more than a bureaucracy trying to perpetuate itself, NSF has emerged as a unique institutional solution to the political and economic problems surrounding manpower development during the last 40 years. More than any other federal agency, NSF has become a federal instrument for allocating people in technoscientific fields without direct federal intervention or centralized policies of manpower development and allocation, such as the policies in the USSR and other socialist countries. When a threat has called for a massive mobilization of scientists and engineers, as happened for example, after the launching of Sputnik, the U.S. Congress has tried to enact legislation to create a national manpower policy. These bills have always failed to become law, first, because of a constitutional provision that prohibits the federal government to interfere with State and local education and, second, because of lack of political support from laissez-faire advocates. Democratic legislators have traditionally advocated strong government involvement in the planning and regulation of science and engineering manpower. Republican legislators, on the other hand, assume that free-market forces will eventually take care of regulating the supply and demand of scientists and engineers. Given the lack of bipartisan support for national manpower policies and the constitutional hurdle, NSF has served as an institutional solution to complex
constitutional and political problems surrounding science and engineering manpower: how to redirect (align) manpower in fields that the federal government considers important for national survival without interfering with state and local authority over education, while safeguarding the freedom of individuals to choose their profession.

Other federal agencies, such as NASA and NIH, also make claims about the promises of future returns if the government invests in them. For example, this was the case when NASA tried to justify the Viking-Mars program or the reusable space shuttle program in the early 1970's. Also, both NASA and NIH had implemented education programs, particularly graduate fellowships to create specialized scientists and engineers for their space and biomedical programs. However, these agencies do not have the mechanisms to locate, identify, manage, and project larger segments of the population of free citizens into different fields of national interest to the extent that NSF does. Since the 1950's, NSF has had such mechanisms, what I refer to later as technologies of government, in the form of the National Register and Manpower Studies Program. In the last 10 years, NSF has coupled these population management mechanisms with its education programs, aiming at producing the future numbers and quality of scientists and engineers that national needs require. I am interested in NSF's education and manpower programs as sites of cultural production of stereotypic images of scientists and engineers. By trying to fulfill
time-specific national needs for scientists and engineers, NSF continuously reproduces and reinforces images of scientists and engineers through its policies and programs. Most than just a part of a federal bureaucracy, NSF is also part of American national culture. As such, more than just an organization that changes its mission and function to ensure its survival within the federal government, NSF changes as images and beliefs about the nation change. Furthermore, NSF participates in national culture by reproducing and redefining images and meanings of scientists and engineers.

**Literature Review**

There are other approaches to understanding the development of NSF and its role in the federal government. There are also different approaches to understanding how and why science policy is made in the U.S.. Although existing approaches are important for their contributions to understanding institutional arrangements, political forces, and social groups involved in the making of NSF and science policy, they are limited in their contribution to understanding the making of scientists and engineers for the American nation. While most accounts about NSF have focused on its institutional history, most science policy accounts focus on explaining the funding of research. None of these accounts looks into the history of and funding for making scientists and engineers, that is how scientists and engineers should be educated, trained and
employed in appropriate ways, where what is appropriate changes over time, particularly in the context of national crises. My dissertation fills this gap.

Histories of NSF

Most of the histories about NSF describe the political struggles and legislative battles that led to its formation as the federal agency in charge of funding basic research and education in the sciences. Historians of NSF have focused mainly on important individuals, particularly Vannevar Bush and Senator Harley Kilgore, and how their political differences were played out on the legislation that ultimately created the NSF. Robert Maddox, for example, focuses on the senatorial career of Harley M. Kilgore and his legislative influence on the origins of the NSF (Maddox 1981, 1979) NSF's historian, J. Merton England, has written a detailed account of NSF's formative years (1945-57) that focuses on how populism, represented by Sen. Kilgore, and elitism, represented by Vannevar Bush, battled to define the domain of NSF's funding (England 1982) According to England, his is a "story of the agency's genesis [that shows] ideas quite different from Bush's about the purposes of a federal science agency." (Ibid) Following a similar line, Carl Rowman's work looks into the political battles fought throughout WWII that lead to the formation of the NSF. (Rowman 1985) Daniel Kevles extends these internal histories of the controversies surrounding NSF's origins by recognizing that actors' interests are
determined by their social position. (Kevles 1977) Daniel L. Kleinman advances our understanding of NSF's origins still further by analyzing relations of power and organizational constraints among the different political alliances that lead to the formation of postwar federal research policymaking (Kleinman 1995). In his approach to this problem of the genesis of NSF, Kleinman "puts power at its core", but, he argues, "power has a source, it comes from somewhere. In [my] analysis, I argue that power must be understood in an institutional context. The institutional configuration of society, including the structure of the state, affects the degree of power any set of actors can have in determining policy outcomes." (Ibid)

While this literature explains the institutional origins of NSF mainly as the result of differences in the political ideas between two powerful actors, and even, as in Kleinman's account, when there is recognition of the power differences among actors that determine policy, it presents a number of limitations. First, none of these accounts extend beyond Sputnik. The role of NSF has changed significantly, particularly in the last 15 years, and histories of these changes have not been written. Second, none of these accounts analyze the role NSF has played in the making of scientists and engineers. Throughout its history, NSF has come to define more and more what it means to be a

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8 The only exception is Kleinman's concluding chapter where he briefly explores research and technology policy debates and the future of that policy.
scientist and an engineer in the U.S. My dissertation will tell a history of this role. Third, this type of institutional histories take for granted NSF as a bounded bureaucracy where internal struggles, such as those between Vannevar Bush and Harley Kilgore, result in institutional change. From a cultural perspective, my dissertation looks at how NSF’s changes are part of broader cultural changes that have taken place in America in the last four decades. In contrast with institutional histories, this dissertation does not take for granted a sharp distinction between bounded institutions (inside) and socio-cultural context (outside). It looks at NSF as part of American cultural life.

The making of science policy

Analyses of science policy can be divided into three categories: institutional, constructivist, and cultural. For the most part, institutional studies have analyzed, first, the role scientists play as advisors to governmental institutions, usually known as "science in policy" analyses, and, second, the role policy plays on science as an institution, or "policy for science" analyses. In the first case, the focus has been on scientists as a group with special expertise advising the government on decision-making, usually on setting priorities in the funding of "big science" or in the implementation of large defense projects such as the atomic bomb and the Strategic Defense Initiative. However, none of these analyses looks at the role of scientists, or other experts, in the making of
scientists through their advice to the government, hence participating in the
definition of what it means to be a scientist or an engineer in the U.S..

Institutional accounts of science policy

Robert Gilpin and Christopher Wright wrote one of the first studies of
scientists and national policymaking. (Gilpin and Wright 1964) They analyze
possibilities for "both the proper role of scientists in the making of national
policy and the need to develop policy toward basic scientific research." In a
similar fashion, Dean Schooler looks into the relationship between scientists
and policy making, particularly as developed at the level of the Executive
branch. (Schooler 1971) In the same lines, Gregg Herken looks at the role
scientists have played as presidential advisers. (Herken 1992) A description of
what these histories do can be found in Herken's own account: "this is a history
of the advice that scientists have given the president of the U.S. since WWII,
not a study of science policy which concerns why and how the government sets
priorities in its support of science." (Ibid)

Accounts that look into the role of federal policy in the institution of
science are more diverse and analytical. However, their emphasis has been on
the impact of federal policies on the funding of research, not on the funding for
the making of people. John Wilson looks at a history of values, as reflected in
policies, between the federal government and higher education, mainly research
universities. (Wilson 1983) On a more analytical track, Richard Barke tried to apply scientific methodology to the study of science policy. (Barke 1986) After looking at a number of case studies of federal policies for funding scientific research, he argues that "public policies are constrained and compelled by complex but comprehensible forces that can be [scientifically] studied, understood, and applied to particular types of policies." (ibid) Looking at the last 40 years of U.S. science policy, which he divides into three phases. Bruce Smith analyzes public reactions to the emerging arrangements between the institutions of government and science after WWII. (Smith 1990) While viewing the Nation as a collectivity of passive citizens that react to governmental action, his book "tells how the nation responded to the altered relationship between government and science after the war and especially how changing circumstances have continued to test the arrangements." (ibid) He does not consider the possibility that cultural notions of nation define new arrangements between government and science, especially in the making of scientists and engineers.

Harvey Averch's book on strategic analysis of science and technology policy is of special importance in the category of institutional science policy studies.9 Using qualitative, textual analysis, he "teases out" the rhetorical

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9 Averch defines strategies as "combinations of factual assertions, predictions, prescriptions, and preferences designed to persuade decisionmakers to act in one way or another."
strategies used by the scientific community to persuade decision makers to fund particular areas of their interest, including science education. After his long experience in science policy in the federal government, including a top position at NSF, which led to the writing of this book, Averch concludes that "at the federal level, [science and technology] policy is limited to a few key issues. At heart, it is about money and priorities and who gets them." (Ibid) Focusing almost exclusively in policy making for the support of research, Averch, like the others, leaves out the possibility that science policy is not only about money and priorities but also about making people in science and engineering for specific national priorities. Throughout its history, and with budgets far inferior to those spent in research, NSF's education programs have influenced what we understand as "scientist" or "engineer" more than NSF's big-budget research areas. In sum, institutional analyses of science policy, even those that narrowly analyze institutional discourse, have overlooked the possibility that science policy is also about making selves for the Nation.

**Constructivist accounts of science policy**

Arguing that most postwar institutional studies of science policy have neglected the analysis of "the nature of the boundary between the modern state and science", constructivist studies of science policy have begun this analysis (Jasanoff et al 1995: part VII). Also, recognizing that most STS case-studies of
detailed scientific practice inside the laboratory has led to "a drastically oversimplified view of the world outside the laboratory" (Ibid), constructivist scholars call for STS scholarship to refocus on the interplay between the state, society, politics, culture, and science and technology. Following the constructivist model to explain the construction of scientific knowledge and technical artifacts, new analyses have begun to look into the construction of science policy for the funding of scientific research. However, none of these analyses deal with the construction of policy for the making of people nor conceptualize policy making as the shaping of persons for particular national needs.

Susan Cozzens and Ed Woodhouse looked at existing accounts of science policy to examine "those mutual influences of scientific knowledge and government authority." (Cozzens and Woodhouse 1995: 533-53) They map existing science policy analyses in three categories: scientific knowledge as a product of politics, the role of expertise in policymaking, and the relationship between science and industry. Accounts in the first category have looked for the most part at political negotiations surrounding government funding of scientific research.¹⁰ Cozzens and Woodhouse argue that in these accounts "the balance of knowledge among different fields is a political product." (Ibid) Analyses in the

¹⁰ See for example, Daniel Kevles' work on physics (Kevles 1977), Stephen Strickland's account of NIH grants (Strickland 1989), and Richard Rettig's history of the National Cancer Act of 1971 (Rettig 1977)
second category look into the conflicts that arise between scientists and
government as the former provides expert knowledge to the latter. Cozzens and
Woodhouse argue that as scientists provide this expertise they "win substantial
autonomy to promote knowledge and resource claims in ways that advantage
them at the expense of other equally legitimate social interests." (Ibid) 11

Accounts in the third category look at the role of business in the politics of
scientific knowledge. "The business-government relationship," Cozzens and
Woodhouse argue, "is in fact the most influential power relationship running
through the politics of science." (Ibid) 12

Regardless of the category into which they fall, these accounts have a
limited image of science policy. For the most part, they see the construction of
science policy as a struggle among different groups (industry, experts, public,
etc), over domains of scientific knowledge. My dissertation contributes to this
limited conception of science policy mainly in two ways. First, it introduces a
cultural concept of nation and its changes, as an important element in what
constitutes relevant social groups during the construction of policy. Second, it
expands the concept of policy from a struggle between groups in a confined

11 See, for example, Daniel Kleinman's analysis of the role of business interests in the origins of NSF (Kleinman
1993), and David Dickson's account on the influence of business and the military on scientific research funding
(Dickson 1988).

12 See, for example, Daryl Chubin and Ed Hackett's work on peer review and science policy (Chubin and
Hackett 1990), Mark E. Rushefsky's account on the making of cancer policy (Rushefsky 1986), and Dorothy
Neikin's analysis of the political impact of technical expertise (Neikin 1975)
policy arena for the funding of specific research areas to a struggle between
groups within a cultural space defined by concepts of nation for the making of
people.

Cultural accounts of science policy

Cultural analyses of science policy have conceptualized it as a cyclicai,
socially constructed process of interaction between science, technology, and
groups of people and institutions that form a culture. Aant Alzinga and Andrew
Jamison (1995) have called these bounded groups "policy
cultures", claiming that they are "the main constituencies in the realm of science
and technology policy" and categorizing them as bureaucratic policy culture,
academic culture, economic culture, and civic culture. Alzinga and Jamison
advance constructivist analyses by showing how policy cultures appropriate the
discourse that shapes science policy for the funding of research priorities during
a particular time period.

Alzinga and Jamison also advance the concept of change, or

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13 Alzinga and Jamison (1995) characterize bureaucratic culture as mostly "based in the state administration
with its agencies: committees, councils, and advisory bodies and concerned primarily with effective administration,
coordination, planning, and organization." (Ibid: 576). They claim that academic culture is based primarily among
scientific practitioners themselves and concerned with policy for science and preserving what are seen as traditional
academic values of autonomy, integrity, objectivity, and control over funding and organization. Economic culture is
based on industrial firms, focused on the technological uses of science, and working under an entrepreneurial ethos
"that seeks to transform scientific results into successful innovations to be diffused in the commercial marketplace."
(Ibid: 576). Civic culture is "based in popular, social movements, such as environmentalism and feminism, and
whose concerns are more with the social consequences and implications of science than with its production and
application." (Ibid: 576)
"periodization" as they call it, in policy making. They argue that so far academic analysis of science policy focuses on change of policy priorities as determined by institutional coordination and management by science policy advisors, economic analysis on the periodization of supply-side economics vis-a-vis demand-side economics, and social movement analysis on the periodization of emergence and disappearance of social movements in the political scenario. An example of academic analyses is Harvey Brooks' (1986) periodization of science policy in three distinct epochs: the cold war period from 1945 to 1965, the period dominated by social priorities from 1965 to 1978, and the period of innovation policy from 1978 to the late 1980s. An example of economic analyses of periodization is Christopher Freeman's (1977, 1988) economic study of R&D. Freeman argues that the 1940s and 1950s represent a period of "supply-side" research economics, when government effort was devoted to expanding the resource base for industrial innovation, mainly in the areas of basic research and higher education. After 1965 and throughout the 1970s, Freeman argues, science policy entered a period of "demand-side" economics where the market concerns came to dominate science policy. In the 1980s, Freeman sees a third period, characterized by a combination of demand- and supply-side research economics aimed at fostering innovation. An example of social movement analyses of periodization is Jamison et al's (1990) study of the making of new environmental movements in Europe. There they argue that the
1950s and 1960s are seen as a time of "awakening" when the detrimental social and environmental consequences of industrial development were articulated and made visible. The late 1960s and early 1970s, they claim, were a time of organization, when new forms of activism emerged and stimulated alternative thinking and calls for institutional reform. From this perspective, the 1980s represented a resurgence of the technocratic optimism of the immediate postwar era and a dispersion of activism into professional public interest organizations and think tanks. (Ibid)

Alzinga and Jamison (1995) prefer to focus on periodization as the result of different levels of the influence of "policy cultures" in the making of science policy in the U.S. in the last 50 years. They describe the following time epochs that have resulted from this process: 1) the 1940s and 1950s, from Pearl Harbor to Sputnik, as a period of "scientistic hegemony...dominated by the voices of academic culture defending academic autonomy and scientific freedom"; 2) the 1960s, from Sputnik to Vietnam, as a period of alliance between academic and bureaucratic policy cultures in response to Sputnik; 3) the 1970s as the period of social relevance when science and technology policy agendas were opened to the concerns of academic and civic cultures but ended with the strengthening of the corporate/economic culture seeking fiscal reorganization; and, 4) the 1980's as the period of "policy of orchestration" dominated by the values of the economic culture responding to the economic
challenge of Japan. In the 1990's, Alzinga and Jamison argue that we are witnessing "a more intimate integration of academic and economic policy cultures" brought upon by institutional reforms and the new entrepreneurial ethos colliding with the traditional values of the academic culture. This is happening as the intensification of economic competition brings more conflictual relations among the Western countries, especially between the three blocks of North America, Europe, and east Asia. (Ibid: 585-7)

There are two striking similarities between Alzinga's and Jamison's analysis of policymaking and mine. First, throughout this dissertation, I make a similar analysis of how different groups struggle to define national agendas during the construction of policy for the making of scientists and engineers. Second, analyzing the same 40 years, I come up with similar time epochs, but mine are defined around different notions of nation that emerge under external and internal threats to the Nation. However, their analysis has two limitations that my dissertation intends to overcome. First, their concept of "policy culture" implies a bounded and homogeneous group of people and institutions sharing the same beliefs and values that are fixed through time, disappearing and reappearing later having the same constitution. By following changes in the meaning of "nation", my dissertation does not bound groups by shared values and beliefs but by the way they position themselves with respect to the emerging cultural model of "nation". at a particular time, in attempts to legitimize
their participation in the making of policy. This conceptualization of social 
groups around the notion of nation allows me to explain change in their values 
and beliefs through time. For example, my analysis can explain why groups that 
once belonged to what Aizinga and Jamison call "civic culture", as it was the 
case of women and minorities in science and engineering in the 1970's, came 
to belong to the "economic culture" in the 1980's. Second, Aizinga and 
Jamison's analysis focuses completely on how "policy cultures" influence the 
development of particular institutions and areas of scientific research. They do 
not account for "policy cultures" influencing the making of people as means to 
fulfill national agendas.

By giving agency primarily to some form of agent, whether in the form of 
institutions, social groups, or policy cultures, the accounts above have 
overlooked the power of discourse. My dissertation analyzes not only the 
construction of official knowledge by social actors but the power of discourses 
about the nation in legitimating their participation in this process. Both discourse 
and social agents make policy and give meaning to what we understand as 
"scientist" and "engineer" in the U.S..

**My approach: The Making of Policy and Selves in Science and Engineering**

I am interested in analyzing the problem of making scientists and 
engineers for the U.S., particularly during periods of perceived national crises.
As we have seen, the approaches mentioned above focus for the most part in
the construction of knowledge but do not provide much conceptual guidance to
analyze the making of persons. For analyzing this problem, I have found
significant guidance in the work of Michel Foucault and contemporary political
theorists who have expanded his notion of "governmentality." Following their
analyses, I have come to understand the problem of making scientists and
engineers as a problem of governance, which in the U.S. centers around the
National Science Foundation. Due to the increasing importance of science and
technology in all areas of American life, the making of scientists and engineers
has become a significant act by the government to ensure national security,
economic growth, and, sometimes, social well-being. However, I recognize the
limitations of foucauldian analyses in dealing with the concept of nation, how it
changes, and with the construction of knowledge. To compensate for the first
limitation, I turn to ethnography of popular and scientific media to observe the
changes of the cultural models of nation and follow their trajectories into
statements about scientists and engineers for the Nation. For the analysis of the
construction of official knowledge, I use concepts from social constructivism as
it has been used in STS. Finally, looking at education and manpower policies in
science and engineering that emerge from power struggles and social
negotiations within time-specific national discourses, I discuss their influence in
defining stereotypic images of scientists and engineers in America. Since I
cannot analyze the impact of these policies and programs on all scientists and engineers, I briefly look at the kind of images of scientists and engineers prescribed in these policies, in order to propose further research to study the impact of these images in the lives of scientists and engineers.

**Foucauldian Contributions**

Most of Foucault's early work and that of his followers focuses on specific "carceral" institutions and corresponding population categories made by these institutions. Most of this work has been oriented towards the clinic and the ill (Foucault [1963] 1973; Finkelstein 1990; Goubert 1982), the prison and the criminal (Foucault [1975] 1979), and the school and the student (Ball 1990). However, a new wave of political theorists are beginning to advance Foucault's theory of power/knowledge as a theory of government or "governmentality".¹⁴

According to Foucault, managing the population of the nation-state became the central problem of governance since the 19th century (Foucault [1978] 1991). This problem led governments into the implementation of techniques of power to reconfigure individuals into specific categories that would allow the nation-state to survive. As Foucault argues, these techniques of power "were never more important or more valorized than at the moment when

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¹⁴ See for example, Burchell, Graham, Colin Gordon, and Peter Miller (1991) collection of writings that try to advance Foucault's concept of "governmentality."
it became important to manage a population: the managing of a population not only concerns the collective mass of phenomena, the level of its aggregate effects, it also implies the management of population in its depths and details."

(Ibid: 102) Furthermore, he argues that "[p]opulation is the object that government must take into account in all its observations and savoir, in order to be able to govern effectively in a rational and conscious manner. The constitution of a savoir of government is absolutely inseparable from that of a knowledge of all the processes related to population in its larger sense: that is to say, what we know call the economy." (Ibid: 100) Contemporary foucauldian theorists argue that these techniques of power, or technologies of government as they also call them, have become instrumental in the management of population and hence in the survival of the modern nation-state. As Miller and Rose put it, these "technologies of government", understood as "mechanisms of objectification of individuals through which authorities of various sorts have sought to shape, normalize and instrumentalize the conduct, thought, decisions and aspirations of others in order to achieve the objectives they consider desirable." (Miller and Rose 1993) In one of his last writings, Foucault himself has referred to the coordinated ensemble of these technologies of government as "governmentality." This ensemble "which has as its target population, as its principal form of knowledge political economy, and as its essential technical means apparatuses of security... is what has permitted the [modern] state to

The study of governmentality has become a particular ethos of analysis "marked by a desire to analyse contemporary political rationalities as technical embodiments of mentalities for the government of conduct." (Barry, Osborne, and Rose 1993: 265) Specifically, these analyses focus on new ways of analyzing the exercise of political power in advanced liberal democracies by means of technologies of government which eventually lead to the "shaping of the private self." 15 Ultimately, these technologies of government are intended to bring social and economic order in contemporary liberal governments by serving both ends of economic government: political economy and social security. (Gordon 1991) The former is served through the efficient allocation of population in the different sectors of the economy, for example, allocating engineers in industries needing technological innovation. The latter is served through the creation of self-regulated social citizens who will eventually integrate themselves into the economy.

Both the situating and the tracing of power and knowledge that ultimately allows the deployment of technologies of government require an attention to language. As Miller and Rose have recognized, "[g]overnmentality has a discursive character: to analyze the conceptualizations, explanations and

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calculations that inhabit the governmental field requires an attention to language." (Miller and Rose 1993: 78-79) This is why I focus my attention to the language of political actors (government officials, representatives of industry, advocates of underrepresented groups in science and engineering) as they struggle to define national problems and their solutions by means of scientists and engineers. However, as Miller and Rose further suggest, in order to understand policy, it must be situated within a discursive field that gives legitimacy to its means and ends: "we suggest that policy should be located within a wider discursive field in which conceptions of the proper ends and means of government are articulated." (Ibid) This is why I locate the language spoken by groups and actors, either in the form of official statements, ad hoc reports, or written policy, within time-specific discourses about the nation. The more their language resonates with the discourse, the more legitimation they have to define problems (ends) and solutions (means).

Miller and Rose do not provide a clear vision as to where this discourse is located and how to access it. A clue comes from Foucault's writings on "politics and the study of discourse" where he points at archaeology as the methodology and the archive as the location to find a discourse. in studying discourse, he writes. "I am not doing exegesis, but an archaeology, that is to say, as its name indicates only too obviously, the description of an archive. By this word, I do not mean the mass of texts gathered together at a given
period....I mean the set of rules which at a given period and for a given society define...the limits and forms of the sayable. What is it possible to speak of? What is the constituted domain of discourse...Which utterances does everyone recognize as valid, or debatable, or definitely invalid? Which has been abandoned as negligible, and which has been excluded as foreign?...The limits and forms of appropriation. What individuals, what groups or classes have access to a particular kind of discourse? How is the relationship institutionalized between the discourse, speakers and its destined audience?...How is the struggle for control of discourses conducted between classes, nations, cultural or ethnic collectivities?” (Foucault [1969] 1991: 58-60)

So what is the discourse(s) that has legitimized policy for the making of scientists and engineers in the U.S.? After having worked with NSF’s programs in education and human resources in engineering, and after having read numerous reports calling for more scientists and engineers in the U.S., I began to discern a particular discourse that gave meaning and legitimacy to everything NSF administrators and policymakers said, proposed, and did about educating and training scientists and engineers in the U.S.. Economic competitiveness began to emerge as a narrative that these actors invoked every time they sought legitimation to their proposals for new programs, budgets, etc. This narrative had the American nation as its domain for it always held the economic interests of the U.S. as the maxims of every action. It is
within this narrative that groups and actors defined the *limits of the sayable* and the *limits of appropriation* about educating and training scientists and engineers. As I read the language used by actors and groups proposing actions for the education and training of scientists and engineers before the 1980's, I noticed that they used different narratives during each decade. For example, officials in the 1960's spoke about the American nation under threat by Soviet science while officials in the 1970's invoked a notion of a nation threatened by social and environmental problems. In sum, in the last 40 years I was able to locate four different narratives, one for each decade, which I call discourses about the nation. I locate the study of policy within discourses about the Nation because, as I will demonstrate, this discourse more than any other has shaped the actions of government (policy) with respect to educating and training people in science and engineering.

An interesting feature of the discourses about the nation is how actors and groups redefine the notion of American nation as they perceive foreign and domestic threats. Explaining the nature of this change is beyond the scope of this dissertation. What is important here is, first, how the notion changes, second, how the new nation looks like, and, third, what kind of scientists and engineers are called to save the Nation from the perceived threat. Both discourse and notions of the nation can be found in many locations of U.S. cultural life. I have selected popular media as one of the most appropriate
repositories of concepts of the nation for many important reasons. Popular media is the place where threats to the Nation are first reported by journalists, politicians, and experts, and usually the only outlet where both the public and government express their immediate opinions on the state of the Nation. In some instances, I use scientific media, such as Science magazine, as the location where scientists and science policy makers meet to talk about national problems and how to solve them through science and technology. As spaces where different languages meet to talk about the Nation, both popular and scientific media provide an appropriate window into the archive of national discourse(s) where one can see what can be said, how can it be said, and who can say it.

Discourses about the Nation do not start nor end in printed media. Actually, locating the exact origin or end of discourse is not what is important. What is important in analyzing discourse, as Foucault argues, "is the law of existence of statements, that which rendered them possible -- them and none other in their place; the conditions of their singular emergence; the correlation with other previous or simultaneous events, discursive or otherwise." (Foucault [1968]1991: 59-60) Hence, my interest in analyzing statements made in the media is to see how the discourse about the Nation cuts across and travel across different areas of national life, for example, from public domains into official domains and vice versa. I am particularly interested in the "law of
existence" of official statements about the needs for scientists and engineers: Who can pronounce these statements? Which concepts of nation are valid and which are not? Who is excluded altogether from making statements?

The appropriateness of official statements, however, does not depend only on how well they resonate with the discourse about the nation. It takes more than addressing the nation's problems and proposing sound solutions for an official statement to influence policy. Official statements' existence and subsequent power to influence policy depends also on who makes them. Groups and actors guarantee their participation in policymaking, not only by how they address national concerns, but also by their relative position to economic and political power. For example, even after groups and actors participating in educational policymaking in the 1980s reached consensus about a notion of the American nation defined in terms of economic competitiveness with Japan, their position with respect to economic and political power played a significant role in whether their statements influenced policy or not. Hence, looking at which official statements, among many, actually end up influencing policy can tell us something about the distribution of power in the making of scientists and engineers.

Foucauldian theorists have given us hints as to what might constitute a statement, let's say about population management, but they do not tell us how these become accepted as official knowledge (procedures) to actually manage
the population. As Miller and Rose claim "discourse requires attention to particular technical devices of writing, listing, numbering, and computing that render a realm into a knowable, calculable and administrable object. 'Knowing' an object in such a way is more than a purely speculative activity: it requires the invention of procedures of notation, ways of collecting and presenting statistics....It is through such procedures of inscription that the diverse domains of 'governmentality' are made up, that objects such as the economy, the enterprise, the social field and the family [including science and technology] are rendered in a particular conceptual form and made amenable to intervention and regulation [policy]." (Miller and Rose 1993: 79) However, we should not assume that statements containing similar "procedures of inscription" (tables, statistics, graphs) have the same level of acceptance. Actually, most statements about scientists and engineers during the 1980's contained sound statistics, tables, graphs, etc. to support their arguments but not all were accepted by Congress as official knowledge to influence policy. Who writes these statements, who endorses them, what kinds of networks of economic and political power support them or attack them, has significant relevance on whether or not these statements become official knowledge. For the analysis of how statements become legitimate official knowledge, according not only to their appropriation of concepts of nation but also on the struggles among social actors who write them, I turn to social constructivism.
Contributions of Constructivism

Constructivism as adopted by the field of STS demonstrates the social nature of scientific knowledge and technological artifacts. According to most constructivists, social groups or individuals define what counts as valid scientific knowledge or technology after negotiating the content of knowledge or the final form and function of an artifact. Cultural, political, and social perspectives of these social groups influence the final outcome of negotiation. For example, in his study of French and U.S. engineering education, Eda Kranakis (1989) explains how cultural differences among relevant social groups in 19th-century French and American engineering shaped different approaches to engineering practice in the two countries. As she argues, "acculturation causes members of a particular community to give consistent preference to certain approaches and to certain 'ways of knowing', which in turn profoundly shape the structure and content of the body of knowledge they produce." (Ibid:7) Meanwhile, Steve Shapin and Simon Shaffer (1985) have shown us how natural philosophers in 17th century England battled from different political perspectives on the relationship between the state and its citizens to construct scientific knowledge that reflected those views. In their words, "solutions to the problem of knowledge are solution to the problem of social order. Knowledge, as the state, is the product of human actions." (Ibid: 344) Wiebe Bijker et al. (1987) show how groups of bicycle users with different socio-cultural and
political perspectives negotiated the meaning and function of what came to be known as the Penny Farthing bicycle: "the sociocultural and political situation of a social group shapes its norms and values, which in turn influence the meaning given to an artifact." (Ibid: 46)

Distancing themselves from the kind of social determinism as outlined above, scholars of actor/network theory argue that the settlement of controversies between actors over what counts as valid knowledge is the result of the proper deployment of allies and resources behind the winning claim. As Bruno Latour (1987) writes, "scientists and engineers speak in the name of new allies that they have shaped and enrolled; representatives among other representatives, they add these unexpected resources to tip of the balance of force in their favour." (Ibid: 90) Furthermore, actor/network theorists argue that scientists and engineers constantly (re)create society ("society in the making") as they battle to legitimate knowledge claims, through the positioning and deployment of other actor and networks. Analyzing how French engineers designed an electric car, Michel Callon (1987) argues that "as they enrol other entities [behind] them, [they] build a world in which everything had its own place." (Ibid: 96)

Like the social constructivists, I view official knowledge about scientists and engineers as a social construct by individuals and groups with different perspectives (cultural, political, and social) on how scientists and engineers are
to be educated and trained. Like actor/network theorists, I also recognize that
the success of statements (claims) in becoming official knowledge depends to a
great extent on the deployment of allies and resources by the actors making the
statements. Nowhere is this more evident than in policy making. Interest groups,
such as universities and industry, and federal agencies, like NSF, deploy allies
(congress persons, lobbyists, expert witnesses) and resources (statistics,
reports, visual metaphors) to legitimate their claims about national problems and
possible solutions with the hope that the claims will eventually direct policy. But
more than the result of negotiation, as the social constructivist would see it, or
the appropriate deployment of allies and resources, as actor/network scholars
would claim, official knowledge in policy making for science education is the
result of a power struggle between participating groups to define the problem of
a nation in crisis in terms of scientists and engineers. It is a power struggle for
the control of reality as defined by the existing discourse about the Nation.
Groups and individuals struggle for dominance of a national reality: for the
appropriation of the notion(s) of nation, the definition of the crisis or problem,
and the proposal of solutions in their own terms. In Foucault's terms, it is a
struggle for the definition of the limits of appropriation of the discourse. Those
groups that establish dominance in the appropriation of the national discourse
and in the solution of the national crisis through scientists and engineers will
eventually shape the meaning of what we understand for "scientist" and
"engineer" in the U.S..

Both social constructivism and actor/network theory have been criticized for their neglect of the power differences between social groups or actors and the "silent voices", their neglect of structural relationships between classes, races, and genders, and the problematic conclusion that knowledge or artifact is final product after reaching closure or after settling a controversy.16 My analysis of the construction of official knowledge for the making of scientists and engineers takes into consideration these criticisms of constructivism not only as a sign of its theoretical limitations but also of its "anemic politics."

In my analysis of groups and actors constructing official knowledge, I consider the power dimensions among those that participate and between these and those who do not participate. The limits of appropriation of a discourse, as outlined by Foucault, establish one level of power differences among individuals, groups, and classes that have access to the discourse and those who do not. This is what happened in the 1960's when a scientific elite excluded the voices of working classes and racial minorities from the discourse about the nation to be saved by science from the threat of Soviet communism. However, once the field of participants has been established, both by the way participants appropriate the discourse about the nation and by their relative position to economic and political power, those who participate are not equal to

16 A criticism of this "political anemia" of social constructivism was first made by Langdon Winner (1991).
one another. Significant power differences along race, gender, and class lines exist among these that cannot be ignored in the analysis of the construction of official knowledge. For example, in the 1980's when women and minorities advocates helped define the problem of economic competitiveness with Japan and proposed solutions, they did not occupy the same position of power as the vice president of IBM who, also as chairman of the NSB, defined the problem of the American nation in similar terms and proposed similar solutions. Likewise, the policy outcomes had different implications for who these two groups. Whose knowledge claims are being voiced and whose are being silenced in the construction of official knowledge about education and "manpower" in science and engineering? Who benefits more from the policy that results from this knowledge? What is this knowledge for? And how does this official knowledge affect the distribution of power in American society? are questions that I address throughout my analysis.

My dissertation serves as a guide for further political action. More than a constructivist account of official knowledge for education policy in science and engineering, my dissertation conceptualizes the absence of and the possibilities for participation of different social groups wanting access to science and engineering education. For example, by conceptualizing the silent voices in the "Age of Science" vis-a-vis the hegemonic voice of scientific academism, the emergence and disappearance of minorities and women from science education
in the 1970's, and their re-emergence in the 1980's as significant statistical categories for economic competitiveness, my dissertation is also a historical account of the possibilities and strategies for marginalized groups to participate in the construction of official knowledge and hence influence policy for science and engineering education.

In contrast to the social constructivist accounts, my analysis does not assume that official knowledge reaches closure. Official knowledge and its subsequent policies undergo continuous transformations as the discourse about the Nation changes. What counts as official knowledge and who participates in its construction is time-specific according to the existing discourse. Different notions of nation require different problem definition and solutions and different groups to propose them. For example, the educational solution that Congress accepted for the Sputnik challenge was not the same solution, nor proposed by the same groups, as the one it accepted for the Japanese challenge of the 1980's.

Scholars from different perspectives within STS have criticized both social constructivism and political theory for their sharp distinctions between the technical domain (e.g., machines, engineers, technical knowledge, facts) and the social domain (e.g., people, politicians, political rhetoric, beliefs). For example, Callon and Latour (1992) have criticized social constructivism for making an unwarranted distinction between the technical and the social, giving
primacy to the latter in determining the form and content of the former. Langdon Winner (1986) has criticized political theory and practice for neglecting the increasingly technical constitution of political society, for its "inability or unwillingness even to begin...the critical evaluation and control of our society's technical constitution." (ibid:57) My dissertation aims at expanding our understanding of how the scientific/technical meets the social/political in the making of selves. This dissertation is an account of how these two dimensions, until now understood as sharply defined and separate by most social and political theorists, are brought together by a discourse about the nation and actually live in the selves of scientists and engineers. As Donna Haraway (1995) would put it, my story of the making of scientists and engineers is one that "insists on the inextricable weave of the organic, technical, textual, mythic, economic, and political threads that make up the flesh of the world."

Back to policy/self making at NSF

After analyzing the construction of official knowledge during different discourses about the Nation, I look at how specific policies that emerge from this process aim at educating and training scientists and engineers as required by the existing needs of the Nation.

As we can see, I have expanded the meaning of science policymaking. We should not view it just as political decisions made by social actors, usually
politicians and experts, about funding priorities for research and education.

Science policymaking is a process that takes place in a discursive space about the Nation. It is a power struggle to appropriate this discourse and define notions of nation, its problems, and solutions. It is about influencing policies and programs to locate, educate, train, and redirect scientists and engineers in appropriate ways. In sum, policymaking is also about making selves for the Nation.

**Methodology**

How do we locate discourses about the Nation? From these discourses, how do we follow different notions or cultural models of nation through a discursive space that includes the media, official statements, into the construction of official knowledge and the making of policy? Where do we look for the very processes and actors that continuously construct knowledge that prescribes how NSF should go about producing the scientists and engineers that the Nation requires? In short, how and where do we enter the *archive* that will lead us into the different levels of power struggles in the making of scientists and engineers for America?

First, I situate discourses about the Nation around important national events that have had significant scientific and technological dimensions: the launching of Sputnik (1957) which took America into the Age of Science during
the 1960's, the Apollo moon-landing (1969) and the emergence of anti-
science/technology movements that marked the beginning of a decade of
science for domestic needs during the 1970's, the rise of Japan as a challenge
in the technological marketplace in the 1980's, and the appearance of new
economic competitors and resurgence of local and global markets that drive the
need for a flexible workforce in the 1990's. From mainstream popular and
science newspapers and magazines, I have collected media representations of
the nation, paying particular attention to calls for science and/or technology, and
hence for specific types of scientists and/or engineers, to save the Nation from
the perceived threat. I am aware that mainstream media representations are
only a window into national culture. These representations, even in the form of
opinion polls, do not represent the views and beliefs of everyone in American
society. For the most part, the articles I used for this dissertation are accounts
from top-level scientists, politicians, and academics on what they believe about
what science and technology can and cannot do to help solve national needs. I
am also aware of marginal representations appearing in the discursive space
that, being ignored or silenced, do not become part of official statements nor the
process of knowledge construction. For example, representations of the Nation
under threat after Sputnik or the significance of the Apollo moon-landing for the
American nation found in *Time, Newsweek, Life,* and *U.S. World News,* differ
greatly from those in the working-class and African American presses, such as
Saturday Review and Ebony. This is representative of what Foucault referred to as "the limits and forms of appropriation" which deny access to groups or classes to the shaping and control of discourse.

Second, I follow dominant notions of nation into official statements made by different groups and actors who try to define the problem and its possible solutions in their own terms. These statements are found in places such as oral and written testimonies during congressional hearings, blueprint reports suggesting national actions, and popular and academic articles, all by groups trying to define the problem, to propose solutions in their own terms, and seeking government and public support. Given its unique mandate to supply the Nation with scientists and engineers "as our national goals require" (USHR 1966), I pay particular attention to those statements that involve the NSF in the solution of the problem. I have collected and analyzed more than 200 reports from the last 40 years from groups and organizations representing government, academia, industry, the professions, and coalitions among these.

I locate the construction of official knowledge around legislative action which usually follows significant national events as mentioned above and an output of statements from different groups and actors defining the problem and proposing solutions. Inside legislative forums, usually a series of congressional hearings that sometimes conclude in the passing of legislation, I analyze the process of knowledge construction as a power struggle among competing
groups trying to gain the control of the problem and its solutions. As Bruce Bimber and David Guston (1995) have argued, "the legislative processes, which unfortunately receive little attention in studies of science policy, reveal directly competing conceptions of how science should operate and of what utility science affords society." Nowhere is this struggle better represented than in congressional hearings dealing with the role of NSF in the solution of the problem, particularly those dealing with proposals for educating scientists and engineers in new ways. Bimber and Guston also recognize this when they write that "the U.S. Congress is a good place to examine how important political institutions are in the shaping of science." (Ibid) Therefore, I have collected and analyzed a large number of congressional hearings and reports which specifically address the role of NSF in the solution of national problems by helping educate and train scientists and engineers. Who participates? who is left out? where do they come from? how do they understand the problem and how do they propose to solve it? are the kind of questions that guide my analysis through this process of knowledge construction.

I conducted and analyzed twelve personal interviews, mostly of government officials, in order to excavate the struggles, past and present, during the construction, legitimation, and transformation of one of the most recent official knowledges and technologies of government institutionalized at NSF: the science and engineering pipeline. These interviews reveal some
conceptual limitations of constructivism for they reveal "subjugated knowledges" or "silent voices" that traditional constructivist accounts have ignored. The interviews illuminate the different interpretations of official knowledge and of technologies of government, thereby showing that "closure" is not final. I am also aware of the limitations that the lack of interviews with scientists and engineers bring to my account. Including such accounts could provide a more comprehensive description of how the cultural processes of policymaking analyzed here influence the lives of scientists and engineers. I intend to include this kind of accounts in future developments of this work.

Finally, I follow the trajectory of official knowledge from its construction to its materialization as programs and policies in education and human resources at NSF, paying particular attention to changes in budget, program, and specific target populations.

Description of Chapters

In chapter 2, I locate the national discourse around the launching of two Sputniks in 1957 which made policymakers and the public in the U.S. question its supremacy in science. I follow a dominant notion of nation advanced by a scientific elite into the construction of knowledge that transformed the national importance of NSF, including its science education programs. My focus in this chapter is on how a scientific elite, responding to the new Soviet threat,
redefined the making of policy and scientific selves through NSF in the 1960s.

By the end of the 1960's, the triumph of U.S. technoscientific over the Soviet threat in space, symbolized by the Apollo moon landing, shifted the perception of the enemy. At the same time, the Vietnam War, energy crises, awareness of environmental degradation and social and racial inequalities in American society defined the face of a new threat. In chapter 3, I locate the national discourse around these events. Then I follow an image of nation "at war with itself" into the struggles to reposition NSF's education and "manpower" programs around these developments. My focus here is on the making of policy for the making of scientific selves to solve domestic problems through applied science. Women and minority groups emerged for the first time demanding their participation in science to help solve national problems.

While in the 1970's the discourse about the nation spoke of internal struggles for social justice, environmental problems, energy crisis, and a war that had come home, in the 1980's the discourse shifted to a national preoccupation with Japan. In chapter 4, I locate the national discourse around the emergence of Japan as an economic challenge to the U.S. I follow a notion of nation formulated mainly in terms of economic competitiveness into the power struggles that redefined NSF, particularly its education and manpower programs, as an instrument to develop technological innovation. I also analyze the emergence of women and minorities in science and engineering as
significant demographic categories to help the U.S. produce large numbers of scientists and engineers "to beat the Japanese." My focus here is on the making of policy for the making of scientists and engineers for economic competitiveness.

In the 1990's, the face of the enemy has become multidimensional and complex. With the Soviet threat gone for good, the appearance of a unified Germany and the "Seven Tigers" of the Pacific Rim as new economic competitors, a discourse about the nation in terms of intensifying global competition has emerged. In chapter 5, I locate the national discourse around these events and follow an image of the nation, reconceptualized in terms of flexibility in a global political and economic space, into the construction of knowledge that pretends to transform NSF "for a changing world". My focus in this chapter is on the current shift of NSF's policies and programs, from producing large numbers of scientists and engineers "to beat the Japanese" towards making flexible technoscientists capable of rapidly adjusting to changes in knowledge production, dissemination, and application brought by ever-changing global markets.

I conclude with some general remarks about what a cultural history of NSF can tell us about national culture, including the making of policy and images of what we call "scientist" and "engineer." I include some questions for further research and research recommendations for the field of STS.
CHAPTER 2
Scientific Academism and Science Policymaking after Sputnik:
Making Scientific Selves for the Cold War

The launching of Sputnik brought significant changes in the discourse
about the American nation, mainly by shifting an anti-communist sentiment from
the political to the scientific and educational arenas. McCarthyism became a
thing of the past only to be redefined as a fight against communism by means
of science and scientists. A group of scientific elites seized upon America's
fears and called for science to save the nation. Government action immediately
followed, dramatically increasing support for science and science education.
Consumerism, as the main feature of the "American Way of Life" of the 1950's
took second place to science which the government began promoting as a "way
of life." (HEW 1961). This chapter analyzes how the a narrative of a nation now
under threat by Soviet science permeated the policymaking process that
positioned NSF as the institutional mechanism to make the scientists required
for the "Age of Science" in the 1960's.

During the early years of the Cold War, a discourse of the nation
emerged around two central themes: anti-communism and consumerism.
America became a space that government and public needed to defend from
communism and producers and consumers kept prosperous through production
and consumption of a large output of goods and services generated under a
bountiful post-war economy. Government and the American public launched a
war against communism both at home and abroad. As Whitfield (1991) tells us, "[v]igilance against communism was a national priority during the darkest days of the Cold War, from the late 1940s until the mid 1950s. Abroad, the government mobilized alliances and vast military resources to combat Soviet expansionism... [at home, popular media] consistently hammered the theme of an enemy within, working to subvert the American Way of Life." (Ibid: vii) Corporate America and mainstream consumers entered into a holy relationship of mutual production and consumption. Manufacturers produced endless quantities of labor-saving devices and sold them to buyers seeking immediate status and gratification.¹ Corporate America promoted images of individual consumerism as symbols of good civic and family virtues. Arthur Bec Var, head of appliance design at General Electric in the U.S. put it clearly, " [in the 1950's]...more emphasis is placed on home and family living... larger families and lack of servants have necessitated as many automatic helpers in the home as possible. By this investment in mechanical servants, an individual can show how he is providing for his family." (quoted in Forty 1986) Consumerism came to define the "American Way of Life." "Credit cards were launched with the first Diners Club card in 1950, repudiating the ancient commandment of frugality and encouraging immediate gratification instead...[t]he bounties pouring forth from

American factories and laboratories, made available in such profusion in stores and markets, had become perhaps the chief ideological prop—the most palpable vindication—of 'the American Way of Life'." (Whitfield 1991: 71)

The successful defeat of Communism began with the individual. The church played a significant role in bringing the notion of the American nation into the individual. Individual praying, motivated by evangelist preachers such as Billy Graham, was the first line of defense: "Only as millions of Americans turn to Jesus Christ at this hour and accept him as savoir, can this nation possibly be spared the onslaught of a demon-possessed communism." (quoted in Ibid: 81) American households became sites of civil defense against the threat of Communism where psychological and social emotions were "managed." ²

American education embodied this notion of a patriotic nation free to produce and consume and willing to fight communism. After WW II, the federal government implemented educational programs which assisted mainstream middle-class individuals to realize the "American Way of Life" while instilling civic virtues. In return, the American individual ensured the well-being of himself, his family, and his nation. The most ambitious of these initiatives was the G.I. Bill which became a legislative mechanism to bring the mainstream in line with the needs of the nation. Through the G.I. Bill, the federal government

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² For an account of the strong connections between anti-Communism and religiosity, see Mark Silk’s (1988) Spiritual Politics: Religion and America since World War II. Also, for an account of the management of individual and social emotions during the Cold War, see Guy Oakes’ (1994) The Imaginary War: Civil Defense and American Cold War Culture.
gave war veterans the opportunity to integrate back into civilian society and realize their capabilities as productive citizens. Approximately 7,800,000 veterans went to school under the G.I. Bill. Most of them studied liberal arts, humanities, social sciences, and business. This legislation brought renewed attention to progressive education, particularly its emphasis on vocational education (homemaking, health, commercial English, auto mechanics) at the expense of more intellectual endeavors such as basic sciences and foreign languages. (Lora 1982)

As Cold war tensions increased in the early 1950's, with the Chinese revolution and the outbreak of the Korean War, the focus of education began to move away from personal and community goals towards national goals. For the first time a pervasive national logic seeped into American classrooms. Some educators began viewing educational institutions as instruments of national security. Hence, schools needed to educate in "moral and spiritual values, teach democracy, increase devotion to public welfare [and] make 'efficient producers' [as] a 'resource' to be used by the government for national purposes." (Ibid: 237) Likewise, institutions of higher education had “to lift

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3 See for example, John Emens' (1965) “Education Begets Education: The G.I. Bill Twenty Years Later.”

4 For examples of the influence of Progressive education on American education in the early 1950's see U.S. Office of Education (1951) Life Adjustment for Every Youth, and the National Education Association (1944) Education for All American Youth.

5 See, for example, National Education Association and American Council on Education (1951) Education and National Security.
'each student to his highest capacity to contribute to the nation's strength'. They would contribute to the national defense by educating a major portion of the officer corps and by producing a young population that was unflinchingly anticommunist." (Ibid) Powerful actors brought these views to the forefront of educational policy making during the years before Sputnik. A scientific elite, including Vannevar Bush, James Bryan Conant, and James Killian, came forward to oppose the instrumentalism and collectivism of progressive education while favoring the development of a [national spirit] through the "deliberate cultivation of the ability to think" nurtured by basic disciplinary education, particularly in the basic sciences.\(^5\) I call this group of selected individuals, and the ideas and values they promoted, scientific academism.

In his account of the role of science in American education, Scott L. Montgomery (1994) has labeled the emergence of this elite after Sputnik as "the return of academism." He defines academism as "the oldest educational philosophy in modern Western culture...[which] grew out of a system of higher learning originally intended to strengthen and perpetuate monarchical government and its elite servants, by training a stratum of 'higher individuals'". (Ibid: 21) I have added the word "scientific" to Montgomery's definition of

\(^5\) For the most controversial criticism of progressive education in the 1950s see Arthur Bestor's (1953) *Educational Wastelands: The Retreat from Learning in Our Public Schools.*
academism because this group of extremely influential scientists proposed to strengthen, perpetuate, and save the American nation and its government by educating an elite group of citizens in the basic sciences. The newly educated elite came to embody the very concept that scientific academists themselves represented: a scientific expert with significant power in both academia and government. Their location in both government and academia differentiated them from academic scientists who were strictly located inside academia. For example, Vannevar Bush was president of the MIT corporation and became director of the Office of Scientific Research (OSRD) and science advisor to President Roosevelt. James Conant, the "high priest of Academist policy", was president of Harvard University before becoming NSB's first chairman in 1951. James Killian was president of MIT before becoming science advisor to President Eisenhower after Sputnik. These scientific academists hoped to ensure the survival of the nation through a newly educated elite that would move from the academy into high-level positions in the government during times of national need. If successful, scientific academists would connect the nation to the academy not only through themselves and their networks but by promoting and popularizing the idea of elite education for national security.  

\[7\] Scientific

\[7\] Besides writing his influential report *Science: The Endless Frontier*, Vannevar Bush also wrote *Modern Arms and Free Men*. For Conant's elitist ideas on science education, see his (1945) *General Education in a Free Society*, and his (1952) *Modern Science and Modern Man*. For Rickover's views on academic elitism and national security and his pleas for more scientists and engineers to lead the war against Soviet communism, see his (1959) *Education and Freedom*.  

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academism became the most influential voice in the construction of official knowledge for postwar science policymaking, particularly for the creation and development of NSF and its science education and manpower programs.⁸

Occupying top positions around and within NSF, scientific academists began reinterpreting NSF's mandate on national security. This group of elite scientists used NSF's seal of approval to publicize the dangerous effects that progressive education was having on national security. Probably directed by Conant, president of Harvard and chairman of the NSB, NSF commissioned Nicholas DeWitt, of the Russian Research Center at Harvard University, to conduct a comparative study of U.S. and Soviet scientific and engineering manpower (DeWitt 1955). With the full endorsement of the National Academy of Sciences and NSF's director Alan Waterman, the report criticized the products of progressive education claiming that the U.S. was producing too many businessmen, lawyers, and humanity scholars and not enough scientists and engineers. The report claimed that even though the U.S. had larger enrollments in higher education than the Soviet Union, particularly in the areas associated with progressive education, it fell behind in the production of scientists and engineers:

Graduating classes in the Soviet Union are today [1954] still substantially smaller than those in the United States....There is, however, a radical

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⁸ See Kleinman (1995) for a detailed account of how a small group of scientific academists shaped the policymaking process during the postwar that defined NSF's structure and future.
difference in the composition of these graduating classes in the two
countries. This difference in the graduating classes represents a
reflection of the emphasis placed upon the training in specific fields in the
two countries...[i]n the Soviet Union over 60 percent of the graduating
classes were composed of engineering and other natural and physical
science majors... In the U.S., less than 25 percent of the graduating
classes were in the[se] fields...Therefore,...the Soviet Union, with
substantially smaller total graduating classes, produced more
professionals in the various technical and scientific fields than the
U.S....At the same time, of course, the Soviet Union had a drastically
small number of “other field” graduates -- in the humanities, the social
sciences, and the liberal arts -- which represents 65 to 70 percent of all
U.S. graduates...(Ibid: 167-9)

Scientific academism now had in their hands an important official
statement with a clear message: the Soviet Union produced more scientists and
engineers than the U.S.. But even with the powerful endorsement of scientific
academism, Dewitt's report, only 375 pages long in 1955, received little
government attention outside the science policy circles previous to the
launching of Sputnik. Although it gained access into the policy arena, the report
was not yet certified knowledge able to influence policymaking and action. As
U.S. House Representative Albert Thomas (D-Tex) said during NSF
appropriation hearings in 1956:

This little book, Soviet Professional Manpower, I have read word for
word...and after reading it completely reversed my thinking...Of course
we do not have to tie [with] the Russians by any means, but we found
out what Russia is doing...If this [book] is true...in another five or six
years they are going to be ahead of us. Lord help us if they ever reach
the point where they are ahead of us, and they are too close to us now.
(quoted in Kriehbaum and Rawson 1969: 187)
Government attention on manpower was focused on developing scientists and engineers for atomic energy. Confident with a number of "firsts" in the use of atomic energy, but worried that the Soviets were catching up, the Joint Committee on Atomic Energy of the U.S. Congress held congressional hearings on manpower throughout 1956 to assess how the federal government was to initiate "a crash program to increase swiftly and steadily the number of adequately trained American scientists and engineers" (U.S. Congress 1956: v). U.S. House Representative Melvin Price (D-III), Chairman of the Subcommittee on Research and Development of the Joint Committee, understood the potential danger as defined by DeWitt but realized that Americans had not yet come to see this reality:

It should be no secret that the U.S. is in desperate danger of falling behind the Soviet world in a critical field of competition—the life and death field of competition in the education and training of adequate numbers of scientists, engineers, and technicians. But although it is not a secret, the facts have not sunk into the public mind (Ibid)

National reality as described by DeWitt "had not sunk into the public mind" because all the nation needed to fight communism was patriotic citizens educated in the liberal arts and humanities. In pre-Sputnik America, an official statement like DeWitt's, even if endorsed by scientific academism and believed by Congress, could not become official knowledge until the nation demanded

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9 U.S. explodes its first atomic bomb in 1945 and it is the first one to use atomically generated power in 1955.
science education for its survival.

For now, NSF was a small agency not even considered important in the development of manpower for atomic energy. Even after the Joint Committee recognized that the emphasis on the creation of this type of manpower "must be on federal leadership because nothing else will do", NSF was not considered as a plausible institutional solution for this task. Eventually with two Soviet satellites up in the sky and a nation calling for science education, DeWitt's report, re-published in 1961 and 836 pages long, became a significant piece of the official knowledge that guided post-Sputnik manpower policy, positioning NSF's manpower and education programs at the center of federal efforts to make scientists for the Cold War.

Influenced by scientific academism, congressional leaders such as Melvin Price, the President, and high-ranked military officials began to describe a nation in need of education to fight communism. They began to see education as an institution to produce enough scientists and engineers for national security. However, prior to Sputnik they had not yet made a commitment to basic science education. For example, in May 1957, the Joint Committee on Atomic Energy declared that:

The war which international communism is waging against us has been referred as the "war of the classrooms". It is a war that at present is not being fought with spectacular weapons as guided missiles, but which is employing a proper instrument of civilization seized upon and converted to use as a weapon; namely education. (U.S. Congress 1957)
Key national figures, such as President Eisenhower, delivered official statements in the progressivists backyard that conceptualized education in terms of national survival to communism, not in terms of individual fulfillment. Addressing the powerful and pro-progressive National Education Association (NAE)\textsuperscript{10} in April of 1957, President Eisenhower stated:

Our schools are strong points in our national defense. Our schools are more important than our Nike batteries, more necessary than our radar warning nets, and more powerful even than the energy of the atom (quoted in U.S. Congress 1957)

Statements by scientific academism that spoke of manpower numbers, such as DeWitt's, resonated with the existing military logic that called for large numbers of personnel to be enlisted and ready for combat. The Armed Forces began defining the problem of the Cold War as that of numbers of scientists and engineers. Early in 1957, Lt. Gen Emmett O’Donnell, Chief of the Air Force, declared that:

We are losing a war. We are losing it because we are losing the race to produce more and better engineers and scientists than the Communists are doing (U.S. Congress 1957: 4)

Scientific academism was careful to position basic knowledge in its proper place. The Cold War, as they saw it, was not just about classrooms and numbers. It was about the best and brightest students being educated for basic

\textsuperscript{10} Lora (1982) claims that the NAE embodied the “anti-intellectual educational climate of the times” when its Educational Policies Commission endorsed “civic competence and personal development” over “intellectual education.” See, NAE, Educational Policies Commission. 1944, \textit{Education for All American Youth}. Washington, D.C.
scientific research. In the words of NSB's second director, Detlev Bronk, in his foreword of NSF's 1956 Annual Report to the President and the nation:

New discoveries of natural knowledge and its application at an unprecedented rate have strengthened our military defenses, stimulated our national economy, and bettered human welfare...In this scientific age it is more true than ever before that trained minds are our greatest sources of power and our most powerful weapons. The mission of the NSF is to prepare the minds of young scientists for the high purpose of research...Appropriations for such a purpose are secure investments in the future of our country and in the welfare of its people. (NSF 1957: vii) (Emphasis mine)

On the eve of Sputnik, scientific academism was seeking national consensus on the importance of science education for national security. "[When] Sputnik finally pierced the thick armor of American pretensions to superiority," Lora (1982: 243) argues, the powerful proponents of scientific academism "looked very much like prophets whose time has come." However, before October 1957 there was no national consensus on what kind of education and what level of federal involvement was best for the nation. The American public was still content with liberal education for the mainstream while the military was trying to define the problem of education as a matter of numbers. Knowing that the Soviets placed most of their professional workforce in engineering and sciences, Congress worried about a federal mandate overemphasizing education in specific fields while cognizant of the need to increase numbers in science and engineering. Summarizing the main legislative question in their
agenda during hearings on the development of scientific and engineering manpower, the Democrat-led\textsuperscript{11} Joint Committee on Atomic Energy asked: "how to protect the Nation against communism while giving the whole population educational advantage in many fields of knowledge not required by the communist dictatorship." (U.S. Congress 1957: 29). On the other hand, Congress and the President wrestled over the dangers of federal involvement in education. Fearful of federal control of education, H. Rep. Albert Thomas (D-Tex) stated during NSF's appropriation hearings in 1956:

The Congress is now wrestling with the aid to education bill. Congress is pretty well divided and the country is pretty well divided on whether the federal government should step into the field of education or whether the field should be left to the States....Is the NSF getting into that field of education that has heretofore been left to the States? Is the Federal government through the Foundation moving into that field? (quoted in Kriegbaum and Rawson 1969: 189)

Sputnik made the question of federal involvement in education less important as congressional leaders from both sides of the aisle and the President reached consensus on the importance of science education for the survival of the nation. But for now, there was no symbolic evidence of Soviet superiority, only numbers. Reflecting on his directorship of NSF (1950-1963), Alan Waterman recalled where government officials and policymakers turned to for knowledge to initiate science education programs to respond to Sputnik:

\textsuperscript{11} The Committee's chairman was H.Rep Carl Durham (D-NC) and its vice chairman was Sen. Clinton Anderson (D-NM).
"when all the soul-searching began after Sputnik, a lot of people remembered DeWitt's book and the emphasis the Russians had been putting on training scientific manpower..." (interviewed in Kriegbaum and Rawson 1969: 226)

Sputnik would make DeWitt's official statement into knowledge and scientific academists into "prophets" and also into the highest-ranked officials to advice the government on scientific matters including science education and manpower. But first, they had to appropriate the discourse about the nation, defining national problems and solutions in terms of science and scientists.

Sputniks and the Making of Science

Americans' love affair with space technology began at least two years before Sputnik. Advertisement campaigns, popular writing, amusement-park attractions, TV shows, and volunteer organizations, such as the Moonwatchers, contributed to the dissemination of space technology into the national discourse as early as 1955 (see Parks 1995). However, when Americans witnessed a great success of space technology with the launching of the Sputniks in 1957, they stood in fear of this new aspect of the Soviet threat. The launchings brought the image of communism home in a way that not even the paranoia of Sen. McCarthy was able to do. With Sputnik flying over American skies every night, its radio signal beeping on TV's and radios deep inside the American household, the threat of communism moved to a new dimension in the popular
imagination. Popular media depicted Sputnik as "the feat that shook the earth" (Life 1957b) and as the Soviet satellite that sent the U.S. "into a tizzy." (Life 1957a).

Sputnik changed the national discourse in many ways. Different sectors of American society came to deal with the newest Soviet threat in different ways. For example, American industry and the American consumer appropriated the discourse in their own terms: consumerism. Restaurants began serving "Sputnikburgers", bars sold "Sputnik cocktails", and Americans began watching TV programs such as The Jetsons, My Favorite Martian that positioned space and scientific themes right at the heart of the popular imagination. (Parks 1995: 11) As Lisa Parks tells us, "mainstream American culture commodified and domesticated Sputnik, positioning it within the discourse of American nationalism rather than leaving it to circle the earth on its own accord." (Ibid:16)

Sputnik was also appropriated by scientific academism as an opportunity to sell science to the general public. Sputnik became visible and audible evidence of Soviet communism proximity to the U.S., its possibility for world expansion, and its superiority in science:

For the brotherhood of man, this tremendous scientific achievement

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12 For a feminist analysis of the appropriation of discourse through film and sci-fi literature, see Lynn Spigel's (1991) "From Domestic Space to Outer Space." For a more general analysis of the appropriation of discourse through business, see Walter MacDougall's (1985) The Heavens and the Earth: A Political Economy of the Space Age.
should have been an occasion of universal pride and triumph, a time of rejoicing. But the grim, sad fact was something entirely different. Because this achievement had been reached, in a torn world, by the controlled scientists of a despotic state—a state which had already given the word "satellite" the implications of ruthles servitude. Could the crushers of Hungary be trusted with this new kind of satellite, whose implications no man could measure? (Newsweek, October 14, 1957)

Through science the USSR had solved the technical problems to keep the U.S. under constant threat and surveillance. As one weekly magazine put it: "Russia had solved important problems of guidance necessary to aim its missiles at U.S. targets...[and could] watch the U.S. unhindered and [with] deadly accuracy." (Ibid)

Science made it into popular media as both the reason for the Soviet success and as the only alternative through which the U.S. was to fight the latest communist threat. First, the Soviets immediately reaffirmed their success by releasing international press statements letting the world know the significance of Sputnik for the Soviet Union. A.P. Aleksandrov, president of the USSR Academy of Sciences, wrote to the international press:

The initial decisive step of a new [scientific-technological revolution] was taken in the first country of socialism. In this region of technology, socialism has surpassed capitalism. The scientific-technological superiority of the new, more progressive social order is clear. And if we still haven't passed the most progressive capitalist countries in all regions of science and technology, ten in any case their superiority is a thing of the past. (quoted in Josephson 1990: 177)

Aleksarov concluded his article by observing that the USSR had more
engineering students than the U.S. and by suggesting that training in physics and mathematics was specially important to ensure the USSR’s leadership.  

Without knowing, Aleksarov was legitimizing both scientific academism in the U.S. and their official statement on the numerical superiority of the Soviets.

At home, mainstream popular media popularized the views of both Soviet and American scientists. The same magazines that ran countless ads of labor-saving products for the American home began writing editorials that questioned the usefulness of these products in the race to world supremacy:

The central fact that must be faced up to is this: As a scientific and engineering power, the Soviet Union has shown its mastery. The U.S. may have more cars and washing machines and toasters, but in terms of the stuff with which wars are won and ideologies imposed, the nation must now begin to view Russia as a power with a proven, frightening potential (Newsweek Oct 14, 1957)

In a field-by-field survey of all Russian sciences, scientific experts from all over the world agreed that while the USSR lagged in some fields of applied science, it led the U.S. in most fields of basic scientific research. (Newsweek, Nov 11, 1957) "What is important about the Russian satellites is the base of science beneath them," the survey article asserted as it went on to ask world experts, "but where do the Russians stand over-all, in the many studies lumped together as science?" (Ibid) "Today they are probably ahead of the West in this science."

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13 For a complete analysis of how Sputnik was viewed in the USSR see Paul Josephson's "Rockets, Reactors, and Soviet Culture" in Graham (1990)
one expert said referring to mathematics, "[but] the Russians may lag in the applied mathematics of automation and computers." Another expert on solid-state physics asserted that "their basic research is as good as any to be found in the West, and this somewhat counterbalances the fact that Russia has fallen two to five years behind in application." (Ibid) Through the popular media, scientific experts popularized their definition of the problem: while lagging in most fields of applied science, the Soviets accomplished Sputnik through basic science, more specifically mathematical and physical sciences. The position of basic science in the survival of the nation became very clear. As that weekly magazine concluded:

The recent Russian advances are not merely isolated technological breakthroughs; they are the result of a long-term emphasis on basic research which is the great strength of Soviet science. An estimated 20,000 Soviet workers annually enter this field, where great discoveries are made (including weapons). By contrast the U.S. increases its basic research staff by fewer than 10,000 workers a year, concentrating instead on applied research leading to the better air-conditioner and the noiseless commode. (Ibid)

These media depictions of the Soviet threat gave a clear message: basic science had become a weapon to impose political ideologies, "the stuff with which wars are won and ideologies imposed," as Newsweek reported it. Scientists working on basic scientific research became the new soldiers in the "War of Science", and figuring out "how to mobilize" scientific brainpower became a matter of national survival (Newsweek 1957). Both popular media
and scientific academism excluded engineering and engineers from the efforts to save the nation. For example, a special issue of "Life" magazine that followed Sputnik showed scientists teaming up with armed forces and business to "map the future [and] to produce missiles" while engineers helped build a dam in Pakistan. (Life 1957) So overwhelming was the image of science in America that as early as 1961, the federal government began promoting "Science as a way of Life."(HEW 1961). Addressing the American public through promotional literature, the U.S. Department of Health, Education, and Welfare (HEW) asked:

"What must be done to make certain that our schools will produce more and better trained young men and women to become the scientists of tomorrow--trained and inspired to make the break-throughs that can help secure both the economic and military leadership of America for the decades ahead?..."(Ibid: 9)

The response that HEW proposed was that

...Our schools must teach science so that it becomes a way of life for all pupils. or these pupils when they get out into the world, will be unable to cope with the problems which that world will thrust upon them...To move and vote and eat and sleep--in short, just to exist in the world means that each individual must be scientifically literate..."(Ibid: 11)

Sputnik not only put basic science on center stage but also the federal agencies in charge of funding basic scientific research and education. As MacDougali (1985) tells us "Sputnik became a catalyst for various governmental agencies to sell their particular programs as cures to the presumed ailments of American life that contributed to the loss of the space race." (quoted in Parks
1995: 16) As another group of leading scientists criticized the state of affairs of American science, Dr C.C. Furnas, former Assistant Secretary of Defense for Research and Development, concluded that

in order to go back and win the race for scientific supremacy, we must revise our naive attitude toward basic research...And Congress, now that it has created the National Science Foundation, should have the courage to vote it the funds it needs to carry out many important programs. (Life, 1957:22-3)

As scientists from all walks of life defined the problem in terms of basic science and scientists, scientific academists connected the nation to science education. After publishing early reactions from professional educators on Sputnik14, popular media turned its focus to comparisons between Soviet and American educational systems. Although since 1955 Dewitt's report had contained the most comprehensive USSR-U.S. comparison and had illustrated the U.S. shortfall of numbers, popular media achieved better success in shifting national attention to science education. In early 1958, Life magazine ran a 5-part series on the "Crisis in Education" that explored every aspect of "the field of battle for future brain power--the U.S and the Russian schools." Referring to the champions of scientific academism, the first article of this series opened by stating that "for most critics of U.S. education have suffered the curse of

Cassandra-always to tell the truth, seldom to be listened to or believed. But now the curse has been lifted. What they were saying is beginning to be believed. The schools are in terrible shape. "What has long been an ignored national problem, Sputnik has made a recognized crisis." (Life, March 1958)

The article continued criticizing the outcomes of progressive education saying that

in their eagerness to be all things to all children, schools have gone wild with elective courses.....where there are young minds of great promise, there are rarely the means to advance them. The nation's stupid children get far better care than the bright. The geniuses of the next decades are even now being allowed to slip back into mediocrity...There is no general agreement on what the schools should teach. A quarter century has been wasted with the squabbling over whether to make a child well adjusted or teach him something. (Ibid)

The series of articles concluded with James Conant's blueprint for high school curriculum, the first published statement of his overall idea. (see figure 2) In this plan, the article claims, Conant is giving "the essence of a significant and workable answer to the basic problem of U.S. education: how to raise its intellectual quality -- giving the best minds a chance for unhampered intellectual growth-- and yet still preserve its traditional democratic ideas." (Life 1958)
Figure 2. James Conant's Blueprint for High School Curriculum
This series of articles is a good example of how scientific academists appropriated the discourse about the nation in popular media, developing a notion of nation on their own terms, connecting nation and education. Exacerbating the fears of Soviet expansion and domination, they defined the problem as a nation in danger that only basic science and top quality scientists could save. Conant's proposal is the best example of how scientific academists also defined the solution: a meritocratic educational system where the "bright" were to be nurtured into scientific careers, the "average" were taught how to build the physical infrastructure, and the "slow" were trained to provide basic services for society. While scientific academists defined the problem, NSF remained absent only to appear every so often as a possible solution to carry out programs in science education.

The new notion of nation with its problem and solution now defined by scientific academism and popularized by mainstream popular media flowed into official statements on educational and manpower policy in science and engineering. Early official statements, such as the one by President Eisenhower only one month after Sputnik but before the overwhelming popularization of science, shows how the problem was still perceived under a military logic as a matter of numbers. Addressing the nation about Sputnik for the first time, he said: "this [national security] is for the American people the most critical problem of all... we need scientists by the thousands more than we are now presently
planning to have." (Eisenhower 1957) Official statements made a couple of months after Sputnik reflect how the new notion of nation entered the policy making space and served as a reference point for congressional leaders and scientific academists to begin setting the limits and forms of what was sayable about education in the U.S..

Congressional hearings on "Science and Education for National Defense" held by the Committee on Labor and Public Welfare of the U.S. Congress at the beginning of 1958 exemplify this process. During these hearings, Senator Lister Hill (D-Ala) not only began setting the limits of discourse but he did it with the help of scientific academists who Hill enrolled as witnesses. As Clowse (1981) claims in her historical account of the educational crisis following Sputnik, "his [Lister Hill's] remarks set the tone of the entire proceedings. Both the choice and order of witnesses aimed to establish that education and national defense were now inseparable. HEW officials helped Hill's staff locate witnesses who would testify along those lines." (Ibid: 83) Lee DuBridge was among Hill's scientific academist allies. According to Clowse, "DuBridge was to testify later at the House hearings, and while in Washington, he conferred with committee staff members. He reiterated his hope that federal action could raise intellectual standards in both high schools and colleges. He wanted to see promising

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15 At the time, DuBridge was president of CalTech. He had been a member of AEC (1948-52), chairman of the Science Advisory Committee of the U.S. Office of Defense Mobilization (1952-56), member of the National Science Board (1950-54 and 1968-64), and member of the National Manpower Council (1951-64). He eventually became science adviser to the President in 1969-70.
students identified and rewarded. DuBridge believed that the federal scholarship idea would help if it were based on merit. He had already offered his opinion of the administration bill to Dr. Killian. He told Killian that the program was justified and attacked serious problems. Like other administrators, he thought that it was a mistake not to offer funds for new buildings." (Ibid 84) Other impressive enrollments which allowed Senator Hill to shape the limits of discourse were German rocket scientist Wernher Von Braun and U.S. Admiral Rickover. Both endorsed education programs oriented towards creating a scientific elite. With an impressive lineup of elite scientists, scientific academists, and high-ranked military officials, it became possible for congressional leaders like Hill to speak of a nation under threat not just by Soviet communism but by its science and technology. Chairman Senator Lister Hill (D-Ala) opened the hearings wondering how

The Soviet Union, which only 40 years ago was a nation of peasants, today is challenging our America, the world greatest industrial power, in the very field where we have claimed supremacy: the application of science and technology. (USS 1958:2)

Second, lawmakers like Hill could now admit that America’s position in the world had been shattered, provoking a national self-questioning maybe unprecedented since times of the Depression. According to Lister Hill:

[a] severe blow--some would say a disastrous blow-- has been struck at American self-confidence and at her prestige in the world. Rarely have Americans questioned one another so intensely about our military position, our scientific stature, or our educational system. (Ibid)
Third, if before Sputnik congressional leaders had any doubts of the value of science education for national needs, after Sputnik lawmakers were able to propose policy for science and science education as means of national defense. Chairman Lister Hill opened the door for support of basic scientific research and "brainpower" as means for national survival:

We Americans are united in our determination to meet this challenge. We Americans know that we must give vastly greater support, emphasis and dedication to basic scientific research....We Americans know that we must mobilize our Nation's brainpower in the struggle for survival...(Ibid)

Fourth, high-ranked military officials were then able to criticize, as popular media and scientific academism had already done, the "American Way of Life." Consumerism was undermining new national duties. No one was more explicit on this issue than Admiral Burke, Chief of Naval Operations, who during a congressional hearing comparing U.S. and Soviet science education to determine appropriations for the National Science Foundation, said:

Our country has grown strong in an environment of personal liberty, human dignity and sound moral and spiritual values. Today, however, in our preoccupation with fringe benefits, higher pay for less hours of work, two cars and a motor boat for every family, we run the grave risk of becoming complacent in our position of world leadership, and of becoming indifferent to the realities of the hard competition we face from the Soviets (USHR 1960: 4)

Fifth, as long as there would be no interference with the constitutional rights of states and localities, proposals for the federal government to intervene in education were acceptable. Chairman Lister Hill (D-Ala) recognized the
inevitability of federal intervention and the potential for conflict with States and localities:

The particular task of this committee is to consider how best to stimulate and strengthen science and education for the defense of our country and at the same time preserve the traditional principle, in which we all believe, that primary responsibility and control of education belongs and must remain with the States, local communities, and private institutions (USS 1958).

What the new notion of the nation still did not allow was to speak about the possibility of the federal government to tell its citizens where to work, even if it was in the best interests of the Nation. As Senator Lister Hill put it:

the Russian under their system tell a scientist or engineer where he is to work and what he is to do. He has to do what they say or get a trip to Siberia. Under our free system we do not seek to tell anybody what to do. If they want to work with a tobacco company, of course, they are free to do that. So it makes it all the more important for us, because we do not want to control what people do, that we have a sufficient number [of scientists and engineers] to do these jobs for defense, for teaching of our youth... (Ibid: 225)

Congress dismissed those bills that proposed centralized actions, such as the proposal to create the U.S. Science Academy to train scientists and engineers in a centralized location, in favor of actions that did not compromise individual liberties nor infringed on State and local governments.16 As Dr. Harry Kelly, Associate Director of Educational and International Affairs at NSF, put it:

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16see U.S. Senate (1958, 1553) for a list of all bills related to science education, particularly S. 2957 and S. 2967. 85th Cong, 2d sess
Education in the Soviet Union is completely designed for purposes of the State... and the function of education is to produce the needed servants. The Soviets, in planning the future of their State determine the needs for people in different professions and thereby determine the number of students in each area. In the free world, education is directed towards the development of the individual... (USHR 1960b: 14)

Educators dismissed any attempts to transfer any part or concept of the Soviet educational system. Testifying on behalf of the National Education Association, Mr. William Carr said:

The Soviet system of education is set up to serve a totalitarian society in which assignment to work is determined by the Government, the allocation of manpower is subject to centralized control... Given our basic economy and our basic values, it is probably as bad a system of education as we could get. I think we ought to go ahead and set up an American system of education, as we have been doing over these years, and not try to worry too much about what the Soviet Union, or any other country, does. If there would be any single rule about the Soviet system of education that we ought to adopt, I would say let us be as different from it as possible... (USS 1958:477-8)

NDEA was signed into law by President Eisenhower on September 2, 1958. Although it had small impact on subsequent authority and appropriations of NSF, NDEA set new limits of what was sayable about the federal governments and its role in education for the new national needs. According to James Killian in his memoir as first special assistant to the President for science and technology, "the bill [NDEA] skillfully avoided the church-state issue and other issues that had earlier proved to be roadblocks to the federal support of education. Not only did it help to strengthen education in both precollege
schools and the colleges by providing new funds; it set the stage for subsequent congressional actions that were to bring the federal government into a whole new relationship to the educational system.” (Killian 1977:196)

New congressional actions included substantial appropriations for NSF's science education programs. However, congress did not define NSF’s programs. They were defined by scientific academists in both the President's Science Advisory Committee (PSAC) and in top positions at NSF.

**NSF: Nation, government, and people**

According to Foucault ([1968]1991), in addition to setting the limits of what is sayable, discourse also shapes the way in which the relationship between discourse, speakers, and its destined audience is to be institutionalized. By appropriating the discourse about the nation, scientific academism also shaped the way in which discourse (nation under threat to be saved by science), speakers (scientists, academists, and, most recently, lawmakers), and its destined audience (American public) became institutionalized. Two institutional solutions emerged out of a large number of legislative proposals on education that followed Sputnik: increased budgets for NSF's science education and manpower programs and the National Defense Education Act (NDEA) of 1958.

The emergence of NSF and NDEA as solutions, and not others, can be
explained by the limits imposed by the discourse. These two solutions not only
comiplied with the limits of what is sayable but included the visions on education
that scientific academism had for the Nation. For example, neither the powerful
centralized Department of Education nor the U.S. Academy of Science,
envisioned as a centralized national university, were possible given the
reluctance of government to replicate anything similar to a centralized state like
the USSR.

Under the jurisdiction of the U.S. Office of Health, Education, and
Weilfare, this law provided funds to several kinds of education programs: student
loans; science, math and foreign language instruction; NDEA general
fellowships; training institutes for counselors; language development research;
new educational media; and vocational programs. Historians of education claim
that NDEA was the major legislative event in education following Sputnik
(Ciowse 1981; Lora 1982). Dow (1991) goes as far as claiming that NDEA of
1958 was "the most sweeping federal education legislation in the nation's
history." Although the NDEA had major impact on general college education, it
had a relatively minor impact on science education and manpower when
compared to NSF. NDEA was oriented mostly to undergraduate loans and
fellowships in all areas, and to increasing education in and providing facilities for
foreign languages. For example, during FY 1959-63 only 32% of NDEA's funds
for undergraduate fellowships went to physical and natural sciences, 10% went
to engineering, and 58% went to social sciences and humanities.\textsuperscript{17} Although most of NDEA's activities were modelled after NSF's existing programs, NDEA's only legislative link to NSF was through the authorization of the Scientific Information Service Program. Kriechbaum and Rawson (1969) describe the difference between NSF and NDEA programs in terms of executive mandate:

The recommendations made by President Eisenhower in his 1958 message reflected agreements between officials of NSF and the Office of Education over the respective post-Sputnik roles of the Foundation and the Office in the Federal educational establishment. As described by the President's message to Congress, NSF's domain was to include those programs which "deal exclusively with science education and operate mainly through scientific societies and science departments of colleges and universities." On the other hand, the Office of Education would work primarily through the state and local school systems to strengthen both science education and general education. (Ibid: 228)

The difference between NDEA and NSF programs can also be explained in the way the problem and solution were defined in terms of both quality and quantity. NDEA was to provide federal assistance to the "general" population, or the "average" and "slow" using Conant's terms, mostly in elementary and secondary levels, hence producing large numbers of educated individuals to serve the nation's needs in manufacturing, infrastructure, and basic services. NDEA was to be managed by the office of the federal government that also administered health and welfare programs. In short, it was a comprehensive

federal assistance program in education for the masses. Meanwhile, NSF programs provided federal assistance to the "best and brightest" in quality scientific education in order to produce the scientific elite that was supposed to lead the basic scientific research of the U.S. through the Cold War. These programs were administered by NSF, which had become the headquarters of scientific academism. In sum, powerful scientific academists like Killian and Conant envisioned NSF science education programs in terms of the production of quality scientists to save the nation from the Soviet threat. According to Killian himself

in education, I urged, we should not engage in an academic numbers race with the Soviets. We must not throw quality out the window in order to handle numbers; our shortage today is one of quality as well as quantity. We should not allow the pressure for scientists and engineers to obscure the need for first-rate talent in other fields...James B. Conant expressed a similar concern in a telegram that he sent to the President...These various considerations helped to shape the message on education which the President sent to Congress as well as the bill introduced in the Congress in behalf of the administration. One of the most important parts of the President's message was that the programs of the National Science Foundation for research and for science education should be increased... (Killian 1977:193-4)

Other scientific academists in charge of NSF such as Alan Waterman (NSF Director) and Detlev Bronk (NSB Chairman) brought the new notion of nation, that of the "best" individual scientists saving the nation, into its education programs after Sputnik. Originally conceived to "provide opportunities which will carry talented youth, who have already chosen science as a career, to the
highest levels of training in engineering and science” (NSF 1956), NSF’s science education programs were redefined by scientific academists in the 1960's to “develop capable men and women who [could] be depended upon by the Nation to attain the goals of its scientific endeavors.” (NSF 1960) In the best expression of scientific academism, NSF top administrators designed almost singlehandedly education programs that would reproduce the higher levels in the division of labor as envisioned by Conant. They envisioned NSF programs to produce top-level quality scientists to create the foundations of the new scientific state and enough second-level scientists and engineers to carry these foundations forward. NDEA was to produce the rest. As NSF Director, Alan Waterman, put it:

our first concern must be to ensure that we are producing in our educational system the relatively small cadre of top-level, creative scientists whose genius must provide the foundation and the framework for our total scientific effort. We must then do the best that we can to train sufficient numbers of highly competent supporting scientists and technologists to carry forward the work at a sufficiently rapid rate to meet our national needs...(USHR 1959: 113) (Emphasis mine)

Since this vision depended on a well defined hierarchy of scientists and engineers, scientific academists decided that it was important to know the location, characteristics, supply, demand, etc. of the population of scientists and engineers (past, present, and future) in order to redirect it and manage it “to meet our national needs.” Having at its disposal knowledge about scientists and engineers, the government would then able to manage these populations.
without centralized national planning like in the Soviet Union. Here, scientific academists defined the problem in terms of an equation with an unknown variable X. As Dr. Detlev Bronk, president of NAS/NRC and chairman of the NSB, put it: "I do think there is a crisis which requires X number of scientists, but the difficulty is no one can say what the numerical value of X is." (USS 1958:13) Even if finding the numerical value of X was going to be difficult, Congress rapidly authorized NSF to begin searching for X now that this value had become relevant to a national "crisis." During congressional hearings on "Scientific Manpower and Education" at NSF held by the House Committee on Science and Astronautics, U.S. House Representative Edgar Chenoweth (R-Colo) asked NSF Director Alan Waterman: "Do you think this is altogether a matter of numbers?" Resisting the definition of the problem as a matter of numbers instead of quality, Waterman replied: "It is not a matter of numbers, but when you have numbers you can expect a higher percentage, too, of top people, providing their training is equally good." (USHR 1959: 223) The stage was set for NSF to begin studying manpower resources in science and engineering, to find out how many there are, how many are needed, and how to go about producing that number.

NSF begins to emerge as an institutional solution for the manpower political problem of the 1960's: How to redirect, educate, and train enough individuals in science and engineering so that a few top-level scientists will
emerge to lead the scientific effort of the nation while respecting the freedom of individuals to choose their education and employment. Now that the relationship between discourse, speakers, and audience was institutionalized at NSF, Congress and NSF officials revealed that the more general political problem had two sides to it: quality education and finding the number of present and future scientists and engineers. These two sides of the problem found a home at NSF’s already established Division of Scientific Personnel and Education (SPE). I turn now to the analysis of the construction of official knowledge that led to specific programs at SPE designed to solve the problems of quality and numbers.

Scientific academism sits at the White House and NSF to make policy and scientists

Immediately after Sputnik, President Eisenhower selected MIT president James Killian as his full-time Special Assistant for Science and Technology and established the President’s Science Advisory Committee (PSAC). These appointments opened the door of the White House to scientific academism.18

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18 Membership of the PSAC included: Robert F. Bacher, Professor of Physics, Cal Tech; William O. Baker, VP (research), Bell Telephone Lab; John Bardeen, Professor of Electrical Engineering and Physics, University of Illinois; Hans Bethe, Professor of Physics, Cornell University; Detlev W. Bronk, President, The Rockefeller Institute; Britton Chance, Director of Biophysics, University of Pennsylvania; James B. Fisk, President, Bell Telephone Labs; George B. Kistiakowsky, Professor of Chemistry, Harvard University; Edwin H. Land, President, Polaroid Corporation; Emanuel R. Piore, Director of Research, IBM Corp.; Edward M. Purcell, Professor of Physics, Harvard University; Isidor I. Rabi, Professor of Physics, Columbia University; H.P. Robertson, Professor of Physics, Cal Tech; Glenn T. Seaborg, Chancellor, University of California; Cyril S. Smith, Institute for the Study of Metals, The University of Chicago; Paul A. Weiss, Member and Professor, The Rockefeller Institute; Jerome B. Wiesner, Director, Research Laboratory of Electronics, MIT.
Kreidler (1964) claims that with these appointments "members of the scientific community were given direct access to the President and an established means of expressing themselves on matters of science policy." PSAC's mandate was to build a national policy for science "in regard to ways by which U.S. science and technology policy can be advanced, especially in regard to ways by which they can be advanced by the Federal government." (Killian 1958 quoted in Ibid) PSAC developed policies in three main areas: basic research, facilities, and science education. Their influential role in the last area shaped the form and size of science education programs at NSF.

PSAC's first report on science education, Education for the Age of Science (May 1959) came from its Panel on Science and Engineering Education. This Panel, directed by physicist Lee A. DuBridge, a champion of scientific academism himself, was representative of scientific academism sitting on both academia and government. The Panel recommended three specific areas where the federal effort in science education should be placed: 1) recognition of "academically talented" and "unusually gifted" students; 2) development of quality teachers; and 3) curriculum and course development. Far from being policy, this official statement outlined specific educational objectives for the nation and one of them stood clear: quality science education.

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19 James Killian, president of MIT and now the President's science advisor brought two of his favorite MIT professors to serve in this panel, Jerrold Zacharias, Professor of Physics, and John Buchard, Dean of Humanities and Social Studies. See Killian (1977:196) for his own account of the formation of this elite panel.
As Kreidler (1964: 127) argues, "the report did not attempt to make policy. Instead it defined the objectives of policy."

Two important questions arise here. First, who set the policy that guided the largest increment in the science education budget ever seen at NSF? NSF's total budget went from $51 million in FY 1958 to $137 million in FY 1959 while the science education budget went from $20 million to $60 million in the same period. This represents an increase for science education from 38% to 45% of NSF's total budget. Second, why was PSAC reluctant to make educational policy in 1959? In other words, why did PSAC limit itself to make an official statement instead of official knowledge? Looking at these two questions leads us into the relationship between official knowledge and policy to make scientific selves in the early 1960's.

Knowledge/policy within NSF before Sputnik: quality vs. quantity

PSAC's recommendations in 1959 found a niche in the existing categories of science education programs at NSF: Fellowships in Science, Science Teacher Training, and Curriculum Improvement. However, these programs changed after Sputnik not only in budget size but also in direction. Was it possible that the national crisis brought on by Sputnik was so dramatic that official knowledge to direct these efforts was made in its entirety within NSF? Was it possible that Congress appropriated $60 million dollars of federal
funds to science education without being certain of its actions hence relying completely on NSF insiders to spend this money as they saw fit? Answers to these questions open windows into the making of policy and selves in the aftermath of Sputnik.

Ever since its original conception in Science--The Endless Frontier, the NSF Fellowship program has been scientific academism's instrument to ensure quality training to a "small cadre of top-level scientists." England (1982:13) shows how the different committees that reviewed Bush's proposal for fellowships in his 1945 report unanimously agreed on the value of the program to achieve the goals of quality. By 1956, NSF Fellowships were of two kinds: pre-doctoral and postdoctoral. At that time, the objective of the pre-doctoral program was "to seek out the most able science students interested in training beyond the baccalaureate degree and to afford them the opportunity to spend full time at the institutions of their choice and in the type of training they desire so that each fellow can develop his potentiality as a scientist to the fullest." (NSF 1956: 72) The main goal of the postdoctoral fellowships was "to provide opportunities for scientists who have demonstrated superior accomplishments in a special field to become still more proficient in their respective specialty by studying and doing research in outstanding laboratories." (Ibid) Scientific academists, such as Alan Waterman and James Conant, in charge of NSF throughout the 1950's envisioned and protected the Fellowship program to
ensure the making of "higher individuals" in science. For FY 1956, NSF awarded a total of 925 fellowships, 70% of them in the physical sciences, which included engineering, and 30% in the life sciences.

In 1956 President Eisenhower created the National Committee for the Development of Scientists and Engineers. Housed at NSF and paid for from NSF's budget, the Committee was mostly made up of representatives from the engineering profession, teachers associations, labor unions, state and local governments, and social sciences and humanities. Out of 21 members, the Committee only had one scientific academicist (Detlev Bronk, NSB Chairman) in its membership and not even on the Committee's top posts.29 The Committee's charter was to "assist the Federal government in identifying the problems associated with the development of more highly qualified scientists and engineers" which included the Fellowships. (NSF 1956: 17) Throughout its one-year existence, the Committee stayed away from assessing the Fellowships, only issuing recommendations on how to expand the available supply of qualified technicians. The exclusion of the Committee from assessing programs such as the Fellowships shows how jealous and protective the advocates of scientific academism were with their cherished program.

The situation differed for those education programs which did not aim at creating "higher individuals" but instead targeted the general population of pre-
college students taking science such as the Teachers Institutes, conceived by scientific academism to deal with quality in the teaching of science and mathematics in high school. Responding negatively to the appointment of the President's Committee for the Development of Scientists and Engineers, leaders of scientific academism agreed at a NAS symposium that the "U.S. should not get into a manpower production race with Russia but 'should concentrate on raising the quality of scientific education.'" They envisioned the Institutes program to take care of the problem of high teaching of science and mathematics (England 1982: 253). However, the Institutes program was quickly redefined, by its constituency of mostly high school teachers and also by the Office of Defense Mobilization (ODM), in terms of numbers. "High school science and mathematics instruction must be improved numerically...." wrote the ODM to NSF, through "courses in science and mathematics which are aimed at high school teachers (and not graduate student) level." (quoted in Kriehbaum and Rawson 1969) Here quality of science and math education, as envisioned by scientific academism, was compromised by large numbers of high school teachers who could not even meet graduate-level standards. The Institutes program rapidly outgrew the Fellowships program in budget size but not in prestige. Scientific academism, more keen on retaining control of the Fellowship program, allowed lower-level regional committees and teachers associations, such as the National Council of Teachers of Mathematics, to define the
Institutes program goals and criteria.

Knowledge/policy within NSF after Sputnik: alignment behind the nation

After Sputnik, scientific academism framed the specific problem of education for NSF as how to provide quality education in the sciences to the "best and brightest" of free-choosing individuals who will save the nation. Speaking of a nation under threat to be saved by quality scientists, official statements made by NSF officials requesting money for science education received no opposition. With scientific academists, now in administrative positions at NSF, positioning science education as a matter of national security, their requests for education were taken by the Administration as certified knowledge. Beginning his quest for more money for science education only six days after Sputnik’s launch, Alan Waterman told the National Security Council on Oct 10, 1957:

This recent event drives home with even more force the conviction that if this country is to compete technologically and maintain military and economic superiority it must maintain its head in science. This is primarily dependent upon the numbers and especially the quality of our trained scientists and engineers and the research facilities they need. The country must, therefore, realize the necessity for effective steps toward maintaining progress in basic science and the training of capable scientists and engineers. (quoted in Kriegbaum and Rawson 1969: 221) (emphasis mine)

The President’s budget and subsequent congressional appropriation for FY
1959 resulted in an increase of 300 percent to approximately $61 million for existing NSF educational programs and for the initiation of new ones (NSF 1958: 9) The percentage of NSF's total budget ($137 million) devoted to education reached an all-time high of 45% (see figure 3).

Figure 3. Basic Research and Science Education as Percentages of NSF's Total Budget: 1960's
Never had so much of NSF's budget gone towards science education. Most of this budget went to funding teachers' institutes and graduate fellowships. With Sputnik in space, scientific academists within high-level policy circles made important decisions regarding program priorities, both target areas and budgets, that shaped the course of scientific research and education. Who were these people and how did they make those decisions? What did allow them to make those decisions in the first place?

The Making of Science Teacher Institutes: Lots of high school teachers to make a "small cadre of top-level scientists"

As we have seen, after Sputnik scientific academists such as Killian, Conant and Waterman redefined the problem of numbers in terms of quality: the top-scientists who were to lead the nation's scientific enterprise would eventually come out from a large pool of potential scientists. With this redefinition of the problem of numbers, NSF's Division of Scientific Personnel and Education (SPE) became involved in the education of large numbers of science teachers with the hope that they would produce a few top-quality scientists from among their students.

After receiving direct recommendation from PSAC to continue and expand the program, SPE set off to singlehandedly redefine the program's guidelines. Howard Foncanon, special assistant to SPE's Division Director Harry
Kelly, remembers how SPE put together the new institutes program: "We had no real guidelines. The Bureau of the Budget just told us to create a program that would meet the national interest...[and] we wrote the new programs." (quoted in Kriehbaum and Rawson 1969: 227) Most of the expenditures for this program, which became "the largest single item in the manpower part of the budget" (Ibid), went to train large numbers of high school teachers with the hope that they would impact large numbers of students that would produce few of the very best. The reach of the Institutes program went even further when they were extended to the elementary level. As Kriehbaum and Rawson claim, "extension of the institutes to the elementary school level was the most significant program development during the 1958-59 period." (Ibid).

Originally designed to enable the nation's teachers to improve their teaching so that they could better stimulate their students to pursue science careers, SPE's administrators redefined these programs after Sputnik in terms of national survival but within the limits of what was sayable. Infringement of State and local authority over education was still beyond these limits. Hence, scientific academists at SPE redesigned these programs to preserve "the traditional place of State and local governments as managers of their educational systems through the NSF system of support to locally initiated

21 Harry Kelly was one of the best representations of scientific academism. A colleague of James Killian at MIT, Kelly also worked as chief of the Scientific and Technology Division of the U.S. Army in the occupation of Japan during 1945-50. Before joining NSF in 1953 as an appointee of Alan Waterman, Kelly worked for the Office of Naval Research.
projects [in science teacher training] rather than through the establishment by the Federal government of its own educational operations." (NSF 1961: 11)

Recognizing the accomplishments of SPE's staff in realizing his visions of scientizing high school education through the Institutes, James Conant wrote in his 1963 book *The Education of American Teachers*:

> The use of [NSF] summer institutes for bringing teachers up to date in a subject-matter field has been perhaps the single most important improvement in recent years in the training of secondary school teachers. (quoted in Kriegerbaum and Rawson 1969: 307) (italics in original)

What began with high-level recommendations from PSAC to educate the high school teachers of America in the sciences was really an effort to create a large pool of scientists from where the "best and brightest" would ultimately come. This was even publicly recognized by NSF in 1958 when its first annual report after Sputnik stated that "the most serious and urgent problem at the present time in the training of future scientists and engineers is *not to find* great numbers of additional students, but to provide a high caliber of training in science for the competent student who will seek it." (NSF 1958, 49) NSF further envisioned the making of a select few top-scientists through its Fellowships program.
NSF Fellowships: The making of a "small cadre of top-level scientists"

Consistent with the limits of what was now sayable about the nation, NSF top-administrators defined the Fellowship program "to strengthen the Nation's scientific potential" by "offering aid to graduate students, teachers, and advanced scholars in science, mathematics and engineering according to plans designed to meet the educational needs of individuals." By connecting quality of scientific training to the survival of the nation, they were able to increase their Fellowships budget more than 100% immediately after Sputnik, from $5.6 million (1527 awards) in FY 1958 to $13 million (3937 awards) in FY 1959 (see figure 4). While in 1956 only two kinds of programs existed, by the early 1960's the program developed into seven types of fellowships: graduate fellowships, cooperative graduate fellowships, summer fellowships for graduate teaching assistants, postdoctoral fellowships, senior postdoctoral fellowships, science faculty fellowships, and summer fellowships for secondary school teachers. In 1960, the Fellowship program even included the NATO Fellowships and the Organization for European Cooperation (OEEC) Fellowships as a demonstration to the Soviets of scientific cooperation between the U.S. and Europe.
Figure 4. Growth of NSF Fellowship Program. Number of Awards Offered: 1952-60

By 1963, NSF's Scientific Personnel and Education Studies section produced the most comprehensive projections on numbers of scientists and engineers for the 1960's: The Long-Range Demand for Scientific and Technical Personnel (NSF 1961) and Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply (NSF 1963). Lacking its own source of certified knowledge on manpower resources, PSAC relied heavily on NSF's
official statements mentioned above. Based on its own evaluation of these official statements, PSAC recommended that NSF begin a program to support Ph.D's in engineering: "of all the manpower areas we have evaluated, strenuous and sustained efforts to develop more Ph.D's in engineering are considered most critical." (PSAC 1962, 1963) This process is indicative of NSF producing the official knowledge that shapes its own policies. However, for now, scientific academism at NSF resisted the redefinition of its Fellowship program in terms of numbers, especially if it was to make engineers, in two ways. First, instead of Fellowships in Engineering, NSF created a number-oriented Traineeship program exclusively for engineers, while keeping the Fellowships devoted to the making of few quality individuals. Referring to its Fellowship program in its 1964 Annual Report, NSF states

"From the beginning of its existence the Foundation has stressed the importance of providing support for graduate students and advanced scholars of outstanding ability in the sciences. These individuals represent the backbone of the Nation's scientific potential." (NSF 1964:63)

A couple of pages later, NSF justifies the creation of a new program different from the Fellowships

Recently much stress has been placed on the problem of graduate education in engineering...In 1962 , [PSAC] urged that immediate steps be taken to increase the number of master's and doctoral degrees...in th[is] discipline. Thus the Foundation is now giving attention to new forms of support of graduate training in certain specialized areas...which are known to be in short supply of highly trained manpower....Graduate education for engineers was the first one to receive such supplementary NSF support, since manpower statistics indicated that engineers in particular were in need of advanced training. (Ibid: 65)
In 1964 NSF gave out a total of 6,350 graduate awards of which 1,220
Traineeships (20%) went to engineering, 265 Fellowships (4%) went also to
engineering, and 1,856 Fellowships (30%) went to the physical sciences.

Second, scientific academism made engineering to conform to the
demands of science. Criteria for the support of engineering was redefined in
terms of criteria for scientific excellence. In 1962 when NSF established the first
Engineering Section and began support for graduate engineering education,
NSF made clear its criteria for engineering

the NSF has adopted a policy which clarifies the engineering research
supportable by the Foundation by indicating that intellectual pursuits at
educational institutions intended to advance significantly the basic
engineering capabilities of the country are eligible for support by the NSF
as basic research in the engineering sciences. Such work must be of a
true scientific nature and not routine engineering practice, and must meet
the usual NSF standards of originality and excellence (NSF 1962: 10)
(Emphasis mine)

Making scientific selves through projections and the Register

Scholars of NSF and science policy have paid very little attention to
manpower studies at NSF. Most of the attention has gone to basic research,
where the majority of NSF's budget is allocated. So far this chapter has focused
on science education because that is where scientific academism materialized
their vision about the kind of scientist necessary to save the nation. However,
as we will see, one of the first requests by both Congress and the President
immediately after Sputnik was to find out the number of scientists and
engineers available to the needs of the nation. Why did the federal government requested knowledge about the population of scientists and engineers if scientific academism seemed to be making the kind of policy the nation needed without such knowledge?

As Foucault has told us, the ensemble of technologies of government "which has as its target population, as its principle form of knowledge political economy, and as its essential technical means apparatuses of security is what has permitted the [modern] state to survive." (Foucault 1991: 100) Post-Sputnik America was no exception. The federal government needed to be certain of its actions, especially if it has to justify continuing them for a period of time. But more than public acknowledgement of its actions, the government needed knowledge of its population to survive. In the U.S., this knowledge about its population of scientists and engineers, obtained mainly through projections of available manpower and registers of individuals and their characteristics, became essential for national security after Sputnik.

This deployment of technologies of government to project available manpower in science and engineering took place in the early 1960's when NSF received a request from the President to begin the creation of knowledge about American scientists and engineers. Sputnik created an immediate need for knowledge about available manpower. In 1957, the President through the Bureau of the Budget requested the NSF
to develop a program for collection of needed supply, demand, employment, and compensation data with respect to scientists and engineers...Because of its functions, its relationship to the National Committee for the Development of Scientists and Engineers, and because it has already arranged for studies of employment in scientific fields, we believe the Foundation is the most logical agency to undertake such a task (U.S.H.R. 1959: 768)

By 1959, NSF received an additional mandate to develop a national program of information on scientific and technical personnel in cooperation with all federal agencies and scientific organizations engaged in scientific manpower information activities. This was consistent with the on-going reorganization of science and technology activities in the federal government. NSF became the government’s repository for information about U.S. scientific and technological resources, including manpower. As Congress soon recognized, "NSF is the only agency to assemble the available scientific manpower information...recording individual scientists by name, profession, and characteristics..." (USHR 1959: 335) With an insignificant budget ($1 million or 0.6% of NSF’s total), NSF accomplished this important function of:

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24 This is exemplified with the establishment of the Federal Council for Science and Technology in 1950 which included the Departments of Agriculture, of Commerce, of Defense, of Health, Education and Welfare, and Of Interior, and from NASA, NSF, and the AEC. See Executive Order 10807, signed by President Eisenhower in March 13, 1959.
"governmentality" through its Scientific Manpower Program and its two elements, Manpower Studies and the National Register.

**Manpower Studies**

As happened with science education programs and policies after Sputnik, manpower projections made by NSF in the early 1960's also reflected an image of the American nation made of free individuals but in the need of government actions to ensure its survival from the latest Soviet threat. As such, more than just producing numbers about available manpower for current national needs, these economic projections also divided the national space, known as the economy, into specific areas of national interest and created population categories according to the needs of these new areas.

After Sputnik, NSF manpower experts recognized that there was not a projection model available for this unique situation. Manpower projections for WWII and for the prosperous free market of the 1950's had been made using models appropriate to those national scenarios. In early 1960's, manpower experts told Congress that "no impression should be given that precise future estimates of scientific personnel requirements will eventually be possible [because] the lack of an adequate conceptual framework has been the basic problem." (USHR 1960a: 33) Immediately, Congress authorized NSF to initiate a study "to develop a systematic methodology for the long-range projection of
demand for scientific and technical personnel" mainly "as a national defense resource." (Ibid) Accordingly, NSF defined the goal of its Manpower Studies in national terms: "[it] is the central program in the Federal government for the provision of ... data on the supply, demand, education, and characteristics of the Nation's scientific and technical personnel resources". (NSF 1960) In the next three years, NSF's SPE single-handedly constructed a model based on the new notion of nation (see NSF 1961, 1963). Projections from this model became the most important official statements to influence official knowledge and hence guide education manpower policy for the remainder of the 1960's.

The new model reflects a shift from perceived national needs in the 50s to those required by a nation now under threat by Soviet science. In the 1950's with a free market of goods, services, and labor, plentiful after the war, projection models utilized "free-market" models. Free-market models took into account adjustments in the supply and demand of labor due to changes in salaries. In these models, salary differences among occupations play a major role in influencing supply of workers and in determining where they go. NSF adopted this model in the 1950's as developed by its grantees Blank and Stingler (1957) who utilized a free-market model made of "free" individuals behaving as economic actors in accordance to economic incentives of a free-labor market. No notion of centralized or state-directed economy existed in this model. Black and Stingler's model, which superseded wartime models used to
project manpower in a government-controlled labor market for wartime needs, now depicted the behavior of free American individuals choosing careers that suited their best interest, usually graduate degrees in science and engineering. They concluded that the market of supply and demand of scientists and engineers had adjusted over time, that there was no shortage, and that more students went into graduate degrees as shown by the increase of the ratio of Ph.D to B.S degrees. This model depicted the nation space as made up of two broad areas of national importance, military and civilian industry, and free-market forces allocating individuals well within these areas: "It appears clear, therefore, that economic incentives have played an important role in attracting science and engineering students toward those fields in which demand has been high and increasing." (Ibid: 83).

After Sputnik, new national needs required the government to intervene in the supply of manpower. New needs redefined the two broad areas of the economy into specific areas of national importance. Among these, basic research became one of the most important areas within both civilian and military industries. Within the category of basic research, the categories of physical sciences, life sciences, engineering, social sciences, etc. began gaining national attention and were ranked according to their contribution to the survival of the nation. All these were further sub-divided according to specific disciplines. The government now had to intervene by allocating people in these new areas.
of national significance hence it had to act on the supply of manpower. Accordingly, NSF shifted its projection model to a "fixed coefficient" model which allowed for government intervention in the supply and demand projection of manpower. Fixed coefficient models rely upon past and projected future trends of education and employment distribution of individuals, and the parameters that affect these distributions. Parameters usually selected are those where the government has a strong influence like federal employment and R&D spending. Projected demand is a function to the input to that activity (e.g., R&D spending), its outputs (e.g., scientists required), and assumption about its productivity trends (e.g., more R&D means more scientists required). Projected supply is based on demographic patterns of educational and occupational choices of persons entering the labor market. To eliminate the major influence of the free market in favor of government role, salary compensation is not taken into consideration in the projection of supply and demand.\footnote{For a complete analysis of both free-market and fixed-coefficient models see NSB (1974:5)}

NSF's new fixed-coefficient model positioned the federal government as the main determinant of projected demand. The model assumed that demand of scientists and engineers was in direct relationship with federal R&D spending and with government employment of scientists and engineers. It established a history of demand of scientists and engineers for known levels of federal R&D
spending and utilization of scientists and engineers during the 1950's and extrapolated it to the 1970's. Supply was projected on the basis of population growth, proportion of college-age population going to college, and proportion of all college population going into science and engineering. (NSF 1963) To remedy this demographic determinism, NSF's model also positioned federal programs, particularly those at NSF, as a solution to the supply problem by increasing the number of students going into science and engineering.

The new model, which became "the most comprehensive and systematic attempt at quantification of the future of [s/e] personnel...in this country", projected a shortage of 170,000 scientists and engineers by 1970 (NSF 1961). These projections became the most influential official statements to guide educational and manpower policy by both Congress and the President throughout the 1960's. For example, Congress conducted its own policy analysis based on this model and projections only to find that NDEA of 1958 had a minimal effect on post-Sputnik population going to college. Referring to his own study and the findings on NDEA, Spencer Beresford, special counsel to the Committee on Science and Astronautics of the U.S. House of Representatives, asserted that

all present programs and legislative proposals of this kind appear inadequate in scope and extent. For example, Dr Bolt's study [congressional study using NSF model] failed to show that the NDEA has had any influence whatsoever on the annual percentage of Americans getting college degrees, that is, its influence has been too small to be
seen on the chart. The ideal is economic aid on the scale of the GI Bill after WWII -- which is reflected on Dr. Bolt's chart by a sizable 'postwar bulge' (USHR 1962: 8)

Since no GI Bill came after Sputnik, NSF was left as the only solution to this shortage through its science education efforts. We already saw how the President's Science Advisory Committee also endorsed NSF projections and recommended specific policy for graduate education in engineering which NSF reluctantly carried out through a new traineeship program. In short, these projections positioned NSF not only as the producer of the most legitimate and respected official statements about the future supply and demand of scientists and engineers but also, through its programs, as the executor of policy to solve the manpower crises. This would create a conflict of interest during the coming decades when the threat to the nation was not so vivid in the public imagination.

NSF's projections for the 1960's, as legitimate as they were, still had to comply with the limits of what was sayable. After comparing DeWitt's study of Soviet manpower with NSF's projections of U.S. manpower, Beresford, speaking on behalf of the Committee on Science and Astronautics, was reluctant to compromise individual liberties in order to compete with the USSR:

Obviously, any comparison of education or of s/t manpower in the U.S. and the USSR must be viewed with reservations. The political, social, and economic institutions--and, above all, the policy objectives--of the two countries are very different. In the U.S., the individual citizen is regarded as an end in himself; in Communist society, he is merely an
instrument for promoting the collective good. The United States educates approximately twice as many citizens, at every level, as the Soviet Union. In the Soviet Union, all education is planned and directed by a central authority, which heavily emphasizes engineering, the natural sciences and mathematics... (Ibid: 4)

Aware that salary regulations or directing people into critical scientific fields by force was "not feasible", the Committee on Science and Astronautics proposed the deployment of technologies of government in order to establish control over science and engineering manpower:

It is probably not feasible, either, to establish economic or physical controls for critical types of scientific and technical manpower. If such controls were adopted, they would probably be voluntary. Short of controls, however, it would help to keep track of the supply and utilization of scientific and technical manpower (Ibid: 7)

NSF exercised manpower control through its National Register of Scientific and Technical Personnel.

The Register

The Register's legislative origins go back to the NSF Act of 1950 as "a register of scientific and technical personnel to serve as central clearinghouse for information covering such personnel." Before Sputnik, the categories included in the Register reflect the wide range of possible categories envisioned as scientific manpower. In 1956, the Register was described as containing "data necessary for an understanding of the adequacy of present and potential
supply of science manpower range from relatively abstract psychological problems of creativity to practical questions of numbers now employed in research and development as against estimates of science manpower needs 10 or 15 years from now under a variety of possible conditions." (NSF 1956: 74) Also redefined around the new national needs after Sputnik, the Register's new goal became "to insure that information on the resources of scientific manpower is available, and that individual scientists and engineers with specialized skills can be identified and located as required in the national interest." (NSF 1959: 85) Accordingly, NSF began redefining old categories into new ones now considered of national importance. In 1958, one year after Sputnik, the NSF intended "to place the Register program on a more current operating basis and extend the coverage of the Register to new fields of vital importance to the nation, such as rocket and missile technology, communications and electronics, aeronautical science, ceramics and metallurgy. (NSF 1958:68)

In addition to endorsing scientific academism's vision where the "best and brightest" students of science would save the nation through basic scientific research, NSF established important traits about scientists to be collected by the Register. In 1964, NSF published the first comprehensive study describing U.S. scientific and technical manpower according to the following characteristics: employment status, geographic distribution, level of education,
age, years of experience, type of employer, type of work activity, foreign
language proficiency, and income (NSF 1964). A look at these categories can
give us a further sense of who was considered to be a scientist in the 1960's.
For example, the average scientist was a 30-year old male from the middle
Atlantic states (usually New York), with a Ph.D., 10 years or less of experience
in the field, was employed in either academia or industry, and more likely to
know German than Spanish.

This average scientist deserves further analysis because, in many ways,
several aspects of it have become ingrained in what we understand as
"scientist." For many years after Sputnik, this was, and still is, the image of
"scientist" we saw in popular literature, movies, TV, oral descriptions, etc. and,
for the most part, the person who inhabited science labs and presented papers
in professional conferences. However, in the processes of making this scientific
self, NSF took for granted some important traits. I finish here with a look at two
of the most important-- gender and race -- for it was these traits about scientists
that, although invisible in the 1960's, became contested in different ways in the
following decades as new discourses about the nation emerged.

After looking at the concept of "scientist" made by NSF, legitimate
questions come to mind: Where were the women and non-whites in these
scientific efforts to save the nation? Even after congressional committees, NSF,
and policy advisors knew of the participation of large numbers of women and
racial minorities in Soviet scientific manpower, why were American women and
racial minorities not invited to participate in the efforts? In trying to answer these
questions, it is worth looking at the limits of appropriation of discourse that
developed around Sputnik.

In determining these limits, Foucault asked us to pose questions such as
"what individuals, what groups or classes have access to a particular kind of
discourse?... How is the struggle for control of discourses conducted between
classes, nations, cultural or ethnic collectivities?" ([1968]1991) Images of the
nation advanced by women, racial minorities and working classes existed and
were also made public in non-mainstream media.26 However, as we have seen,
powerful actors with very definite ideas of how to save the nation through
science defined the problem of science education in their own terms, never
allowing other social groups to advance their images of the nation nor their
definitions of the problem nor their proposed solutions. Even though DeWitt's
analyses of Soviet manpower (1955, 1961) revealed a significant diversity
among Soviet scientists and engineers,27 and Congress acknowledged that
"other social groups, such as the Negroes, make a disproportionately small
contribution to the national supply of scientific and technical manpower" (USHR

26 See for example, Stuart Loory's (1961) "Why this Space Race?", and Joseph Krutch's (1965) "Why I Am Not
Going To the Moon."

27 DeWitt's analyses show significant contribution from Soviet women and national and ethnic minorities to their
scientific and technological manpower. For example, women constituted 50% of the science and engineering
professionals in the Soviet Union.
1962:5), NSF projections and Register’s categories, all based on a notion of nation defined by scientific academism, rendered the categories of gender, race and class invisible. This is a clear reflection of the limits of appropriation established around Sputnik. The American nation was to be saved by a specific concept of "scientist" that NSF helped create.

Conclusion

Under the symbolic threat of Sputnik, scientific academism successfully appropriated the limits of what was sayable about the nation and its science and education. Strategically located both inside the federal government and elite academic institutions, this group defined a very specific national problem and its solutions, silencing alternative voices and their proposals. The problem: an American nation under threat by Soviet science and science education. The solution: the production of "a small cadre of top-level" scientist who will lead the scientific effort to save the nation. With pressure coming from other groups, such as the military and the teaching profession, to define the problem also as a matter of numbers, scientific academism successfully resisted number-oriented solutions to a problem they had defined in terms of quality.

Within the limits of what was sayable and acceptable in the discourse about the American nation in the early 1960’s, NSF emerged as an institutional solution for the political problem surrounding the production of scientific
manpower. That is, NSF became the federal government's solution to redirect, educate, and train enough individuals in science and engineering so that a few top-level scientists would emerge to lead the scientific effort of the nation while respecting the freedom of individuals to choose their education and employment. However, the solution to this political problem required more than an institution. Given the significance of scientists for national survival, the federal government also needed certified knowledge about the nation's scientific and technical population to be certain of its actions on science education and manpower. NSF's manpower studies program became the site where this certified knowledge was produced. The manpower projection model used by NSF embodied an image of a nation under threat where federal intervention was required but not at the expense of the free-market. NSF used fixed-coefficient models which allowed the government to intervene in the supply of required manpower without intervening on salaries. The creation of this knowledge within NSF would create an interesting conflict of interest since it is the same knowledge that shapes NSF's own policies.

Throughout the 1960's, NSF, by means of its technologies of government -- education programs, manpower projections, and Register -- helped create a self with specific traits, skills, and specialized knowledge who would save the nation from the Soviet threat. The image of this scientific self continues to influence what we understand for "scientist" today.
How about the marginal actors who never made it into the policymaking process but who were nonetheless trying to define problems and solutions for new national needs? I recognize that I have not given enough attention to groups and organizations (e.g., civil rights movements, labor unions) who also struggled to appropriate the narrative about the nation. To include marginal perspectives would require a different methodological approach for they do not appear in mainstream popular media nor in congressional or other governmental literature. In order to reveal these perspectives, one needs to relocate to the capillary levels of the archive, and then locate and analyze actors and their struggles through access to their written and oral stories. This is a theme for further research as I indicate in the conclusion. However, their absence from the media accounts and official knowledge is in itself indicative of who did and did not participate in the making of policy and scientists for the Age of Science.
CHAPTER 3
NSF Resists Policymaking for Social and Environmental Problems: Making Selves for Domestic Needs

To educate scientists who will be at home in society and to educate a society that will be at home with science.¹

In the end of the 1960's, the Apollo moon-landing symbolized the triumph of U.S. technoscience over the Soviet Union. Meanwhile, the Vietnam War, the energy crisis, awareness of environmental degradation and social and racial inequalities defined the face of a new threat to the American nation. The discourse about the Nation shifted from saving the country from communism to saving the country from itself. If science had saved America from Sputnik by putting it ahead in the space race, now science and technology were perceived as threatening America's social and natural environments. Both triumph and fear of technoscience coexisted in this discourse. This paradoxical view of technoscience served as the context for proposals to include a new kind of science within NSF's mandate with the hope that it would help solve new national needs. This marks the beginning of a tension between a renewed scientific academism, who still occupied the higher ranks at NSF and supported basic science, and a bandwagon of progressive groups, who wanted to bring NSF in touch with the social and environmental problems of the nation through its support of applied science. These two opposing groups battled for budget

¹ Motto on the cover of NSB's (1970) report Science Education: The Task Ahead for the NSF
allocations and programs throughout most of the 1970's as NSF's responsibilities for funding this new kind of science grew, thereby threatening its commitment to basic science. Within this context, NSF's priorities in education and manpower development shifted from producing top quality scientists for the "Age of Science" to producing scientists capable of solving the new problems that plagued American people, cities and environment. This chapter looks at a decade of making policy for making scientists and engineers at NSF who instead of solving the problems of the space race could solve the problems of society and the environment.

**America at war with itself**

Throughout the 1960's scholars and social critics of different kinds and political affiliations depicted America as a space where two notions of Nation coexisted side to side. For example, in his closing chapter of *The Other America*, Michael Harrington (1962) describes America as "Two Nations ", one rich and one poor, whose economic differences have also translated into cultural and spiritual differences between the two. In 1966, in his book *The Arrogance of Power*, Senator J. William Fulbright wrote about "The Two Americas" describing them as: "...One is generous and humane, the other narrowly egotistical; one is self-critical, the other self-righteous; ...one is moderate, the other filled with passionate intensity; one is judicious and the
other arrogant in the use of great power." (quoted in Lora 1974: 204). This view of America as a divided economic and political space shaped most of the political discourse about the nation in the 1960's. Although social critics, such as Lewis Mumford and Jaques Ellul, had linked political criticism to criticism of technoscience since the early 1960's, these criticisms did not translate into significant science policy until the 1970's.

By the end of the 1960's, the triumph of technoscience over the Soviet threat in space, symbolized by the Apollo landing on the moon, removed the perceived scientific advantage of the Soviet Union over the U.S. and shifted the perception of the enemy. With the moon landing of Apollo, popular media claimed that America had regained its supremacy in science and technology over the Soviet Union. As one weekly magazine celebrated one week before the launching:

Just a few years ago, the U.S. seemed hopelessly outstripped in the space race. It was an uneasy America that watched the Russians score one "first" after another in the skies. Today it is America, not Russia, that stands at the threshold of the greatest space conquest of all --landing men on the moon. For much of mankind, setting foot on the moon has been a dream for centuries. It was left to Americans to fulfill that dream. (U.S. News 1969a)

More than an event symbolizing the mastery in the realms of science and technology, the moon landing represented a triumph of American capitalism over Soviet socialism. Just two weeks after the Apollo landing, mainstream media summarized the triumph as follows:

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A race won. Here on earth, practical evidence was given that the U.S. has emerged, after a decade of self-doubt, as the most technologically and scientifically advanced of all nations. The U.S. won the race to the moon and threw back into the face of the Soviet Union a boast of seven years ago that Russian space achievements would "demonstrate the great advantage of the socialist system." In the end, it was a society of free men and competitive industry that demonstrated the advantage... (U.S. News 1969b) (emphasis in original)

While most Americans celebrated the Apollo success, some questioned not only the usefulness of the event but also the responsibility of the scientific and industrial establishments in social and environmental degradation of the American landscape. For skeptics, putting a man on the moon was a dubious accomplishment in the face of other crises facing America. Mainstream popular media juxtaposed images of both technological enthusiasm and skepticism: "A mixture of awe and uneasiness: That is the reaction to Apollo 11." (Science News 1969) Reports questioning whether "60 pounds of lunar rock were worth twenty-four billion dollars" accompanied reports chronicling medical, environmental and urban crises facing the nation. For example, only one week after the moon landing, U.S. & World News published three main stories under the titles "How useful is the moon", "Medical Crisis and How to Meet it", and "The Breakdown of Our Cities." As one editorial summarized: "We embraced the space program and the industrial-technological juggernaut it spawned...but the verdict of history may well be that, while the world erupted, we ignored the real challenge and chased a rocket trail to the moon." (Science News 1969)
Among stories surrounding Apollo, one became more and more publicized: the effects of a shrinking space industry on American workers. As reports published how "Apollo has absorbed the efforts of a half-million workers, charted the technological course for 20,000 corporations...and it has built a dependence on Federal financing into a massive segment of the national economy," others reported the" big let down after a big build up." (Science News 1969; U.S. News 1969a) Among those workers were many scientists and engineers.

Within the discourse about the nation, two notions emerged in the beginning of the 1970's that linked the nation to technoscience in different ways. One celebrated and viewed the triumphs of the nation as results of its scientific and technological prowess and wanted more of the same. At the highest levels of government and academia, a renewed scientific academism endorsed this notion and resisted criticisms on the status quo of the scientific establishment. In an extensive interview article with the most influential of these scientific academists, one leading national magazine summarized their views on what they called a "senseless war on science" and put in brief their beliefs on the nation and its science as follows:

Over the last quarter century, despite dips and lags, science and the U.S. economy together have had the longest period of sustained growth, discovery, innovation, and new industry in recent history. While none of this has brought the millennium...still it has measurably widened the options and potentials of human life on earth. Perhaps the pinnacle of
this period was reached when man stepped on the moon, a feat that will rank in history among the few clear, large, and positive achievements of the last decade, a great human feat that once would have swelled the lyrics of a Homer... (Fortune 1971)

The other notion of nation viewed the many crises facing the nation as a result of an industrial technology out of control and basic science being misdirected into seemingly useless research. Instead of neglecting dissenting voices like in the late 1950’s, mainstream media provided now space to contesting notions of nation that questioned the glories of American science and technology developed since WWII. In the 1970’s, high level academics, including scientists, promoted a notion of a nation now at risk of being destroyed by science and technology. This time even some scientists such as Harvard biologist Everett Mendelsohn came to criticize science, raising the possibility that science, as developed after WWII, had reached both its rational and practical limits. In contrast to media reports after Sputnik where scientists elevated science to the level of national savior, reports from the early 1970’s depicted not only a polarized nation but also a divided scientific community arguing about whether science was savior or oppressor. Reporting the views of science critics, including those of scientists themselves, a special issue of Time magazine titled "Second Thoughts about Man: Reaching Beyond the Rational" reads.
...there has begun to emerge, even within the laboratory, a new fascination with what traditionalists consider the very antithesis of science: the mystical and even irrational. Says Harvard Biologist-Historian Everett I. Mendelsohn: 'Science as we know it has outlived its usefulness'...Science did indeed bring forth a Brave New World-of transistors and miniaturized electronics, antibiotics and organ transplants, high-speed computers and jet travel. But progress came at a price. It was the genius of science that also made possible such horrors as the exploding mushroom cloud over Hiroshima, the chemically ruined forests of Indochina, the threat of a shower of ICBMS, a planet increasingly littered with technology's fallout. It is this Faustian side of science, with its insatiable drive to conquer new fields, explore new territory and build bigger machines, regardless of costs or consequences that worries so many critics. (Time 1973)

Science enthusiasts, which included practicing scientists and scientific academists in government, rushed to regain control of the attack on science by trying to redefine it in their own terms and through their own media. Read by science policy makers and academics alike. Science magazine became a frequent forum through which scientists tried to regain control of the discourse about the nation and define its problems and propose solutions. Scientists from all ranks rushed to defend the accomplishments of science and resist changes to the status quo of federal funding of science. As one physicist wrote in an editorial of Science: "How should we defend science against its attackers? To what extent should we change direction so as to work more specifically on the applications of science to the public good? Should we as scientists throw our support behind one or other of the major social and political forces, or indeed behind some other political force?...No, the only effective defense of science is
through strengthening science itself..." (Thimann 1970) Just one week later in the same editorial, a scientist trying to defend basic science quoted the voices of the nation's top scientific academists:

To the extent that society insists that basic scientists do work that is more relevant to present social needs...scientists will be less able to work where nature appears willing to answer their questions. They may be required to work on relevant questions that perhaps cannot be answered at all at present, or can be answered only with uneconomic use of resources. Thus, excessive efforts to make science more productive in terms of immediate social goals may actually make it far less productive in the long run. (quoted in Abelson 1970)

On the other hand, science critics also tried to define the problem and its solutions in their own terms and in their own media channels. Having defined the problem as that of science unresponsiveness and even threatening of the nation's needs, some of these critics developed a solution where the most immediate national problems were to be solved by a technoscience "of a different kind." For example, Professor Robert Heilbroner of the New School in New York, after outlining the nation's most pressing problems --poverty, collapse of urban infrastructure, racism, and environmental degradation-- proposed as the main priority for the seventies to be "not for less technology, but for more technology of a different kind".

The priority then is technological research -- research aimed at devising the techniques needed to live in a place that we have just begun to recognize as our Spaceship Earth....(Heilbroner 1970)

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Defining the solution even further, Heilbroner proposed using existing scientists, engineers, and technicians and training new ones in American research universities to carry out this "different kind" of technological research:

Many people wonder where we can direct the energies of the engineers, draftsmen, scientists, and skilled workmen who are now employed in building weapons systems, once we cut our military budget. I suggest that the design of a technology for our planetary spaceship will provide challenge enough to occupy their attention for a long time....I can suggest aimed specifically at the upper echelons of the educational apparatus...that they direct major portion of their efforts toward research into, training for, and advocacy of programs for social change...(Ibid)

Given the emerging image of nation plagued by social and environmental problems, proposals of science education and research for social change became possible. Stories of scientists from all ranks putting their service to social problems became acceptable even in scientific media. One editorial, after telling the courageous decision of James Shapiro, "one of the most promising molecular scientists in the nation", to leave scientific research for political activism, concludes:

New scientific knowledge will be required to counter the effects of the uses to which current knowledge has been put...we wish Dr. Shapiro success in his new career -- for today, more than ever before, it is imperative that the fruits of science and technology be turned exclusively to the service of man. (Cass 1970)

While some scientists proposed science education and research for social change as a plausible solution to national problems, others eager to establish
control over these new proposals for science recommended a variety of "fixes" to the scientific establishment, including adjustments to existing governmental institutions. (see for example Gershinowitz 1972) One of these moderate reformers, A. Hunter Dupree, one of the nation's most respected historians of government and science, became aware of the potential implications that these attacks and proposals could have in the partnership between government and the scientific establishment. Regarding the role of government, Dupree suggested

...on the government side of the partnership, the problem is not to make a paper reorganization, to create a Department of Science, or to disturb the functioning of the science advisory...within the White House. It is rather to provide a comprehensive rationale by which the government can continue to support free science in the universities and whatever else it can find an institutional home...Any new arrangement must improve the position of the NSF in...emphasiz[ing] the chain of connections, and not the disconnections, between long range basic research and applied science generally, in the interests of both national security and of alleviation of social and medical problems besetting mankind. (Dupree, 1970)

Top science leaders came to accept these proposals of education, training and research for new national problems to be located at specific government agencies. As Bentley Glass, president of AAAS (1969) and vice president of SUNY at Stony brook, said: "Science PhDs must be equipped to meet social needs." (Business Week, 1971). In one editorial of Science, NSF Director, W.D. McElroy was more specific about the institutional location of these solutions:
there must also be a heightened awareness of the requirements placed on all science, and for this reason a significant share of the total resources available to NSF in the future must be devoted to the social and technological needs of the nation. To bring the best of science to bear on the social and technological problems of society requires at least three steps. A larger number of the most creative members of the scientific community must be encouraged to associate themselves with the great problems of man and society; for even though not all of the world's ills have a scientific or technological base, the thought patterns of science and its intellectual-material accomplishments are proof that science has much to offer society. (McElroy, 1972)

This apparent acceptance of education and research for social needs into the bastions of basic science, mainly NSF, did not happen without a struggle. Defenders of basic science and proponents of science for national needs battled for budgets and resources, contesting whether the basic science that saved the nation in the 1960's was enough to save the nation of the 1970's.

Can basic science still save the nation?

Since 1965, the Subcommittee on Science, Research and Development of the U.S. House Committee on Science and Astronautics had been pressuring NSF to adjust its national mission to meet growing social needs. As the Subcommittee's chairman Emilio Daddario (D-Conn) said in 1966 during a review of NSF's first fifteen years:

within the present scientific, political and social context, NSF is operating in a manner which was satisfactory a decade ago but which does not appear adequate for either today or tomorrow...Now it is time to make the Foundation into a broader instrument for forging and shaping the national policies to foster the national resources for science and to focus
and direct them toward the attainment of great national goals: full employment, a clean world to live in, a population in balance with resources... (USHR 1966)

As we have seen, powerful actors by themselves do not make policy. They have to speak within the limits of what is sayable. In the mid-1960's, the U.S. was still in a science race with the Soviets, science was still endorsed by the government as "a way of life", and NSF was providing quality science education for the unmet Soviet challenge. Demands by Daddario began what became known as the Daddario-Kennedy Amendment which resulted in the NSF Act of 1968. This amendment brought some organizational changes by restructuring the discipline-oriented directorates into area-oriented ones and NSF's new areas of responsibility became: basic research, manpower and education, institutional development, and science information. Despite the changes, the Act of 1968 did not challenge basic research as the main category for NSF funding. For example, in 1969 when Congress appropriated only $6 million (1% of NSF's budget) for Interdisciplinary Research Relevant to Problems of Our Society Program (IRRPOS), basic science took 82% of NSF's budget, only 3% less than the year after Sputnik. However, in the 1970's, with new national needs facilitating the positioning of social and environmental problems within NSF's mission, basic science became threatened.

Speaking within the limits of what is sayable, powerful actors in congressional committees with jurisdiction over NSF articulated this notion of a
nation in turmoil to be saved by a "different kind" of science. Senator Edward Kennedy (D-Mass), Chairman of the Special Subcommittee on NSF of the Senate's Committee on Labor and Public Welfare, in the opening statement of the 1971 authorization hearings for NSF, recognized that

We are meeting at a crucial period in the history of American science. Science and scientists are facing both unprecedented criticism and unprecedented opportunity. The critics contend that our scientific resources are too heavily concentrated in the defense area and that our scientific technology has too often ignored the needs of our environment. But even these critics must recognize how much we require science's help if we are now to cure our domestic ills, including pollution. That is the opportunity facing science today (USS 1970: 1)

Also within the limits, policy makers located a special kind of science education and research at NSF, hence proposing NSF as an institutional solution for the new national problems. Having witnessed NSF as a responsive policy instrument to produce basic research and quality scientists for the "Age of Science", policy makers like Kennedy contested how NSF should be made into a policy instrument for new national needs. Kennedy used the new notion of nation in turmoil to contest the appropriateness of NSF. As he put it:

We live in an age of immediacy. From TV screens to the youth culture, the emphasis is on now. Each evening we view the human carnage which took place in Vietnam that morning and we are immersed in the immediacy of our problems--from the war to the economy, crime to pollution... To solve these problems and build the kind of world we want, we need the best knowledge we can develop and the best educational system we can shape. The National Science Foundation has a unique role in meeting these goals... (USS 1972: 1)
While the national mission NSF carried in the 1960's fit the desires of scientific academism, the emerging mission challenged them. Sen. Kennedy continued pressuring NSF to change not only bringing applied science and social sciences to the forefront of NSF's mission but proposing a new educational mission for NSF:

The NSF has a major role to play in enabling scientists to meet the challenge of the seventies. Through its support for basic research and science education, the NSF prepares the way for important discoveries. Through its support for applied research and the social sciences, it can help mission-oriented agencies at every level of government utilize this discoveries effectively. The administration recognizes the significance of the NSF's role and has increased its authorization in 1971. (USS 1972:1)

Congress listened to Kennedy and appropriated $34 million (or 7% of NSF's total budget) for FY 1971 to establish IRPOS's successor under the title Research Applied to National Needs (RANN). (see figure 5)

![Graph showing the percentage of NSF's total budget allocated to education, applied, and basic research from 1969 to 1979.](image)

Figure 5. Basic Research, Applied Research, and Science Education as Percentages of NSF's Total Budget: 1970's
As Sen. Kennedy, from his powerful position as Chairman of the Special Subcommittee on NSF, pressured NSF to increase its responsibilities in dealing with national problems, scientific academism at NSF top positions resisted. Both Philip Handler, NSB Chairman, and William McElroy, NSF Director, resisted attempts to include applied science within the domains of NSF. As Handler put it before the Special Subcommittee on NSF of the U.S. Senate:

"One should not warp the scientific endeavor by converting all of our capabilities into applied activities and forsaking long range scientific ventures...We must get on with the fundamentals today so that we will have the understanding we will surely require in a rather long distance future...There must be an amply funded Federal agency which has the broadest possible license to support science, without concern for what the ultimate applications will be. That agency is the National Science Foundation." (USS 1970: 7-9).

Following this line of resistance into NSF's 1970 Annual Report, NSF Director William McElroy acknowledged that the "underlying new policies and programs for the 1970's" included a reexamination of science, engineering and technology "as basic tools of service to society" but that "progress in science cannot continue if its foundations--fundamental research--are weakened." (NSF 1970:1)

More increments for applied science followed these acts of resistance. As basic science's share of NSF's budget decreased by 6% in FY 1971, applied science's share increased by 6%. Scientific academism began resisting redefinitions of NSF's science education programs in terms of solving new national problems.
When the NSB declared that NSF's educational philosophy for the 1970's was "to educate scientists who will be at home in society and ...a society that will be at home with science", the door was left open to multiple interpretations and struggles as to what being at home in society meant. The making of scientists and engineers at NSF during the 1970's became a struggle between two competing interpretations. Scientific academists and NSF top officials endorsed one which called for a moratorium on all educational and manpower programs except those aimed at producing top quality scientists for basic research. Senator Kennedy and science critics endorsed another which called for education and training around national problems.

Can quality science education save the nation?

NSF officials sold science education programs in the 1960's with the promise of producing "a small cadre" of top quality individuals to save the nation from Soviet threat. In the 1970's, with a nation redefined around domestic problems to be solved by applied scientists, NSF top officials resisted the creation of new science education programs fearing that they would become further encroachments of applied science not just on the budget but in the very image of "scientist" they had created in the 1960's. Supported by official statements showing an oversupply of scientists and engineers, including those of NSF's manpower unit, by now the most trusted voice on supply and demand
of scientific manpower, NSF officials resented both the creation of new education programs and the possibility of retraining the existing scientific workforce. As NSF Director William McElroy told Congress:

It is the Administration's position that an adequate manpower supply exists in almost every field of science and engineering to meet Federal R&D program needs for the foreseeable future... Very preliminary information on the employment situation for scientists and engineers, as appraised by the College Placement Council, the Office of Education, and the Department of Labor, indicates that the problem today is much more complex than one of reallocation of manpower...Therefore, NSF believes that, when all of the complexities are taken into consideration, it would not be in the national interest for the Federal government to provide special Federal incentives at this time to encourage increased numbers of young people to pursue careers in science and engineering (USS 1971: 98-9).

Under the name of oversupply, McElroy defined the problem of education in terms of numbers to differentiate between Ph.Ds working in basic science and non-Ph.D's working for space and military contractors. Director McElroy continued:

Current problems of oversupply in defense and aerospace industries involve, on close examination, mainly non-Ph.D scientists and engineers who have worked, over some years, on a single intensive technological aspect of a particular space or defense-related project. Completion or cancellation of these projects left these people in a particularly poor position to find new employment in an austere market. (Ibid)

Making clear that oversupply was in the non-Ph.D ranks of applied scientists and engineers, McElroy protected scientific academism's pet program: the Fellowships. He assured Congress that NSF intended to continue support of its

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graduate fellowships in the midst of oversupply

It would be a mistake, however, for NSF to discontinue all programs aimed at encouraging young people to pursue careers in science and engineering. There must be a bases support program sufficient to encourage outstanding young men and women who wish to pursue careers in science and engineering but low enough to prevent oversupply. Therefore, NSF is continuing to maintain a viable program of graduate fellowships based on a National competition. We believe that this program...will help provide the base of support required to insure at least a cadre of skilled scientific professionals over the long term. (Ibid)

This strategy proved successful until 1974 when fellowships for national needs and fellowships for basic sciences received equal share of NSF's education budget (see figure 6).

![Graph showing competing categories in science education as percentages of NSF's total education budget: 1970's](image)

Figure 6. Competing Categories in Science Education as Percentages of NSF's Total Education Budget: 1970's
Another strategy that NSF's administration used to resist the pressure to change its science education programs was to redefine social needs in terms of quality scientific education. As Lloyd G. Humphreys, Assistant Director for Education at NSF, put it to the U.S. House Subcommittee on Science, Research and Development in the 1972 NSF authorization hearings to determine priorities for science education: "The first and most important criterion is social need." (USHR 1971: 396). When asked by the Subcommittee's Chairman John W. Davis (D-Ga) to be specific on the meaning of "social need", Humphreys answered: "I mean the kind of education that our society needs to meet its commitments to our people, needs for scientific talent, needs for high-level technological talent, needs for teachers of science." (Ibid) When asked again by Committee Chairman Davis if what he meant by social need was "purely science-oriented", Humphrey responded: "Yes sir, yes sir." (Ibid).

Following a logic similar to that adopted by scientific academism ten years earlier, Humphrey claimed that continuing support for quality-oriented programs, such as the Fellowships and Teacher Institutes, was in the best interest of society's needs. For FY 1972, this translated into $22 million for Fellowships and Traineeships and $21 million for teachers programs. In relative terms, 50% of NSF's shrinking budget for science education was being devoted to quality-oriented programs while only 3% was spent on needs-oriented programs.
NSF administration went beyond redefining social needs to protect the Fellowships from needs-oriented programs. Under the pretext of oversupply, NSF terminated the number-oriented programs initiated in the 1960's, such as the Traineeships (most of which went to engineers), and graduate support in the social sciences. With certified knowledge from NSF's manpower projections claiming that "some serious potential [oversupply] imbalances for engineering and the social sciences," NSF and the White House justified ending number-oriented programs which now presented the danger of being redirected towards applied science for national needs. As Edward David, science policy advisor to President Nixon, told Congress during NSF's 1972 Authorization hearings:

_We had in mind the decreasing size of the market for engineers and scientists. This implies that our programs of educational support should be aimed at increasing quality rather than increasing quantity of graduates....Thus, we propose to discontinue NSF institutional programs which were primarily pointed at stimulating careers in science. Much of the reduction here results from a continuing phase-out of the graduate student traineeships...That program was aimed largely at stimulating the massive increase in scientists and engineers needed for our space and defense efforts program in the 1960's...At this time it is important to utilize scientists and engineers more effectively and to avoid overproduction... (Ibid: 653) (my emphasis)_

Eventually, NSF administrators completed the phaseout of the traineeships in 1973 while it began granting 3-year Fellowships in 1971 to ensure continued

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1 See NSF's (1971) *Supply and Utilization of Science and Engineering Doctorates, 1969 and 1980* which updated previous analysis to conclude that there is a "greater likelihood of a future oversupply than the previous NSF projections developed two years earlier." The report emphasizes serious potential for oversupply in engineering and social sciences, the two areas that the NSF Act of 1968 included into NSF's mandate.
federal commitment to quality science education.

We have seen that the limits and forms of what is sayable at a given period include those "utterances that everyone recognize as valid, or debatable or definitely invalid". (Foucault [1968] 1991) For how long could NSF's administration keep making quality education, as conceptualized in the 1960's, part of the solution to national needs of the 1970's before it would be recognized as a debatable or invalid solution? Who recognized this and how did they construct official knowledge to initiate acceptable education programs? This is where we now turn.

In 1972 many factors contributed to pressure NSF even further to change its attitude towards applied science for national needs. First, Nixon removed scientific academism from its powerful position inside the White House by abolishing OSTP and PSAC. Guyford Stever, NSF's new director, became an informal science advisor to Nixon. Not only did Stever replace the old-guard of elite presidential advisors but he helped move NSF toward applied research for national needs. Media described his job as: "provide technical answers to down-to-earth problems in transportation, energy, productivity, and health -- a far cry from NSF's basic research charter." (Business Week 1973) To help Stever in his role as advisor, Nixon established an external Science and Engineering Council chaired by William O. Baker of Bell Labs and Simon Ramo of TRW, Inc. While Baker continued the interests of scientific academism, Simon Ramo
endorsed redirecting science education towards social needs. While NSF's administrators used the authority of manpower studies to claim an oversupply, Ramo predicted a shortage of people trained in dealing with new social problems. As he wrote in a speech in 1972:

Long before 1990 it will become apparent that we have a shortage of properly trained people, particularly the interdisciplinary, practical intellectual. We cannot Suddenly turn a large fraction of our engineers into experts on the social side for the problems or opportunities. Because it will be the only way to get started to get the job done, we shall, for a decade or more, create "social technologists" (perhaps we should say "poly-socio-econo-politico-technologists") in the school of hard knocks. These will be key performers in applying science and technology fully to the needs of our society. They will become expert at doing so by pragmatic, day-to-day synthesizing of arts and disciplines and experience and motivations and human ingenuity...(quoted in USHR 1972)

Regardless of his highly influential position, Ramo did not have official statements as legitimate as those coming from NSF's manpower studies unit. However, his statements reflected that the image of nation, where "social technologists" apply science to solve national problems, made it into the higher circles of policymaking. A similar image made it into NSF authorization hearings in 1973. As Chairman of Subcommittee on Science, Research, and Development John Davis (D-Ga) put it to the NSF staff:

A great deal of thought should be given at NSF as to what to do with people who are skilled but are unable to find an application for their skills, or whose technology moves off and requires them to be retooled (USHR 1972:35)
NSF top administrators began to budge on these requests that called for retraining existing scientists. NSB Chairman H.E. Carter, who became Coordinator of Interdisciplinary Programs at the University of Arizona during his NSB tenure, responded to this pressure by saying that NSF science education programs were beginning to adjust to the changing needs for scientific manpower. Retraining also included making scientists and engineers able "to deal with economic, environmental and social problems and [with] the need to develop and apply technology to provide at lower cost and higher efficiency the energy, transportation, housing and other services." H.E. Carter actually recognized that education as conceptualized in the 1960's was no longer adequate for the present needs:

A little over a decade ago when this Nation faced a severe shortage of scientists in the traditional disciplines, we developed incentives and provided resources to encourage the growth of high quality doctoral programs. The need is now different. We are just beginning to develop curricula and organize programs to meet the need for broadly trained interdisciplinary scientists (USHR 1972: 51)

Just how big was NSF's commitment to change its science education program towards national needs? NSF had been responding to these pressures as early as 1970 by putting minimal support towards problem-related programs, such as the Advanced Science Education Program, which included a component for the "training of environmental problem-solvers". (NSF 1970)

With only $2.3 million in FY 1970 (or 1.9% of NSF's education budget) for
graduate education programs oriented towards national needs, NSF increased this kind of support to $12 million (or 15% of NSF's education budget) in FY 1974, matching its support for traditional Fellowships (see graph). Although it would appear that NSF was giving in to the pressures for applied research, its budget history throughout the 1970's tells a different story. Applied research never exceeded 12% of NSF's total budget while basic science actually grew from 59% in 1970 to 81% in 1978. Similarly, applied-research graduate education never surpassed an already shrinking quality-oriented graduate fellowships.

Why did NSF top administrators resist so strongly this seemingly insignificant encroachment of problem-oriented program into basic research? In 1974, when programs for women and minorities also entered NSF's education budget, scientific academism defined the struggle between basic science and applied science as sustained responsibility vis-a-vis crisis response programs. They defined "crisis-response" programs as "crash" programs designed to respond to an immediate need, including those of a particular group, with the potential to compromise quality in science education. On the other hand, they defined "sustained responsibility" programs as those that produce continuously high quality scientists and engineers in basic sciences regardless of immediate national crises. During oversight hearings on NSF science education programs in 1975, NSF administrators aligned groups representing higher education to
call for sustained responsibility programs. Testifying on behalf of the Associated Colleges of the Midwest and the Great Lakes Colleges Association during oversight hearings on NSF science education programs, Dr Lewis Salter depicted the decrease in science education budget (from 45% of the total NSF budget in FY1959 to 12% in FY 1974), as the result of "turning off the manpower spigot" that followed Sputnik. Qualifying post-Sputnik programs as "crisis response" and blaming them for present oversupply problems, Salter opposed the creation of new "crisis response" programs such as energy-related and women and minorities programs in science education (USHR 1975: 178-9). Salter called for NSF to concentrate on "sustained-responsibility" programs to improve the quality of science regardless of the crisis or manpower situation affecting the country. This is exactly what NSF administrators wanted academia to tell Congress. Through representatives of higher education like Salter, NSF top officials kept pushing for quality-oriented programs while resisting the inclusion of "crisis-response" programs such as energy-related programs and those for women and minorities.

White males with Ph.D's alone will not save the nation

Criticisms of the "giant leap for mankind" came through popular media
representing the views of American minorities. Criticizing the massive spending of federal funds on Apollo which had no impact on improving their representation in science education, minorities set the stage to claim more participation in applied science for national needs. These claims criticized a nation whose priorities were to go to the moon at the expense of having failed its minority citizens by excluding them from technoscientific training and education in the 1960’s. This criticisms made it into the halls of Congress and into official statements around mid-1970’s when advocates of minority groups claimed that their inclusion in science was not only a matter of reversing the damage done in the 1960’s but a matter of national survival in the 1970’s.

Marginalized from science education efforts in the 1960’s, minority voices gained entrance to Congress with the help of Senator Edward Kennedy. Black Americans were the first minority voice to appear in this official forum. Mark Miles Fisher, Executive Secretary of the National Association for Equal Opportunity in Higher Education, claimed that black people, with the help of NSF, could contribute to the solution of national problems because they had intrinsic knowledge of Black America, like the inner city, that whites did not have. While unemployed white Ph.D's could be retrained through NSF programs, they could never understand the problems associated with Black

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1 See for example, “Giant leap from mankind?” (Ebony 1969), “Moon and middle America” (Time 1969), and “How Blacks view mankind’s giant step” (Ebony 1970)
America. Testifying to the Subcommittee in support of $5 million for Ethnic
Minority College Projects to the in 1972, Miles said:

To use the area of Research Applied to National Needs as an example,
one might see this possibility of involvement by the traditionally black
colleges, along the following lines: The national problems of the Inner
City could be dealt with through the resources of these institutions.
People from these colleges are knowledgeable of the black community
and should play a bigger role in solving the problems of the inner city.
(USS 1972)

Pointing at the substantial differences between NSF funds allocated to
white vis-a-vis black institutions in FY 1970 (only 0.88% of NSF budget for
institutions went to black colleges and universities), Miles was successful in
arguing for more NSF funds. Minority institutions received around $5 million or
more per year from FY 1973 to FY 1980. Like Miles, other minority advocates
were able to make mobility of Black Americans towards national problems a
desirable characteristic of the nation's manpower in science and engineering.
By 1973 NSF's Assistant Director for Education Keith R. Kelso recognized
mobility as "variety" and declared the goal of its science education program "to
provide for the numbers, variety, and flexibility of scientific and technological
manpower needed to meet the Nation's changing requirements." (USS 1973:
35)

Regardless of their own recognition of the need for "numbers, variety and
flexibility", NSF's top administrators still resisted by recommending that no
fellowships should be funded on the basis of disadvantaged backgrounds as
authorized under the law. In their 1974 report titled *Federal Policy Alternatives toward Graduate Education*, NSB rejected Title IX, Part B, of the Education Amendments of 1972 which authorized graduate fellowships for persons with ability from disadvantaged backgrounds. NSB also discouraged programs for graduate students based on financial need which were modeled on the undergraduate Basic Opportunity Grant. Fisher's strategy to counteract NSF's resistance was to go after funds for institutional development instead of going after fellowship funds, scientific academism's sacred terrain. Funds for Historically Black Colleges and Universities (HBCU's), besides providing high visibility to congress representatives supporting them, would provide the necessary infrastructure to guarantee a minimum supply of black students into graduate programs in science. This would serve two purposes. First, HBCU's would become a mechanism for distributive justice, one of the main national problems according to some, by providing opportunities for upward mobility. Second, HBCU's would educate problem-solvers for Black America's problems.

This is how Miles positioned HBCU's institutions [that] have enabled hundreds of thousands of students shackled by poverty and racism to break free...[as] an existing mechanism that can be improved and used to intensify the positive efforts to equalize opportunity...and to guarantee the supply of blacks trained in science, as well as give a pluralistic mix in terms of the needs of our society. (see USS 1974: 123-5).

By outlining the contributions of HBCU's to the solution of important
national problems, such as racism and poverty. Miles made "blacks in science" a significant category for the needs of the nation. This strategy proved successful, at least partially, for it helped secure 8% of NSF's education budget for minority institutions in FY 1974. Through associations representing white academia, NSF's top administrators still argued that minority programs were to be seen as "crisis-response" and hence detrimental to an already overloaded labor market. Also, according to NSF's manpower projections, there already existed plenty of non-minority Ph.D's who could be retrained if necessary. Minorities argued that these claims of oversupply coming from NSF were biased towards whites. Requesting Kennedy's Subcommittee on NSF to authorize the establishment of minority centers for Graduate Education in Science and Engineering, William Jackson, from the National Organization for the Personal Achievement of Black Chemists and Chemical Engineers, said

I have heard here today that we do not really need to increase the number of scientists and engineers, but that is a reflection of what one of my colleagues calls "monochromatic assumption." The assumption is that since the number of whites in science and engineering are saturated no new programs are needed to increase the number of minorities in science and engineering. (USS 1976a:342)

By criticizing the "monochromatic assumption" of NSF officials, Jackson also pointed the finger at the assumptions built into NSF's source of authority for making claims about the number of scientists and engineers: NSF's manpower projection model.
NSF's source of authority questioned

An oversupply of technoscientific labor, at a time when the nation appeared plagued by social and environmental problems, opened the door to question the validity of NSF's source of knowledge about U.S. manpower. An image of a nation in need of mobile scientists to solve social and environment problems flowed into NSF projection models as a renewed NSB called into question models from 1960's. With old-guard scientific academists retiring from NSB\(^5\), and strong voices for interdisciplinarity and participation of women and minorities in science\(^6\), NSB called for a workshop "to carry out a critical comparative study of existing manpower analyses and the assumptions that underlie them." (NSB 1974:iii) According to workshop participants, which included NSB members and manpower experts, new manpower projections needed to address new national problems. One of the panels titled "Changes in National Priorities, Manpower Projection Techniques, and Requirements for Scientists and Engineers" stated that

Changes in national priorities as they are reflected in government programs in health, pollution abatement, energy resource development, urban redevelopment and other areas can have consequences similar to those that took place [in the 1960's] because of the shifts in R&D

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\(^5\)For example, terms expired in May 1974 for the following NSB members: Harvey Brooks, Professor of Applied Physics and Dean of Engineering and Applied Physics, Harvard University; William Fowler, Professor of Physics, Cal Tech; Norman Hackerman, President, Rice University.

\(^6\)For example, NSB chairman was H.B. Carter, who was coordinator of interdisciplinary programs at University of Arizona. Anna Harrison, Professor of Chemistry, Mount Holyoke College, became the strongest voice for the representation of women and minorities.
expenditures. In effect, the activities undertaken to implement national priorities set up a series of demands for manpower at different levels of skill and occupational specialization in the public sector and, frequently even more so, in the private sector of the economy...[hence] Projections that seek to account for the anticipated consequences of the pursuit of national goals for scientific manpower utilization in the next five or ten years [should] refer to social rather than to market demand. (NSB 1974:79)

Workshop experts found fixed-coefficient projection models, like those used in the 1960's and into the 70's, to be somewhat limited for the new domestic agenda. After criticizing the over-reliance of projections on federal R&D expenditures, they issued the following warning about fixed-coefficient models:

"There is therefore, some tendency for oversimplified forecasts to be translated rigidly into educational policy. Yet fixed coefficient results have been surprisingly correct on the broad scale considering their limitations." (Ibid. 7) Workshop participants also criticized market-models because they did not account for important market controls considered important under new national needs:

"Market models are criticized on grounds that the U.S. economy does not work in a purely market sense; there are numerous controls and rigidities in the system...[such as] equal opportunity and affirmative action brought about by legislation and other forces [which] have affected and shaped a number of significant trends..." (NSB 1974: 7-10) They proposed a shift towards projection models capable of forecasting mobility between disciplines, specialties and problems of national importance. For example, the panel recommended that
"particular attention should be paid to the question of the extent to which occupational utilization depends on educational specialization, i.e., of flexibility in the use of scientific personnel." They also called for "methodology to understand the need for scientists and engineers in emerging priority areas such as environment, food shortages, or areas which will be affected by legislation requiring affirmative action." Furthermore, they recommended that "educational alternatives be provided to the traditional highly specialized Ph.D. program to prepare students for a broader range of careers." (NSF 1974: recomm) Accordingly, the NSF modified the Register. Explaining its shift to a new system that accounted for race and gender of scientists and engineers, NSF's 1974 annual report states "the Manpower Characteristics System, which took the place of the National Register of Scientific and Technical Personnel, ...showed that 6,000 of these doctoral scientists held post-doctoral appointments, 21,300 were women, and 15,200 were members of minority groups." (NSF 1974:100) Also, explaining a new interest for scientists and engineers in areas of national interests, NSF claimed that "one major new program in the manpower area was initiated by the Foundation as a direct result of the recently experienced energy crisis....Consequently, the Foundation started a program of study and analysis of information related to current and prospective utilization of scientific and engineering manpower in energy-related activities." (Ibid) A number of problem-specific manpower analyses followed NSB
workshop. For example, the National Research Council conducted a study on "Manpower for Environmental Pollution Control" (NRC 1977) and one for "Manpower for Primary Health Care." (NRC 1978)

Very quickly, new projection models made it into congressional hearings. In a 1976 "NSF Posture Hearing," NSF reluctantly acknowledged the new model: "Although there remains much uncertainty about the accuracy of such projections [NSB's], it is clear that major problems such as energy, environment, and food production will require large numbers of highly skilled, flexibly trained people in the years ahead." (USHR 1975b) NSB's new chairman Norman Hackerman and NSF's Guyford Stever officially recognized to Congress that NSF had "to learn how to make these people a little more mobile, more willing to move from discipline to discipline or problem to problem..." (USHR 1975b: 23).

After 1974, official knowledge about new national needs for national problems translated into programs. Graduate education in applied research for environmental and energy-related problems increased from 3% in FY 1973 to an average of 12% of NSF’s education budget after 1974. For the first time, funding in these areas was given under the title "Fellowships in Science Applied to Societal Problems" and "Energy-related Postdoctoral Fellowships." Although minority leaders like Miles were partially successful in positioning minority institutions as part of the solution to new problems, for which they received 8%
of NSF’s education budget, they still had to convince NSF that minorities were individuals worthy of awards such as the Fellowships.

Somewhat naively, Congress understood the complexity of projecting mobile manpower for the survival of the nation but still demanded specific numbers to act upon. As we saw in chapter 2, manpower statistics had become a legitimate source of official knowledge to direct policy making. As U.S. House Rep. Kenneth Hechler (D-WVa), of the Committee on Science and Technology, put it to NSF

Dr. Stever and Dr. Hackerman, I think you are both in a unique position to look into the future and assess and appraise where some of our real brainpower shortages are going to occur 10, 15, 20 years hence...Could you quickly put into your computer all the various factors such as student enrollments, university interest, problems of the nation, problems of the world, jobs, state of the economy, and other things, and would you care to sound any kind of alarm or blow any kind of whistle for us as to what we need to be doing in order to protect ourselves 10, 15, 20 years hence? (USHR 1975b:23)

We have seen how minority leaders like Miles successfully positioned minorities as parts of this mobile "brainpower" thus making them significant categories for NSF to fund at the institutional level. What minorities needed now was a legitimate official statement about their underrepresentation in science and engineering in order to show how few they were and to show lawmakers like Hechler how much the government needed to do. In 1976, for the first time, they began using statistics from the Scientific Manpower Commission which showed that of the 207,000 Ph.D’s awarded in science and engineering only
0.8% were awarded to blacks, 0.6% to Latinos, and 0.04% to Native Americans. These statistics became instrumental official statements in the making of the Science and Technology Equal Opportunity Act of 1980 where congress directed NSF to begin publishing data on women and minority representation in science and engineering. However, if by 1974 minorities had found a way into science through institutional support, in 1976 they still had to argue that being a black, hispanic or Native American individual was an important characteristic of a scientist or engineer to have in order to solve existing national problems.

In the midst of resistance from NSB and NSF top administrators to fund individual traineeships or fellowships for minorities, minorities began arguing that individuals with different racial and ethnic backgrounds were good for science. Their argument for individual awards was different from the argument for institutional support. If successful, arguments for individual awards would elevate minority individuals to the highest levels of recognition from NSF and the scientific community. Arguments for institutional support had the stigma of just being requests for federal support of educational environments to nurture underprivileged populations. If minorities wanted full recognition as respectable scientists, it was indispensable for them to go after the Fellowships. If they wanted their research on problems affecting their own communities to be recognized as valid scientific work, they needed Ph.D's and postdocs. This is
what Shirley Malcom and Janet Welsh Brown, of the Office of Opportunities in Science of the AAAS, tried to do as they articulated a language of diversity that went beyond equal opportunity. They claimed that access to science and technology was good for the betterment of minorities, but also the inclusion of minorities was good for science. Testifying for the Senate’s Committee on Appropriations, Janet Welsh Brown, head of the Office of Opportunities in Science at AAAS and president of the Federation of Organization for Professional Women, defined the problem -- too few women and minorities in the sciences-- and its probable causes including the role of NSF.

...in the great scientific progress of the sixties, women and minorities were left further and further behind as the production of white male Ph.D.'s multiplied tenfold. It is a little known fact that our Black population received higher percentage of the science Ph.D.'s at the beginning of the 1960's than at the end -- after all those NSF fellowships had been given out. Federal programs, therefore, actually contributed in some respects to widening the gap between white males and women and minorities in the sciences” (USS 1976b: 1851)

After pointing out that "the nation pays a very high cost for this inequality", Brown defined exactly where the highest cost for the nation was.

The third cost is the cost to science itself. The so-called “search for truth” and the scientific method require that ideas and values and assumptions be subjected to constant challenge and examination. I believe that diversity of cultural and other backgrounds helps assure that challenge and that diversity is necessary for good science. There is much in our accepted and unquestioned knowledge that is based on false assumptions and imperfect of incomplete research...My hypothesis is that if there had been a healthier mix of women and minorities in the world of scientific research, more of those values and assumptions would be questioned earlier. (Ibid)
Brown concluded her presentation with statistics from the Scientific

Manpower Commission which throughout 1975 Betty Vetter, executive director
of the Commission, had disseminated in a series of editorials in Science,
making them part of the scientists’ discussion about the problems of the nation.7

Among those listening to Brown’s statements in the Appropriations Committee
was U.S. Senator William Proxmire (D-Wisc) who during 1975 was criticizing
NSF for wasteful expenditures of taxpayer money: "My choice for the biggest
waste of the taxpayer’s money," he said in March 1975, "has to be the National
Science Foundation." But now impressed with Brown’s argument and statistics,
he told Brown and the Committee

Your statistics are overpowering...I am glad that you have indicated what
role the NSF can play in changing this situation. As I said earlier, I have
been hammering away at them [NSF]. I have been trying to get them to
change their minority and sex policies but primarily just asking them to
hire more women and minorities and put more emphasis on those
groups. But you spell out in specific detail how they can do it. I will write
to the head of NSF, call his attention to your testimony, and ask for some
answers on the extent to which the agency feels they can put these
program into effect promptly. (Ibid: 1864)

What is important here is not that Sen. Proxmire found ammunition to go
after his favorite target. What is important is that Janeth Welsh Brown defined
the problem for NSF to solve: the underrepresentation of women and minorities
in science.

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7 See for example, Betty Vetter’s (1975) "Women, Men and the Doctorate" and "Women and Minority
Scientists", both in Science magazine.
Losing control over the definition of the problems they had to solve in science education, NSF administrators tried to maintain control over the definition of the solutions. With enough political pressure coming from champions of underrepresentation such as Kennedy and Proxmire, NSF finally acknowledged that representation of women and minorities in science careers was their number one priority in science education. However, by using impact assessment modeling (see figure 7), a problem-solving technique widely used in the 1970's by policy experts, NSF remained in control of the next stages of their science education programs, mainly problem assessment, definition of constituency and programs, and problem impact. (USHR 1975)

A SCHEMATIC VIEW OF NSF'S SCIENCE EDUCATION ACTIVITIES CYCLE

Figure 7. Impact Assessment Model Used in NSF’s Science Education Activities Cycle
Here, after problems were defined by "academic community, Congress, NSB, Administration, society...", NSF made an assessment of these problems and determined which problems are unaddressable by NSF, which required a changed emphasis in existing programs, and which required new programs. (Ibid) NSF claimed that "financial distress of many colleges and universities" was an example a problem that it could not address. This, of course, excluded most minority institutions from NSF's domain. Then NSF determined the composition of its constituency as: students, faculty, materials, and institutions. Again, in a "taxonomy of the Academyn" to determine which kind of institutions fell in their constituency, NSF did not recognize HBCU's nor all-female colleges and universities as separate categories from research universities. This meant that the interests of the latter guided the definition of programs. NSF's next step was to define new programs according to its constituency. Here, NSF only listed traditional graduate fellowships and energy-related fellowships as "student access" programs. Women and minorities were still not recognized as "student" constituency. Under "faculty access" programs, NSF created two categories: quality and quantity. While the former represented "intellectual capability", the latter represented numbers of women and minorities. Under "institutional access" programs, NSF listed Minority Institutions Science Improvement. As we have seen, this is the only significant program showing NSF's commitment to minority representation with only 8% of its education budget. Although, NSF
claimed that this methodology was used to do impact assessment of all their programs, it became a tool to screen and experiment on "crises-response" programs such as those for underrepresented minorities. In NSF's 1974 Annual Report, "Minorities and Women in Science Studies and Experimental Projects" are the only career-oriented programs to have experimental status with a budget of $0.6 million (NSF 1974: 91-2). The FY 1975 budget for these programs had decreased to $0.3 million after "impact analysis." (NSF 1975) In short, what this modelling of education by NSF meant is that although images of the nation entered in the definition of the problem (e.g., through NSB’s manpower recommendations, Janeth Brown's own definition, Kennedy's visions on NSF's role), NSF had maintained control over the definition of the solution: its own programs.

Frustrated with their failures to increase their representation in science through NSF programs, minorities shifted their strategy to the newly proposed Department of Education (DoE). At DoE, minorities saw the possibility to regain the power that NSF's modelling had taken away. As Jesse Jackson put it in his testimony to the Committee on Governmental Affairs of the U.S. Senate, assessing the transfer of NSF's science education programs to DoE:

...by lifting education to cabinet status it would become more accountable to Congress, parents, teachers, students, local officials, private institutions and the press....The challenge of education today can only be met with significant public involvement and support, which requires strong leadership, a commitment to public participation in the highest
levels of policymaking, and visible responsible administration... (USS 1979: 13)

The Office of Technology Assessment (OTA), who in charge of studying the impact of DoE on federal science and technology activities, claimed that NSF would lose authority over science education if its programs were transferred to DoE. OTA concurred with President Carter who acknowledged that "consolidating those federal programs aimed specifically at improving access of minorities, women, and the handicapped [at DoE] will emphasize the administration's commitment to alleviating problems of inequity and discrimination in education." (quoted in USS 1979: 264) In the end, NSF only allowed the transfer of minority institutional programs to DoE since those programs had the stigma of being "welfare programs" and NSF did not want them under its jurisdiction. On the other hand, NSF resisted transferring non-institutional programs for women and minorities to DoE. This resistance, which could be interpreted as Kennedy's commitment to keep women and minorities in science programs at NSF or as John Slaughter becoming NSF first black director in 1980, is also the result of NSF's new national mission of solving social problems through applied science. With whites males not being mobile enough to deal with all national needs, particularly those of women and minorities, NSF wanted to remain in control of making mobile and interdisciplinary selves of different races, ethnic backgrounds and genders to
solve national problems. This authority was finally granted by the Science and Technology Equal Opportunity Act of 1980 (PL: 96-516) which Congress justified by arguing that: "it is in the best national interest to promote the full use of human resources in science and technology and to insure the full development and use of the scientific talent and technical skills of men and women, equally, of all ethnic, racial, and economic backgrounds." (Ibid) In its own terms and after a decade of power struggles with NSF, Congress had incorporated in the selves of scientists and engineers an image of a nation plagued with social and environmental problems. As such, the federal government made selves in science and engineering their instruments to fulfill its national goals.

But on the other hand, as Foucault reminds us "the individual which power has constituted is at the same time its vehicle." (Foucault [1976]1980:98) The processes that created scientific selves for national needs in the 1970's, or "biopolitics" as Foucault called these processes, also provided instances of "strategic reversibility" where selves constituted themselves through acts of resistance. This was the case of black Americans in the 1970's who by gaining some access to science education for national needs were able to define and study their own problems hence constituting themselves as a population of national significance. While explaining to me how her own educational experience helped her justify programs for minorities in science to solve their
own problems which white Ph.D.s could not see, Shirley Malcom said

[In the 1970's] there are diseases that impact us [blacks] differentially and yet people aren't studying them....If you don't have people who care about those diseases then you're unlikely to have people... studying them....We [blacks] have a particular problem environmentally within our communities like my whole community in Birmingham. [As a Ph.D in ecology] I knew what happened to the black community when plants in the area were spewing stuff out into the air and we had real bad problems, in particular with pollution, because Birmingham is located in a valley and that stuff could get trapped in there. We had people living at near subsistence level and they would fish in the water around their homes in order to make up for the protein complement for their meals, and yet heavy metals and things like this were in those fish because of the pollution. But we didn't have trusted voices [scientists] who could speak to and deal with these issues. All these things kind of combined to say: "hey! you are what gets studied." But we [blacks] were not the ones who are doing the studying, we're not the ones who are doing the contributing... (Malcom, 1994) (emphasis mine)

Conclusion

In the midst of both triumph and fear of technoscience, a discourse about a nation at war with itself emerged at the beginning of the 1970's. While most Americans celebrated the Apollo moon landing, some Americans, including a few scientists, skeptical of this accomplishment, questioned the competence of science and technology to solve domestic problems. In contrast with the 1960's when few scientific academists proposed basic scientific research and education as the solution to the Soviet threat, in the 1970s, science enthusiasts rushed to gain control of defining domestic national problems in a way that "a different kind of science" emerged as the solution: a nation threatened by its
own social and environmental problems to be saved by applied science. Throughout the 1970s, a renewed scientific academism at NSF resisted this encroachment of applied science into the bastions of basic research, including NSF's education programs.

Given the nature of the domestic problems, which included urban and environmental problems affecting minority populations, underrepresented minorities in science began arguing that white males alone could not solve the nation's problems. These claims only had a significant effect when NSF's source of certified knowledge about scientific manpower came under attack by experts who realized that models from the 1960's did not reflect an image of a nation with new domestic problems. Making "mobility" a desired trait for the new workforce, the new projection models made "women and minorities in science" a significant category for the solution of new national problems hence worthy of federal support. Once minority representatives presented their own certified data that showed their small representation in scientific fields, Congress passed legislation to promote the representation of women and minorities in science "in the best national interest."

The creation of social-problem solvers by the government allowed minority groups to constitute themselves as national selves. By studying environmental and urban problems that were both of national interest and of their own interest, some minority scientists not only served the nation but gave
voice to other minority communities. The image of "scientist" that NSF helped create in the 1960s, although still dominant, had lost its hegemonic status. Even in a small way, minority scientists showed that a black person trained in specialized knowledge could also help save the nation from itself.
CHAPTER 4

Technophiles and Reaganomics Dictate Policies "to beat the Japanese": Making Lots of Selves for Economic Competitiveness

...as a nation, we must develop a consensus that industrial competitiveness is crucial to our social and economic well-being. Such a consensus will require a shift in public attitudes about national priorities, as well as changes in public perceptions about the nature of our economic malaise. (Business-Higher Education Forum 1983)

While the 1970's was a decade of policies and programs for domestic problems, social and environmental, the 1980's was a decade marked with fiscal reorganization of the federal government and expansion of the R&D sector to promote economic growth. A discourse about economic competitiveness emerged as Japan became the nation's major perceived economic threat. Meanwhile, the Soviet Union continued to pose a military threat, reigniting old fears of communism. This double threat shaped the discourse about the nation in the early 1980s. Within this narrative, NSF became instrumental in the late 1980's by developing an image of the American nation which called for large numbers of scientists and engineers for both economic competitiveness and national security to fight the double threat. In this chapter, I explore the emergence of the new discourse and then look at how NSF constructed this model of nation to be saved by large numbers of highly skilled scientists and engineers. I focus on the construction of knowledge around policy issues involving human resources for technological innovation in the 1980's. I am particularly interested in how government officials shifted policy
and programs in education and human resources at NSF from those of the 1970's to new programs redefined in terms of economic competitiveness.

My main argument in this chapter is that what Sputnik did for science and scientists, positioning them as the saviors of a nation facing a Soviet threat, economic competitiveness has done for technology and engineers in the 1980's and thereafter. Some of the power struggles that took place around education and human resources at NSF in the 1980's were struggles to demarcate technology and engineers from science and scientists in a nation that had grown accustomed to see the latter as the answer to all its problems, foreign and domestic. To redefine NSF's education programs around the need for technological innovation, a new cast of NSF administrators would need to prove that engineers, not scientists, would put the nation ahead in the technological race. I analyze how NSF, to be certain of this action, invented a very powerful model and metaphor of the educational system in science and engineering --the pipeline-- to show the nation how many selves, mainly engineers, would be needed to survive both economic and military competitiveness.

National discourse about competitiveness: The making of Japan

In 1980, a year of intense presidential campaigning, headlines stories told the American public how the nation struggled to stay ahead of emerging competitors in the scientific arena. One article titled, "Science: America's
Struggle to Stay Ahead," reported how "U.S. science for the first time is being seriously challenged by its major foreign competitors," mainly the Soviet Union, West Germany, and in third place, Japan. (U.S. News 1980) The report blamed "shortsighted management that [was] concerned with putting its money into short-term applied-research projects," like those of the 1970's, than into long-term basic and industrial R&D (Ibid, 52). The presidential election served as a forum to further expose and question not only America's scientific capability, but also its economic survival. By linking their economic platforms to revitalize the nation's productivity to R&D, both candidates, Carter and Reagan, brought science and technology to center stage. While showing how America's productive machine had gone from net exporter to importer for the first time in its history during the 1970's, popular media compared programs of both candidates to show the American public how each candidate planned to deal with the productivity crisis. One article titled, "The Productivity Crisis-- Can America Renew Its Economic Promise?" summed up the candidates' plans to revitalize productivity through R&D as follows: "Carter promotes new Federal programs to help business cope with competition and regulation-- a smallish made-in-America version of the government-business partnership in productive Japan. Reagan's philosophy, on the contrary, stresses getting government out of business's way and enabling 'free market' forces to take care of the rest." (Newsweek 1980)
These popular media images of the economic malaise of America reflected the emerging narrative about the nation that would dominate all sorts of government policies throughout the 1980's. Since America had slipped into a productivity crisis beginning in 1971 due to government's focus on social and environmental agendas, the story went, America had to invest now in a new kind of science and technology to renew its economic growth and the promise to its citizens for higher standards of living. The fulfillment of this promise by means of solving America's social and environmental problems became no longer possible. National fulfillment came now by reversing the productivity slip and putting the U.S. on top as a global competitor. Several important questions remained to be answered by government and some of its constituencies: which kind of science and technology? where should the emphasis be, in basic research or in technological innovation? how should the federal government participate? To a great extent, answers to these questions would depend heavily on defining who was perceived as the most threatening enemy: USSR? Germany? Japan? All of the above?

During the 1980 elections both candidates focused on Japan as one of America's main competitors and proposed different ways of dealing with it. The popular media followed, creating an image of Japan as an emerging powerful nation that threatened America with its advances in manufacturing technology and its capacity to put new products on the market. Most of these stories
focused on Japan's incredible technological capability almost surpassing that of the U.S. The media made Japan into a riddle for America to solve. In short, it became an American obsession to answer the following question: What makes Japan so successful in technology? As one article asked, "What makes Japan work? What is the secret of Japan's phenomenal success in business and technology? This question is rapidly becoming the obsession with the rest of the world." (Science News 1981) In trying to articulate this question, numerous stories concurred on two main points: there is something unique about Japanese government's involvement in its industry and something unique about Japanese workforce that the U.S. does not have. Responding to the question on government involvement, a 40-page special issue on "Japan's strategy for the '80s", claimed that "Japanese government is still playing an important role in the implementation of industrial policy...[their] Ministry of International Trade and Industry [MITI] determines the industrial structure and tells every industry what it can and cannot do." (Business Week 1981) Responding to the question "Has Japanese Innovation Replaced Good Old Yankee Ingenuity?" posed in a Motorola ad in the early 1980's, articles responded, "with people as her only resource, Japan is outsmarting the United States in high technology products." (Science 1980) The question still remained, "How does she do it?" (Ibid) Fueled by a presidential campaign, media began to define the limits of what is sayable in the new discourse about the nation. First, America's main problem was that
of productivity. Second, its main competitor was Japan. Third, the secret of Japan's success seemed to lie in its government-industry arrangement and in the education of its people. Fourth, in order to compete with Japan, the U.S. had to look into these unique Japanese traits, whether it was to copy, adapt or reject them.

The image of the new "Japanese Challenge" began to appear simultaneously as the reigniting of Cold War fears. The U.S. continued to see the Soviet Union as a major military threat. If in 1977 popular media celebrated the 20th anniversary of Sputnik with headlines like "Sputnik Plus 20: The U.S. on Top" (Newsweek 1977), then by 1980 the media questioned America's ability to stay ahead of the Soviet Union. As one article summarized, "U.S. science for the first time is being seriously challenged by its major foreign competitors. Although comparisons are difficult to make, one commonly used yardstick -- the amount of money spent on research and development as a percentage of GNP-- now shows the Soviet Union far ahead, with West Germany and the U.S. tied for second and Japan close behind." (U.S. News 1980). Still in 1984, media headlines posed the question "Can U.S. Hold Its Lead over Soviets in Science Race?" (U.S. News 1984) The difference between this question and its twin posed after Sputnik in 1957 is that now the race was for technology, both commercial and military. As an article concludes, "A nation that once intimidated America with its Sputnik satellite finds itself playing catch-up in its struggle for
world dominance in technology." (Ibid)

In need of public support for its military expenditures, the incoming Reagan administration fueled fears over Soviet technology and reignited Cold War fears of the Soviet threat. Media stories endorsed the Reagan administration’s "defense priority" of building "high technology weapons" (Pittsburgh Press 1981). Policy experts from the Strategic Studies Center argued not only for another military buildup but also for placing more scientists and engineers in the new "science race" between the U.S. and USSR. (Ailes and Rushing 1982) Even the economic experts who built most of the foundations of Reaganomics connected the trade deficit with Japan as a national security problem with the Soviets, linking the productivity crisis with the Soviet threat. For example, Milton Friedman, leader of the Chicago school of economics and one of the main influences on Reagan's economic policy, was quoted in popular media as saying: "if the decline in productivity were to continue for decades, the most likely outcome is that we would become a Russian satellite." (Newsweek 1980)

Having defined the main problem as that of productivity, media, presidential candidates, economic and policy experts alike, began defining specific limits to this problem. Both Japan and the Soviet Union emerged as new and old enemies of the U.S. with their central governments orchestrating human resources for technology: for economic leadership through
manufacturing and productivity in the case of Japan, and for military leadership through technological weapons in the case of the USSR. Now both government officials and technology experts rushed to gain control of defining the solution. For example, deeply concerned about the nation's technological future in relationship with increasing Japanese competition, U.S. House Representative George Brown (D-Cal) of the House Committee on Science and Technology demanded, "What's wrong with us?... I'll tell you what's wrong. We don't know how to put our act together. We got to take hold and pull up our socks." (NY Times 1981) Experts on American technology, skeptical that economic measures such as increasing saving and tax incentives would solve the problem, proposed "a new spirit of American competitiveness, a rekindling of the desire to excel as a nation, to roll up the national sleeves and get to work." (Ibid) Pointing at federal funding for scientific education and R&D as what put America ahead in the 60's space race, these experts said: "What the nation needs is another Sputnik." (Ibid: 17) However, in contrast with the Sputnik of 1957, which was visible in American skies, or with the civil unrest and environmental problems of the 1970's, which were visible on prime time TV, the "Sputnik of the Eighties", as one government official called it (Jennings 1987), had to be invented. By the end of the 1980s, NSF invented the "Sputnik of the Eighties" after a series of attempted policies to reignite government's interest in education and training of the nation's technological workforce failed. A look at
some of these attempts shows how certain groups appropriated the discourse about the nation and further defined the problem and its solution in their own terms, mainly technology and engineers. However, at the end of the decade, NSF's solution arose as the one that fell within the limits of what was sayable and acceptable in the new image of America.

Technology to save the nation: Can NSF do it?

A wide range of proposals to create incentives for technological innovation appeared in the 1980's. The proposal to create the National Technology Foundation (NTF) is one of the best examples of how an image of the American nation saved by technology came to play a significant role in technology policy formulation in the early 1980's. This Foundation, first proposed in 1980 by the House Subcommittee on Science, Research and Technology led by George Brown (D-Cal), was meant to be the federal government's instrument for technological innovation and development, including infrastructure and human resources. As such, it was meant to be an institutional answer to the problem of productivity. NTF was to do for technology what NSF did for science (see USHR 1980)

The congressional hearings concerning this legislative proposal exemplify the forums where powerful pro-technology actors appropriated the discourse about the nation. These groups and actors came primarily from government,
industry, and academia, and had one fundamental belief in common: technology was the answer to America's productivity problem. They came to define very specific solutions to save the American nation through technology and technologists. Among these groups and actors, we have the Committee on Science and Technology chaired by U.S. Representative Don Fuqua (D-Fia), particularly its subcommittee on Science, Research and Technology chaired by George Brown, Lewis Branscomb, vice president and chief scientist of IBM and now chairman of the NSB, the engineering profession, and academic engineers such as Myron Tribus and Herbert Holiomon of MIT. Branscomb came to symbolize the new cast of high-rank science-and-technology policy officials that replaced scientific academism in the federal government. Branscomb, like others that followed his path from corporate America into policy positions, were scientists or engineers with high regard for technology, occupied high level positions in corporate America, and had similar attitudes towards the free market as the Reagan administration.

These pro-technology actors defined the problem of the American nation in terms of productivity and trade-deficit, the solution in terms of technology and engineers, and included both in the language of the NTF Act of 1980. First, they claimed that U.S. productivity was falling behind most industrialized nations: "the productivity and rate of innovation of many national industries are lagging compared with the historical patterns and with the performance of the same
industries in other nations, and are not sufficient to provide for a healthy national economy." (Ibid:4) Second, they claimed that since the mid 1970's the international balance of trade had been unfavorable to the U.S. and that productivity was to blame: "the international balance of trade has been unfavorable to the United States for several years, including unfavorable balances in some industries heavily dependent upon technology." (Ibid) Third, they positioned technology as the solution to both productivity and balance of trade: "the development of new technologies promises fuller national employment...new goods or services for the national welfare...existing goods and services at lower costs. Thus, new technologies are generally counter-inflationary, facilitate market penetration, improve the national balance of trade, and support the United States dollar in international monetary exchange." (Ibid) Also, they proposed engineers and other technologists to carry out the development of new technology and blamed previous science policies for neglecting these people: "the Nation has not given adequate attention to its requirements for engineering and technology manpower, to the need for engineering and technical research, or to the accomplishments of its engineers and technicians." (Ibid) The main message: technological innovation will save the nation by boosting its domestic industries and improving its international economy, and at the same time new technologies will benefit American workers and consumers. With this in mind, the NTF Act of 1980 aimed at creating a
government agency to promote technological innovation and education and training of a highly skilled technological workforce.

The proposal for NTF questioned the ability of NSF to serve the nation's emerging needs in technology. There were some actors who believed that the United States needed an institution to promote cooperation among government, industry, and academia, similar in nature to MITI in Japan, and the Ministry of S&T in Germany, but believed that NSF was not it. According to Herbert Hollomon, Director of Center for Policy Alternatives at MIT:

> every competitor nation has a mechanism to support technology related to its competitive position except the U.S [but] NSF is not capable of supporting industry-related technology...I think that business starts in the universities of America, in the engineering schools...I would like to see the NTF be clearly devoted to activities that are about doing, not studying, but doing. (USHR 1980: 773-7).

Although most of these pro-technology groups agreed on the need for an institutional mechanism like NTF, they gave it different meanings. Academic technophiles, like Hollomon, saw NTF as an additional source of federal funding for technology. Businesses, large and small, supported it as long as it was conceived as a non-regulatory agency, as a facilitator between government, business, and academia, and as a sponsor of industrial R&D. The engineering profession saw it as a vehicle to reaffirm their legitimation and presence in the federal government since they had occupied a secondary role relative to science at NSF. These groups, however, questioned whether a restructured
NSF could accomplish the new task or whether a new institution like NTF was necessary. Skeptical of scientific academism's past attitude towards technology, academic technophiles claimed that NSF could not be transformed into an institution for technological development. As Myron Tribus, Director of Center for Advanced Study in Engineering at MIT, put it: "no man nor women placed in charge of the NSF... can turn the place around... to support deployment of technology." (USHR 1980: 570)

Skeptics of these sharp differentiations between basic science and technology feared that such distinctions would translate in new, but inconmearable, federal roles in basic science and technological innovation. Lewis Branscomb, as both a physicist/chief scientist of IBM and a self-declared "technophile" (see Branscomb 1995), opposed to the separation of technology from basic sciences and successfully argued that "NSF is the correct institution to operate and implement programs in engineering and technology..." (Ibid)

From his position as NSB chairman, Branscomb became the main character behind aligning NSF's commitment to basic sciences with a new commitment to technology for economic competitiveness. In 1984, Branscomb would help bring Erich Bloch, and electrical engineer and vice-president for technical personnel development at IBM, to materialize this agenda as NSF's director.

After pro-technology groups defined the problem and began to set the limits of the solution, more groups from academia and small business joined to
propose solutions in terms of "engineering manpower." However, there were significant disagreements among them on how to go about producing the technological manpower to compete with both the Japanese and the Soviets. With the proposal for NTF having failed, there were still concerns as to whether NSF could take responsibility for educating and training technological manpower. Some individuals like Myron Tribus believed that NSF could not do it while others rallied behind NSF. For example, Senator Paula Hawkins (R-Fla) of the Committee on Labor and Human Resources argued that Japan had an incredible way "to make engineers out of the workers from the assembly line while the robots took over the floor. Now you just cannot do that to the average line man in the U.S., and I think it is something that we are now seeing that must be addressed in precollege. ... The NSF, I think, has a great responsibility for focusing attention on the plight that we are in today." (U.S.S 1982: 133)

There were still others who believed in the need for a comprehensive national manpower policy. What still remained debatable was the level of government involvement. Limits to this involvement were imposed by an administration committed to fiscal reorganization and reduction of the federal government. The Reagan administration still had to be convinced that more engineers creating new technologies meant productivity and economic growth. For now, in the early 80s the Reagan administration discarded proposals that called for the creation of additional federal bureaucracy to promote engineering manpower.
like NTF. Alan Fechter, who in the early 1980s was head of the Scientific and Technical Personnel Studies Section at NSF and in 1983 became the Executive Director of the Office of Scientific and Engineering Personnel at NRC, remembers the different attitudes in the early 1980s towards government involvement in technological innovation, including manpower.

There was never any doubt, and there still is no doubt in my mind, that the issue of science and technology, as an important positive force in society, is a bipartisan issue. If there's any dispute at all about policy, it's a question of how far should the government support it, not whether the government should support, but how far should it go.... The democrats would more likely go that direction [creating an institution like Japan's MITI] and clearly that's what happened at NIST, a big increase in their budget. Republicans were more skeptical of that kind of approach saying that if there is any way of doing this, the market contains all the right incentives. Give it to the federal government and the bureaucrats and they will screw it up... (Fechter 1994)

How to make selves for competitiveness: national policy or ... ?

The U.S. House Committee on Science and Technology produced a series of proposals which called for national policy to provide the nation with the appropriate supply of engineers for both industrial productivity and national security. In one of the first Committee hearings to debate national policy under the title "Engineering Manpower Concerns" (USHR 1981a), the engineering profession established a clear difference between their contribution and that of scientists. Engineering professionals, represented by Robert Frosch, President of the American Association of Engineering Societies (AAES), positioned
engineers as key agents for competitiveness. He argued that engineers translate knowledge into design and production: "without engineers functioning to make this kind of thing happen, we would be in a very difficult position to even run our society, much less improve its competitiveness...if there is a major change in a lot of areas of economic expenditure, there will be a change in the demand for engineers." (USHR 1981a: 7-8)

Even though the U.S. enjoyed superiority in academic basic research over Japan and other foreign competitors, engineers questioned whether this type of research by itself was enough to ensure a lead in market shares and improvement of the trade deficit. The U.S. needed engineers to do this job.

Jack Geils, senior executive of American Society of Engineering Education (ASEE), stated that:

The key point, of course, is that these applications are the work of engineers, not scientists. The engineer applies the new knowledge created by scientists in a practical way via designs of new and improved structures, products and services. Thus as technology multiplies, increasing quantities of quality engineers are vital to the Nation's well-being...We are in a recognized productivity slump and in my opinion only the engineering effort can pull us out. (USHR 1981a: 22)

To further differentiate between scientists and engineers, representatives of the engineering profession created a sense of urgency that the nation had plenty of basic research scientists but not enough technological innovators. Addressing the Committee on Science and Technology of the U.S. House of Representatives, Robert Gaither, president of American Society of Mechanical
Engineers (ASME), said:

I feel a necessity to clear up a point here, because I see the words 'engineer' and 'scientist' being bandied back and forth as equivalents...there is not today a shortage of physicists, chemists, nor mathematicians... The use of these words scientist and engineer I think has to be very carefully done. I would commend you to be careful with that. (Ibid: 61)

Supporting the engineers' claim of shortages, military leaders established the need for engineers in national security, hence positioning them as worthwhile for the government to make. During one of these hearings, Gen. Robert T. Marsh, Commander, Air Force System Command, claimed that USSR and Japan were surpassing the U.S. in the production of engineers and that an increase in defense spending by the Reagan administration created an immediate demand for engineers that the present supply did not satisfy: "There simply aren't enough engineers to go around...the engineer shortage problem is real", he said pointing to the need for a national policy to deal with this new national crisis:

I see a parallel between today's situation and that caused by the launch of Sputnik in 1957. After that shocking event the entire country was motivated to catch up, culminating in a national commitment to put an American on the moon. I hope such a shock is not required again. But nothing short of the national commitment we made for the Apollo Moon program will do here if we are to maintain leadership. (USHR 1981a:32)

By invoking the Apollo program, Marsh began defining the new problem for the federal government to solve: the creation of large numbers of engineers for
national security. On the other hand, high-level representatives of industrial R&D, now in top government positions, added the demands of industrial productivity to the demands of national security. Lewis Branscomb argued that in addition to large investments in strategic defense weapons, the President's commitment to industrial productivity would bring even a larger demand for engineers:

The driving force behind our industrial performance is the economic environment. The President has placed highest priority on creating the incentives in the private sector for an aggressive commitment by industry to the creation of new jobs at home and economic competitiveness abroad. This economic plan, if successful, will create the potential for growth. It is going to take a sufficiency of well-trained, motivated engineers prepared to address the problems facing our country to achieve the benefits that we want from that economy...if we are going to beat our competitors in productivity, we need manufacturing engineers with production skills who know how to automate a plant and who know how to manage quality work.” (USHR 1981a: 70)

Since in the new model of the nation the main problem was productivity, not research, Branscomb positioned the training of engineers, not scientists, as the educational problem for the government to solve. Up to this point, the government had neglected undergraduate engineering education, focusing on precollege education through DoE and science education through NSF. Aware of this problem, Lewis Branscomb put engineering education on top of NSF's educational agenda:

Let me note that in between precollege education --which some, including this Administration, think is not NSF's role -- and the research -- which everybody, including this administration, think is important and is
NSF’s role --there is the problem of engineering education. I personally think that it is a problem for which an unambiguous, strong, and early effort is really important... I say so because the Japanese are not beating us with research...they are not beating us with development...What they are good at is production, and U.S. engineering schools are not training experts at production. (U.S. Senate 1982: 46)

We see here how Branscomb tried to redefine NSF’s mission according to the new model of nation under threat from Japan. He tried to make NSF into an instrument of national salvation by assigning NSF the role of "training experts of production" with the help of the military, the government/industrial R&D sector, and the engineering profession. Up to this point, Branscomb was at least rhetorically successful in inserting engineering education in the government’s agenda. However, he lacked certified knowledge that technologies of government, like NSF’s manpower projections, could provide. What he had done was to further define the limits of what was sayable, i.e., engineering education is a legitimate problem for the federal government. In 1982, the year of these hearings, NSF’s education budget was at an all-time low (2% of the total budget). With the advent of certified knowledge around 1987 in the form of the pipeline projections, the situation for education would change. But now there was pressure from many groups to establish a national policy in the midst of the uncertainty that comes when there is no certified knowledge informing the policy process. While respected officials like Branscomb called for putting engineering education at the top of the government’s agenda, the Reagan administration still
believed that education was not the business of the federal government. Actually it came very close to dismantling the three year old DoE and terminating NSF's educational programs in 1982-83.

Congressional leaders resisted the administration's position on education by holding hearings outside of Washington and giving local education leaders and industrial leaders from small high-tech firms a chance to participate in the definition of solutions. Congressional leaders sought support for a national policy to produce the required manpower. Unlike the executive who was committed to free-market economics, lawmakers did not believe that the free market by itself could compensate for expected demands on manpower. Hence, they formulated a national manpower policy with the federal government as the main actor. In the words of Frank Press, president of National Academy of Sciences and former Science and Technology Advisor for President Carter: "I believe that the Government has the responsibility to monitor the supply and demand of scientific and technical personnel both in terms of quantity and quality and to supplement the free market role when it is in the national interest." (USHR 1981a: 131) Witnesses, testifying on behalf of colleges and universities, tried to define solutions in their own terms by showing how their institutions, if properly assisted by the federal government, could contribute to the production (supply) of the necessary manpower for competitiveness. In doing so, they aligned their institutional interests with those of the nation. With
these demands, legislators could now legitimate redirecting federal support to their local constituencies for, in the long run, educational institutions at their localities would be contributing to the new national needs. In this way, competitiveness linked the local with the national. We see here how competitiveness became the language through which America began redefining its international struggle from a political and military to an economic idiom, transforming understandings of the nation from a site within which individual interests compete into a single economic actor maximizing a collective interest. (Downey 1995a, 1995b; Downey and Lucena 1996)

An exemplar of these forums was the hearings on "Forecasting Needs for the High Tech Industry" taken to MIT by U.S. Representative Margaret Heckler (R-Mass). She represented one of those Republicans who endorsed a national policy on manpower if ultimately it would favor the competitive position of the U.S. When it comes to manpower for competitiveness, as Daryl Chubin, former director of OTA's Educating Scientists and Engineers project, said, "I'm not sure if policy intervention vis-a-vis relying on free market would distribute neatly between Democrats and Republicans." (Chubin 1994: 15) Heckler brought together leaders of government, industry and academia from Massachusetts to express their concerns about engineering shortages in the state's high-tech industries. A concern arose among these leaders about the lack of models that would provide knowledge about the quantitative status of
engineering manpower. As put by Roger Wellington, President of Augat, Inc., board member of the Massachusetts High Technology Council, and Chairman of the New England Council of the American Electronic Association:

The critical problem is that we do not have a deep understanding throughout this country of the high technology shortage of engineers and the negative impact that this will make on the economic and political leadership of the country.... During 1970-71 engineers were laid off due to aerospace and defense programs cuts. It became a media cause celebre... The public's distorted view of the so-called engineering bust, along with the anti-technology fashion of the Vietnam period caused young people to avoid engineering careers for several years...The great expansion of the 1970's in the electronics industry occurred during a period of declining defense expenditures. The projections of the shortages of the eighties is largely without the needs of the defense industry which will be superimposed on these shortages. (USHR 1981b: 12-14)

It is clear from this quote that manpower projections for the demand of the double threat, high-tech and defense industry, did not yet exist. These calls defined the problem and solution one step further: first, there was no reliable projection model and second, the new model had to account for new needs of technological innovation and national security.

More specific proposals for a national manpower policy came from Chairman Don Fuqua of the House Committee on Science and Technology and Chairman Orin Hatch (R-Utah) of the Senate Committee on Education and Labor.¹ Generally speaking, these bills proposed to establish a national policy

¹Early examples of proposed legislation for national policy include "H.R. 7130: National Engineering and Science Manpower Act of 1982" and "H.R. 1310: Emergency Mathematics and Science Education Act of 1983." It is significant that the word "engineering" goes first in the title of H.R. 7130, proposed to establish a national policy to be administered by NSF. The word "engineering" is missing from the title of H.R. 1310 which is proposed to be
to ensure an adequate supply of scientists and engineers necessary to meet
the needs of the nation in the future by establishing a central policy body that
would dictate government actions. (see for example USHR 1982b; 1982)²
Democratic members of both committees believed that a crisis of this
magnitude needed a government reaction similar to the enactment of NDEA of
1958 in response to Sputnik. As a joint report from both the Senate Committee
on Education and Labor and the House Committee on Science and Technology
states:

These problems threaten to compromise America's stature in the
international marketplace, weaken our industrial base, and undermine our
national defense....The crisis depicted... is not unlike the situation our
country faced in 1957, when the Soviets's Sputnik launch brought to a
head concerns over mathematics, science, foreign language and
technical preparation. In that era, Congress enacted the National

By invoking the image of America losing "stature in the international market
place", Branscomb had been able to place engineering education in the
government agenda. Wellington had been able to call for new projections, and
Congress was now demanding a national policy as sweeping as NDEA. These
congressional hearings at various local forums exemplify how the image of a
threatened nation to be saved by a competitive posture towards technology

²One of these proposals called for a Coordinating Council on Engineering and Scientific Manpower which
included Secretary of Education, Director of NSF, Director of OSTP, Director of OTA, and other members appointed
by Congress and President. (USHR 1982d)
began to take shape, spread and reified. By invoking this image, groups
legitimized their calls for federal support of education and manpower initiatives.

If these kinds of education initiatives were so important for the nation,
why did the administration cut NSF programs in science and engineering
education? Referring to these cuts, Daniel Berg, Provost of Carnegie-Mellon
University, put it during hearings on "Science and Engineering Education and
Manpower":

The thing that many of us find inconsistent is that the goals stated by the
administration, namely increased defense, productivity, reindustrialization,
all require a strong research science and technology background. It is a
sad inconsistency that many of us are having trouble with. (USHR
1982a)

Maybe what Berg did not understand was that the legacy of those programs
came from a model of nation where limits were defined around increasing
participation in science with the hope of solving social and environmental
problems.

If Branscomb and other pro-technology groups had begun to establish
the limits of what was sayable, the Administration was to be the last in defining
the limits of appropriation. That is, the Reagan administration would come to
define how the relationship between discourse (competitiveness), speakers
(Branscomb et.al.) and its destined audience (future technological manpower)
was to be institutionalized. The Reagan administration did not believe yet that
the best vehicle to achieve new educational needs in technology was NSF's education programs. So the question became how to redefine education between the new needs of the nation and the limits imposed by the Reagan administration, i.e., reduce federal bureaucracy, government spending and intervention in education.

**How Reaganomics redefined education: from equal opportunity to economic competitiveness**

Both the National Technology Foundation and proposals for national policy were opposed by the executive who viewed them as attempts to enlarge the federal bureaucracy and centralize manpower planning. The Republican administration wanted to minimize government intervention and instead serve as catalyst to bring industry and academia to form partnerships to pay for educational needs of the nation. The administration believed that in a free-market economy imbalances between supply and demand ought to be handled by the suppliers (academia) and by the consumers (industry) of the products in question (engineering students). Opposing legislation that called for manpower policy based on claims of shortages of engineers stemming from 1970's policies. Dr. Douglas Pewitt, assistant director for science policy at the White House Office of Science and Technology Policy said to Congress:

we cannot centralize national manpower planning for the nation based on current assessment of future needs...centralized manpower planning in
the Soviet Union has been a failure...We cannot talk about problems of shortages of engineers without addressing problems of math and science education, especially at the pre-college level...they were built on a false set of assumptions [that] our nation could afford policies that emphasize the distribution of our existing resources over the creation of new resources. (U.S. Congress 1982b: 212)

The administration’s belief in creating partnerships between government, industry and university to begin redefining the problem of education and manpower in technology is exemplified by the National Engineering Action Conference (NEAC), an impressive national effort that brought together academia, industry, government, and the engineering profession "to focus attention on a significant national problem: the retention of engineering faculty and the shortage of engineers pursuing doctoral degrees and entering the teaching ranks." (NEAC 1982)\(^3\). The Administration wanted to address these problems without national policy but through partnerships such as the Business-Higher Education Forum and NSF.

Forums like NEAC served two very important purposes. First, they served as stage for the administration to inform its intentions of stripping 1970’s education and human resources programs of their legacy of equal opportunity

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and domestic national needs and to redefine them in terms of economic growth and fiscal austerity. Responding to concerns on budget cuts for NSF education programs, George Keyworth, director of the Office for Science and Technology Policy for Reagan, addressed NEAC stating that the Reagan administration "discontinued support for many science and engineering education programs, like those at NSF, because they were rooted in the 1960's. That was an era of rapid economic growth in which the nation concentrated on distributing benefits and broadening participation. But in the 1980's the economy is slipping so we need to focus on economic growth." (NEAC 1982)

During the congressional hearings on "U.S. Science and Technology under Budget Stress" (USHR 1981c), George Keyworth had previously outlined the administration's position with respect to NSF's education and manpower programs. First, the rationale for funding was to move away from criteria based on equal opportunity towards criteria that emphasized excellence. In Keyworth's own words: "My views on how we should approach the task of selecting high quality science have not been a secret. They can be summarized in one word—discrimination... [where] the first criterion must be excellence... In scientific endeavors we should, above all, advocate an unabashed meritocracy." (Ibid: 22). Second, in spite of the numerous claims and emerging evidence of manpower shortages in technological fields, this problem was to be handled by the free-market, that is by suppliers and consumers of manpower with minimum
government involvement on the supply-side. According to Keyworth, this problem "must and can be worked out by those who supply science and engineering manpower [universities] and those who utilize it [industry]" without government intervention. (Ibid) Third, the responsibilities for education in science and technology must be given back to state and local governments. Keyworth argued that as far as elementary and secondary science and math education, "[it] is the responsibility of the school themselves and of the communities that run them."
(Ibid:27-30)

Within these new limits established by the administration, the most powerful sectors of U.S. business and academia promulgated the importance of engineering manpower and education for economic competitiveness and national security. For example, after NEAC, the Business-Higher Education Forum began a campaign to spread the gospel at a national level "that industrial competitiveness is crucial to our social and economic well-being" and that engineering manpower and education are the foundation of America's competitiveness.4 (see Business-Higher Education Forum 1982; 1983) The Forum connected engineering and the nation's competitiveness as follows:

The state of engineering education in the U.S. is deteriorating severely

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4Founded in 1978, in affiliation with the American Council on Education, the Forum is an organization of leading corporate and academic chief executives. Among these we have CEOs from companies like Westinghouse, General Electric, General Motors and universities such as Harvard, John Hopkins, Duke, U.C.L.A., Cal Tech.
with serious consequences for the nation's key industries and defense in a competitive, dangerous world... The past two years have seen a growing recognition of the critical role that the availability of qualified engineering manpower plays in maintaining or reestablishing the technological preeminence that has been the backbone of this nation's economic and social achievements and the basis for our national security. (Business-Higher Education Forum 1982: 12)

The Forum also advocated a coordinated effort between demand and supply of highly skilled labor with minimum involvement of the federal government. From this perspective, government intervention was only plausible on supply-side. This meant that federal activities were only acceptable to help supply both the military and American industry with enough engineers. In a recent analysis of technology policy, Branscomb (1993) confirmed this claiming that the Reagan administration largely confined itself to supply-side activities, that is federal activities to create new technology(ists) which could contribute to both government missions (e.g. SDI) and to private sector innovation and productivity.

In line with supply-side economics the administration proposed new technologies of government to find out what kind of manpower it needed to help supply. The new administration needed certified knowledge to be certain of its actions. As Pewitt told Congress: "I have asked NSF to review its S&E personnel data collection to determine what more information can and should be collected to illuminate these issues [shortages]...NSF will establish a special
technical manpower advisory group to review manpower data collection and
analysis." (U.S. Congress 1982b: 212) This resulted in a NSF 1984 report
"Projected response of science, engineering, and technical labor market to
defense and non-defense needs: 1982-1987" which served as preamble for the
pipeline.

In 1983, the famous report A Nation at Risk, released by the President's
Commission on Excellence in Education, caught the country by storm. In
voking
the new image of nation under threat, the report claimed that "once our
unchallenged preeminence in commerce, industry, science, and technological
innovation is being overtaken by competitors throughout the world." (National
Commission on Excellence in Education 1983: 5) To overcome this threat, the
report proposed an educational reform given that "the educational foundations
of our society are presently being eroded by a rising tide of mediocrity that
threatens our very future as a Nation and a people." (Ibid) Focusing mostly on
strengthening high school education, the report made pre-college education a
responsibility of the federal government. However, the government had made
clear, following its commitment to supply-side economics, that the only
acceptable form of involvement in education would be helping the supply of
students. Therefore by 1983, most of the limits of what was sayable and doable

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5 The reaction of academic administrators and educators, and government and industry leaders is reflected in
an avalanche of articles that followed A Nation at Risk. See for example U.S. Commissioner of Education Harold
Howe's (1983) article "Education Moves to Center Stage: An Overview of Recent Studies" and Mastercard
about education for the new model of nation had been set. First, all levels of education, including pre-college and undergraduate education had become acceptable areas for federal government involvement. Second, like never before, engineering education became a recognized area for the government to be involved in, given its contribution to the main national problem of productivity. Third, government involvement was to be kept to a minimum only on the supply side. Fourth, to reduce government spending, government promoted partnerships between industry and academia to pay for the costs of new education initiatives. Within these established limits centralized manpower policy was unacceptable. Hence, the Engineering and Science Manpower Act of 1982, or any of its successors which called for national manpower policy never became law. Eventually, President Reagan signed the "Education for Economic Security Act of 1984" (PL 98-377) into law in compliance with the policy of economic recovery through a balanced budget, the diminishing role of the federal government in the business of science and engineering education and manpower, and providing incentives to form partnerships between industry and academia to share the expenses of new educational programs. One question still remained: if the limits of what was acceptable in education were laid out, how was the government to implement these at NSF, which had a strong tradition for graduate science education but not for undergraduate engineering education or pre-college education? Having laid out the limits of the new
discourse about the nation with respect to education, I now turn to the
construction of official knowledge at NSF that would allow the federal
government to implement this new kind of education.

The remaking of NSF: from Knapp to Bloch

At the beginning of the "Star Wars/Samurai Era" (Lepkowski 1983),
Edward Knapp, a particle physicist, was nominated and approved as NSF
director by the Reagan administration. Contrary to John Slaughter, a minority
advocate and Carter appointee, Knapp brought NSF into ideological alignment
with the policies of fiscal responsibility that characterized the Reagan
administration, especially by cutting science and engineering education
programs. As he told Science magazine, "We're going to look at how people
spend money. It's one of the reasons I'm interested in the budget. That's one
thing a director can get a handle on." (Science 1983)

He was the last of the scientific academists to direct NSF who favored
science over technology. According to Knapp, "Scientists have a responsibility
to be active and responsible on problems of national security. Science and
national security in this country are completely intertwined. There's virtually no
way we can have our security without involving science and scientists. And in a
sense, every scientist who does research and who has graduate students is
participating in building the infrastructure for national security." (C&EN 1983) At
the same time that he helped terminate education programs from the 1970's, he revitalized NSF fellowships. For FY 1983, Fellowships received $15 million while pre-college education received $1 million. Knapp directed no money to undergraduate education.

Although he was in line with the Administration and the scientific community, Knapp did not understand the mounting pressures calling for NSF to respond to economic competitiveness. While everybody was crying crisis in technological innovation for competitiveness, he put the "chemists in charge of NSF" and pushed Keyworth's agenda of excellence and meritocracy as criteria to support basic science. (Lepkowski 1983) Knapp's failure to understand how to adapt NSF to technology for competitiveness brought about his replacement with Erich Bloch in 1984.

A nation calling for a pipeline

When Erich Bloch became NSF director in 1984, he came in with a mission: to transform NSF for the needs of economic competitiveness through the development of technological innovation, infrastructure, and workforce to help the U.S. perform in the technological marketplace. Appointed by the Reagan administration, Bloch also had the support of the House Committee on Science and Technology which, having failed at making a national manpower policy into law, saw NSF as a plausible policy mechanism to respond to the
emerging manpower shortage crisis and to appease mounting public concerns.

Since 1982 the image of a nation in need of engineers for productivity had spread into the congressional committees with jurisdiction over NSF. Without certified knowledge from NSF on the state of scientists and engineers, those committees developed a sense of urgency that, as we have seen, led to attempts to the creation of a national policy. Also, this sense of urgency led those committees to call for the creation of knowledge about scientists and engineers. Constituents began asking their representatives for explanations and projections that would inform the American public about careers for their children in this new era of economic competitiveness. As Senator Paula Hawkings (R-Fla) of the Senate Committee on Labor and Human Resources with jurisdiction over NSF's legislation put it to Congress:

So many citizens are upset and write to us: Why were we caught short? Why weren't the projections made? Why wasn't this data collected? Why didn't we know ahead of time that our son should have been studying engineering instead of sociology? (U.S. Senate 1982: 134).

Trying to respond to these pressures at a time when NSF was undergoing significant transformations and budget cuts, the Subcommittee on Science, Research and Technology of the Committee on Science and Technology appointed its own studies on manpower to the Library of Congress in the early
1980's. At the same time and maybe recognizing the limitation of such studies, Senator Kennedy of the Committee on Labor and Education pressured NSF to develop a framework for projections. During fiscal year 1983 when NSF's science education programs were abolished and engineering education emerged as an important element for competitiveness and national security, Sen. Kennedy outlined new responsibilities for NSF to begin charting the unknown future of national manpower needs during times of both military buildup and economic competitiveness:

The Japanese now have doubled the number of engineering graduates in the last 10 years. We have held about level...We see the movement of R&D in the military area that is again going to draw [engineers] from the civilian area. I think that what we need are some flow charts and flow lines of what the implications of this are going to be in terms of our economy, in terms of jobs, where we are going to be internationally over a period of time. This committee cannot do that. The only ones that can do it are the National Science Foundation and the basic administration... [G]iven all these considerations, there is a flow line that is taking place in our society, and I think there is an agency that has to awaken this country as to what our needs are going to be. (U.S. Senate 1982:46)

Kennedy directed these responsibilities to NSF through Lewis Branscomb who as former vice president of IBM had successfully managed IBM's manpower for the computer boom of the late 1970's. Unlike NSF, IBM did not have to shift its manpower projections in the 1970s to accommodate the needs of a nation plagued with domestic problems that required interdisciplinary scientists and

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6 See, for example, the report by the Congressional Research Service of the U.S. Library of Congress (1983) U.S. Science and Engineering Education and Manpower: Background; Supply and Demand; and Comparisons with Japan, The Soviet Union, and West Germany.
engineers to solve them. IBM's projections were specific to the new scenarios of the emerging technological marketplace. Now as chairman of NSB, Branscomb was asked by Kennedy to do at NSF what he did at IBM:

We have to know what you [Branscomb and IBM] have been doing. You cannot tell me that IBM was not thinking 10, 15, 20 years down the line. You were, and that is part of the reason that they were so successful. I would like to see the NSF try to give us some guidance about 10 or 15 years down the line and let us make the choices... (Ibid)

Kennedy's demands reflect the lack of reliable projection models for the new image of a nation under threat from Japan's technological success. In addition, there was no consensus among manpower experts on how forecasting of scientific and engineering manpower for the needs of the technological marketplace should be carried out (Vetter 1985). Congressional leaders and manpower experts called for a conceptual framework that would allow making projections for the new national needs of economic competitiveness and national security. The projection models proposed during the mid-1970's based on assumptions of interdisciplinarity and diversity for domestic national needs were now obsolete. Betty Vetter, Executive Director of the Scientific Manpower Commission (now the Commission on Professionals in Science and Technology), a private, non-profit organization that tracks the supply of scientists and engineers in the U.S., argued for the need of a new mechanism to conceptualize the supply of scientists and engineers for the emerging technological marketplace. Having been in charge of the Commission since
1965, Vetter understood that there was no plausible answer to the questions of manpower supply given the new national realities. In her report The Technological Marketplace: Supply and Demand for Scientists and Engineers, Vetter asked:

what is the total supply of scientists and engineers in the U.S.? This seemingly simple question, often asked of manpower specialists, is not simple at all, and the answer is uncertain...increasing or decreasing the supply of trained scientists and engineers requires a lead time of four to eight years. (Vetter 1995)

Alan Fechter who at the end of the 1970's directed NSF's forecasting of supply, demand, and utilization of scientists and engineers, also understood the need for a new framework and data that would allow the government to make policy:

unfortunately, we are currently unable to forecast supply and demand that far ahead with sufficient precision to draw strong policy inferences...we need to substantially strengthen our capabilities to generate long range projections for planning purposes...we have to be thinking now what we want to see 10 and 15 years from now in terms of what is coming out of the pipeline with respect to science and engineering (U.S. Congress 1985: 43 )

Freshmen intentions to major in science and engineering had been well documented throughout the 1970's and early 1980's. The reluctance of white males to go into these fields became more apparent. Not only did the U.S. need

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7 After receiving a NSF grant to study the feasibility of long term forecasts, Fechter went to the SRS division of NSF and began publishing what would become one of SRS's highlight reports Science and Engineering Personnel: An Overview. He later became Director of the Office of Scientific and Engineering Personnel of the NRC.

8 Alexander W. Astin from the Higher Education Research Institute at UCLA has been documenting freshman intentions and attitudes for many years now. For a summary of his research on the 1970's and 1980's see Astin (1987).
a new projection framework, it needed another kind of population group to rely
on for its emerging needs in science and engineering. Betty Vetter knew this
and made a public demand during the July 1985 congressional hearings on
"Supply and Demand of Scientists and Engineers":

Forecasts usually are wrong because too many other factors also affect
the outcome....Another data need is for accurate and timely trend data on
all segments of the education/utilization pipeline in science and
engineering, with the data broken out by sex and minority status...most
valuable data allow us to examine the outcomes rather than the barriers
along that pipeline. (U.S. Congress 1985: 526, 533)

Here she acknowledged the unreliability of past forecasting models.

Recognizing that the decreasing white male population in science and
engineering would not suffice the supply needs of the nations, she called for
new data based on sex and race. This shift in focus, from the predominantly
white-male population as the traditional supply for careers in science and
engineering to women and minorities, was a significant change. Instead of
acknowledging women and minorities for their contributions to solve domestic
problems as it happened in the 1970's, experts began to recognize the potential
numerical contributions of both women and minorities to manpower for
competitiveness. Also, the shift from outcomes (output) to movement along the
different segments of the pipeline (flow) is significant for it sets the stage for
recruitment and retention efforts along the educational system.
Engineers provide the model that would save the nation

A response to these calls for forecasting methodology and data came in timely from the Committee on the Education and Utilization of the Engineer of the National Research Council (NRC). Late in 1985 and 1986 the National Research Council began publishing a 9 volume collection on engineering education and practice in the U.S. that, with the endorsement of the NAS and the NAE, ratified the importance of engineering and engineering education to maintain the nation's strategic and defensive strength and economic competitiveness in the international marketplace. Formed by high-ranked managers and engineering deans of America's most important corporations and universities, NRC's Committee viewed the report as a tool "to assist policy makers in government, industry and academia by treating the various elements of engineering as a cohesive whole" (USHR 1985). NRC's committee viewed the conceptualization of the engineering workforce for this double national agenda as a complex engineering problem to be solved within the limits set by the Administration's concerns for fiscal reorganization and economic growth: "both responsibilities depend on problem-solving approach that is the heart of engineering." (NRC 1985: 27). The solution of this complex problem would serve as the basis for future national policymaking without the need for a

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*Among the members of the Committee, there were Deans of engineering from U.S. prestigious universities, vice presidents of Engineering of large corporations, and Executive Directors of engineering professional societies. There were also numerous engineering faculty, too many to list here (for a complete list, see NRC 1985)*
centralized manpower policy:

this constant flux in the engineering workforce makes it more difficult to characterize accurately the engineering profession, to determine with any certainty who is what, how many engineers there are, and where they work... a clear understanding of the profession is necessary as a basis for national policymaking, for fiscal and economic planning...(NRC 1985: 33-34)

NRC's committee proposed a social engineering approach to the problem of technological workforce. Jerrier Havad, chairman of the NRC committee, claimed that his committee had developed a comprehensive flow model to understand the complex and cohesive engineering community:

Properly populated with consistent data, this model should prove useful in analyzing the engineering community and its essential elements. Unfortunately, existing data bases and their varying definitions and their varying survey methodologies are inconsistent with each other. And this has made it impossible to use the flow model to its fullest advantage. We strongly recommend that a major effort be undertaken to see how best to arrive at the commonality of definitions, survey methodology, and diagraming methodology between the various governmental and private agencies that collect, analyze and disseminate data on science and engineers. (U.S. Congress 1985: 328)

The flow model proposed a framework for tracking past events and for quantifying and forecasting future needs (see figure 8). Symbolic of engineering methodology, the standardized model would allow study of behavior of subsets of the community (e.g., women, minorities) while reducing ambiguity in dealing with the overall technical workforce. The panel "considered a schematic flow diagram to be essential in understanding the complexity and dynamics of the engineering community" (NRC 1986: 2).
This flow model, designed by engineers, to study and predict the behavior of subsets of the general workforce highlights social engineering at its best. The model is based on the balance equation from traditional energy and material balances:

\[ Q1 + \sum f_i - \sum f_o = Q2 \]

where

- \( Q1 \) = number of people in stock at the beginning of period,
- \( \sum f_i \) = sum of flows into the stock,
- \( \sum f_o \) = sum of flows out of the stock,
- \( Q2 \) = number of people at end of period.

It is to "be adopted by the engineering community and used as basis and guideline for collecting data, analyzing flows and relationships, and projecting the effects of changes in flows and relationships." (NRC 1996:7).

**Competitiveness and NRC model come to NSF**

By 1984, the discourse about the nation in terms of competitiveness had been appropriated and its problems and solution well defined by the federal government, the business community, and corporate scientists like Branscomb and Bloch. Appointed in 1983, as recommended by the Business-Higher Education Forum (see Business-Higher Education Forum 1983: recommendations), the President's Commission on Industrial Competitiveness released their report *Global Competition: The New Reality* which concluded that

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9 The Commission members included powerful actors from industry, government and academia such as: John A. Young (Commission's Chairman), President and CEO of Hewlett-Packard Co., Robert Anderson, CEO of Rockwell International, George Keyworth, Science advisor to the President, George Low, President of Rensselaer Polytechnic Institute, Michael Porter, School of Business Administration Harvard University, Mark Shepherd, CEO of Texas Instruments, Inc., Egils Milbergs (Commission's Executive Director), Deputy Assistant Secretary of the U.S. Department of Commerce.
technology and human resources are the two most important elements to improve U.S. international competitiveness (with cost of capital being the third). As the report stated, among the "factors that influence our ability to compete...technology is our greatest advantage." This claim, with the approval of the President and the corporate community, established very specific limits of what was sayable and acceptable to do for the nation. The development of technology and human resources became the paramount solution to a very specific national problem: competitiveness. This new national agenda remained two-pronged (economic and military) until around 1987. When fears of the Soviet threat subdued, especially after 1986-87 when Mikaeil Gorvachev initiated his campaign for glasnost and perestroika, the technological needs of economic competitiveness came first than those military buildup.

When Eric Bloch came to NSF in 1984 from his position as vice president of technical personnel development at IBM, he put technology and human resources issues at the center of NSF's agenda, redirecting NSF's mission towards the improvement of U.S. economic competitiveness. 11 Bloch thus proved Myran Tribus on MIT wrong when the latter said in 1980 "no man nor woman placed in charge of the NSF ... can turn the place around... to support deployment of technology." (USHR 1980:570).

11 In 1984 President Reagan nominated Erich Bloch as NSF director and Nam Suh as Assistant Director for Engineering (former Director of Laboratory for Manufacturing and Productivity at MIT). Suh takes NSF's engineering into new directions following recommendations of NAE on new divisions based on critical technologies. See "Engineering: A More Expanded Role for NSF." (NSF 1985).
Erich Bloch, chairman of NRC's panel in Engineering Infrastructure

Diagramming and Modeling that developed the flow model, took this model to NSF and made it the overall mission of NSF's education and human resource programs. NSF developed this model and made it into one of the most influential technologies of government: the science and engineering pipeline. As Sue Kemnitzer, appointed by Bloch as Deputy Division Director for Engineering Education, remembers:

Erich brought the use [of the pipeline] and he was the first and only director that had this idea as a priority for NSF. He pushed the idea of the whole education system being important and pushed the idea of the importance of human resources, because before that, most people at NSF just focused on graduate school and research... Erich, being more forceful than most other directors, helped articulate the importance of education, competitiveness, and those who do not get a Ph.D.
(Kemnitzer 1994)

When Bloch came to NSF, the education budget had just reached its all-time low of 3% of the total budget. When he finished his tenure in 1990 it was 13%, only to keep growing to 18% in 1996. This accomplishment was achieved by the science and engineering pipeline or the "Sputnik of the 80s."

NSF and the Making of the Sputnik of the 80s

Erich Bloch became the first NSF director to utilize the full powers of NSF's legislative authority in the making of scientists and engineers for economic competitiveness. Authorized under the NSF Act of 1968, Bloch
orchestrated data collection and analysis, authority to recommend policies, and institutional mechanisms to implement policies. He placed this orchestration under the roof of the Policy Research and Analysis Division (PRA) which he reorganized as director in 1984-5.\textsuperscript{12} Bloch aligned PRA with the Reagan administration's policies of orchestration and supply-side economics. Alzinga and Jamison (1995:591) have argued that science policy agenda of the 1980's was marked by the strengthening of the corporate or economic culture and the weakening of the influence of the civic culture. This was achieved in great part by "the policy of orchestration" where government agencies "seek to shape consensus among representatives from the academic, economic, and bureaucratic policy cultures." (Ibid). Erich Bloch achieved this kind of orchestration through PRA. In this division, policy experts brought by Bloch developed a model of the educational system which became the certified knowledge to shape a national consensus on the need for thousands of scientists and engineers for economic competitiveness. In spite of significant criticisms from other sources of policy expertise like OTA, PRA's model achieved unparalleled national attention and support from the different groups that had battled during the early 1980's to define the course of manpower

\textsuperscript{12} PRA existed since 1974-5 when NSF director Gifford Stever became science advisor to the President after the abolition of CSTEP by Nixon. In line with national needs of the 1970's, PRA focused then on technology transfer policy and energy R&D policy. In the mid-80's and now with Bloch as director, the focus was on policy research that reflected an emphasis on free-market and economic competitiveness such as the impact of tax laws on industrial R&D, or government support of high technology in several industrial nations (see NSF 1984)
policy. PRA's model achieved such attention because it embodied the image of the new nation and was developed within the limits of what was sayable and acceptable within the discourse of competitiveness. First, the presence of external threats created new economic and national security scenarios which demanded increasing supply of scientists and engineers. The government had to help supply these manpower needs without intervening in the free-market, namely salaries. By shifting away from salaries to demographics, the government could, without regulating salaries, create incentives to supply the required number of scientists and engineers for the new political and economic scenarios of "Star Wars" and protectionist trade policies with Japan. The PRA pipeline studies did just that: they calculated the present and future supply of scientists and engineers, based purely on demographic trends without considerations of effects by salaries, and proposed intervention strategies to supply the required numbers. By looking at the assumptions that PRA used in the development of their model, one can see how it stayed within the limits of what was sayable and acceptable.

The first set of assumptions disregarded the effect of salaries in the demographic composition of the science and engineering student population. These assumptions set the stage for government intervention in demographics without interfering with the free market. For example, the first assumption PRA made is that a fixed percentage of the student population chose science and
engineering fields irrespective of salaries: "irrespective of the many factors that enter into the choice of careers, natural sciences and engineering (NS&E) bachelors degrees, exclusive of computer science, have been awarded annually to a relatively fixed fraction of the 22 year-old population for about three decades." (NSF 1990) By looking at enrollment history, PRA projected this fixed fraction to be 5% of the 22-year old population irrespective of ongoing increments in college enrollments.\textsuperscript{13} PRA claimed that "according to the Bureau of Census, the decline in the number of people in the 22-year-old age group will continue until after the mid-1990s" (Ibid) Given the new national needs of manpower for productivity, this demographic picture framed the question: how can this fraction be enlarged within the limits of what is sayable and acceptable?

In line with the recommendations from manpower experts like Betty Vetter, PRA focused on specific population groups that could be redirected into science and engineering. For example, PRA claimed that "there has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women offset in large measure by a decline in the conferral rate to males. Most of this rise occurred between 1972 and 1982." (Ibid) PRA also showed the potential contribution of underrepresented minorities to enlarge the 5% fraction.

\textsuperscript{13} It is important to note that career choice into computer-related fields was left out of the assumptions. Enrollment in those fields was in an all-time high and taking them into consideration would not have resulted in a manpower crisis.
PRA claimed that "although the participation rate of the underrepresented minorities [in the 5% conferral rate] has been substantially below average, blacks and hispanics are expected to increase their proportion of the total college age population from about 23 percent in 1989 to 28 percent or more in the year 2000, and 30 percent or more in 2010." (Ibid) PRA recognized women and minorities as an untapped resource whose potential contribution was not being directed towards science and engineering but whose future contribution could help economic competitiveness.14

PRA drew the following conclusion from this demographic scenario: "without some positive action to substantially reverse the decline in student preferences for declaring NS&E majors, bacheiors degree awards in these fields are likely to decline."(Ibid) Having removed salaries from this picture, PRA showed the way for policy makers to increase the student population going into science and engineering without intervening in the free market.

PRA assumptions on the demand side also reflected the new image of nation. PRA claimed that "because of the complexities in the utilization of NS&E training and limitations of occupational census data, quantitative projection of the demand for individuals with NS&E knowledge and training is highly uncertain, and was not attempted in this work. Instead, the average production

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14 For example, PRA stated that "new females baccalaureates in NS&E fields grew steadily from 1.5 % of the female 22-year-olds to 2.4 % during the 1970's. In the first five years, the growth was entirely in life science, while in the latter five years, growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.2 of female 22-year-olds, with the growth almost entirely in computer science." (Ibid: 191)
during 1984-86 has been taken as a proxy for future demand (about 210,000 degrees per year). This proxy is conservative." (Ibid) Not only did PRA select the years with largest production as a base number for demand but it dismissed any quantitative projection such as salary or even government spending on R&D which NSF included in previous fixed coefficient projections. The argument here is that the government had never embarked on large scale spending of the kind of R&D that was now required. R&D spending during the Cold War or for the national needs of the 1970s could not be used under the present circumstances. On the demand side, PRA also disregarded the effect of salaries, keeping away any possibility of government intervention in the free market. For example, PRA claimed that "based on observations from the past decade, it appears unlikely that the labor market for NS&E bachelors will solve this emerging problem by steering a much larger fraction of undergraduates into NS&E majors, for two reasons: first, in the past there has been virtually no relationship between changes in the relative starting salaries and degree production in the combined NS&E fields..." (Ibid)¹⁵

Given these assumptions on supply and demand, PRA concluded that if things were left as they were "the cumulative shortfall of bachelors in the year 2006 would be about 675,000 with 275,000 being in engineering degrees. (Ibid)

¹⁵ PRA made similar assumptions for the supply and demand of Ph.Ds. For example, PRA claimed that the continuation rate from B.S into Ph.D was fixed at 5% for all U.S. citizens receiving baccalaureates in science and engineering. On the demand side for Ph.Ds, PRA claimed that "demand will increase due to new research positions in industry and academia mainly driven by massive retirement of faculty from the boom period of the 1960s."
After defining the problem as indicated above, PRA also defined the solution to the upcoming manpower crisis through attraction and retention strategies in the form of programs coming from NSF (see figure 9). According to PRA, the number of qualified personnel in NS&E fields can be increased through two strategies: attracting more new people into these occupations, or into the NS&E pipeline, and retaining a larger number of those who are in the NS&E pipeline. (NSF 1990: 223)

Figure 9. The Science and Engineering Pipeline: Strategies for Reducing the Shortfall in Natural Sciences and Engineering.
The pipeline reifies within NSF: CASPAR

The pipeline allowed policy experts to foresee possible futures and inform policy, both inside and outside NSF. As Alzinga and Jamison (1995:591) argue, "foresight became one of the central policy methodologies [in the 1980s]. The idea was to bring various actors together, chosen on the basis of their specialized knowledge, to visualize possible futures and select particular technological options that then became inputs in policy. Foresight thus involves a strong element of social construction, whereby governments or agencies connected to government seek to shape consensus among representatives from the academic, economic, and bureaucratic policy cultures." The pipeline became NSF's "foresight" methodology for human resources, but Bloch and his PRA experts needed to establish consensus before the pipeline could influence policy. Once consensus was reached, the pipeline studies, with its assumptions, conclusions and recommendations, would become the certified knowledge that guided NSF's education and human resource programs for almost a decade after 1985.

The search for consensus, however, did not occur without some resistance from other sources of policy expertise but PRA found a way to consolidate the legitimation of the pipeline within NSF. First, there was disagreement among the science policy community about the best way to
project numbers of scientists and engineers.\textsuperscript{16} While PRA based its projections on demographics, SRS and OTA published reports that showed the limitations of demographic-based projections.\textsuperscript{17} Both SRS and OTA advocated market-driven analysis. But the powerful policy of orchestration, led by Erich Bloch and endorsed by the White House, to supply the U.S. with a large number of scientists and engineers without intervening in market forces, mainly by fixing salaries, kept dissenters quiet until 1993.

As soon as Bloch became NSF director, PRA began a series of reports to advise the administration on demand-supply balance of scientists and engineers. These were followed by briefings to NSF and NSB in 1985 and by the modeling of discipline-specific pipelines for all NSF Directorates who embraced the pipeline.

The team put in charge of the PRA Division endorsed a policy practice known as Computer-Aided Science Policy and Research (CASPAR). PRA top officials argued that CASPAR would democratize the policy process: "The

\textsuperscript{16} The lack of consensus within NSF in the early years of pipeline development is exemplified in the inability of PRA to secure a NSF number for its first official report in 1987. Although the report, The Science and Engineering Pipelining, was published with a PRA number, the 1987 Science and Engineering Indicators, NSF’s most visible and most well-known official statement about the state of science and engineering, contained a section on the pipeline. By 1989, The State of Academic Science and Engineering was the first official NSF publication (with an NSF number) containing the complete argument of the pipeline studies and was published in 1989 by direct request of Erich Bloch.

\textsuperscript{17} Throughout the time there was disagreement with demographic-based modeling. SRS published report on Projected Response of s/e labor market to defense and non-defense needs (NSF 1984) and OTA published Demographic Trends and the S/E Workforce (OTA 1985). Both dismissed the importance of demographics on shortages of scientists and engineers.
practice of data driven policy analysis is no longer the monopoly of the few who have access to or can program a mainframe, or who are privy to a sophisticated analytic technique, or possess a database."18 Whether it democratized policymaking within NSF or not will is the subject of another analysis. But what PRA accomplished through CASPAR was an unprecedented level of acceptance for the pipeline within NSF staff in the late 1980's, from the Director and the NSB all the way down the organizational hierarchy. PRA achieved this by disseminating the pipeline model inside of NSF through programmed spreadsheets containing PRA's assumptions as constants. PRA distributed diskettes to NSB members before briefings and board meetings. Program managers at NSF's various divisions could now play with supply variables and create a variety of future scenarios that were specific to their discipline and make appropriate claims of manpower shortages. As Assistant Program Manager in Engineering Education, I also prepared a variety of future scenarios for different engineering disciplines while preparing speeches and presentations to promote NSF engineering education programs to different audiences. One would use discipline-specific data coming from SRS, NSF's statistical unit, plug it into the programmed pipeline model and produce a custom-made pipeline.

18 See, for example. Peter House's and Roger Shull's (1991) The Practice of Policy Analysis: Forty Years of Art and Technology, where they justify the use of PC technology for policy analysis under the argument of democratizing the policy process.
The pipeline spreads outside of NSF: Bloch goes to Congress

As soon as Bloch became director he began filling requests for projections of scientists and engineers by OSTP and NAS.\textsuperscript{19} Bloch's background at IBM and at NRC's Committee on Engineering Education and Practice and his close relationship with the Reagan administration made him trustworthy in the high-level policy circles. He lobbied for the inclusion of the pipeline studies projections in NSF's most consulted source of official knowledge, the S\&E indicators, which until now had relied on external contracts to develop market-based supply models for its projections.\textsuperscript{20} NSF included the pipeline projections in its 1987 S\&E indicators for the first time as follows:

In the 1990's, changing demographics may impose restraints on the supply of newly trained scientists and engineers...In fact, with the population of 18- to 24-year olds expected to decline by 23 percent between 1980 and 1995 college enrollments could decrease by as much as 12 to 16 percent by 1995...These combined forces may hinder workforce ability to meet demand increases over the next decade. (NSB 1987:352)

This is of significant importance considering the respectability of the S\&E Indicators in the U.S. government and its influence on all sorts of policy decisions. For example, the dissemination of the pipeline outside of NSF in


\textsuperscript{20} See, for example, Daufenbach R.C. and J. Fiorito. 1983. "Projections of Supply of Scientists and Engineers to Meet Defense and Nonddefense Requirements, 1981-87." Contractor report to the NSF. Stillwater, OK: Oklahoma State University
official literature like the *S&E Indicators* influenced greatly the new immigration-
policy signed by President Bush which gave special provisions to foreign
nationals with technical and scientific expertise.

With the pipeline argument now carved in stone and receiving the full
support of the NSB, Bloch took the pipeline argument and tied it to the need to
increase NSF funding. The retention and attraction strategies recommended by
PRA were built into the visual image to indicate not only the problem points but
the proposed solutions to overcome the projected shortfall (see figure 9 above).
This visual image became NSF’s poster child. NSF’s assistant directors, division
directors, and program managers not only used the pipeline model to justify
their own budgets internally but also took the pipeline model on the road to
obtain public and congressional support for their own programs. Sue Kemnitzer
remembers the benefits of taking the pipeline image to the halls of Congress:

> Well, it’s a very oversimplified and not a very humanistic way to talk
about students. It’s a very mechanical model but that is important to
some people. I’ve seen enough benefit from using the metaphor if you
have to explain a member of Congress in 30 seconds what the problem
is. This is something they can get and then they have benefited us in
terms of getting support for the program. So it doesn’t bother me all that
much because I’m seeing the benefits. (Kemnitzer 1995: 7)

This is exactly what Erich Bloch did successfully when in 1987 he took the
pipeline message to Congress and successfully argued for increasing the
participation of women and minorities in science and engineering an essential
component of economic competitiveness.
...if we want to supply our industries and government and our universities with the human power that we need in the future...we need to concentrate on the groups which are underrepresented today in the scientific engineering areas--women and minorities. That is something that the Foundation has been focusing on and will have to focus on increasingly in the future. (Bloch in U.S. Congress 1987: 9)

In NSF's 1988 annual report, Bloch's statements reflected how much the pipeline had achieved for NSF's education programs. As he wrote in his front-page statement of the report:

Early in 1987 the administration had asked Congress to double the NSF budget over the succeeding 5 years. This was unprecedented. It recognized the importance of science and engineering to economic competitiveness...our education programs are growing vigorously, with excellent support for the administration and both parties in Congress...Because demographic trends demand it, we will renew our efforts to attract larger numbers of women and minority-group individuals to science and engineering. Women and minorities must be recruited more successfully if we are to have the people we need in science and engineering. This is absolutely crucial. (NSF 1988)

Since 1987 NSF's education budget has grown continuously not only in proportion to NSF's total budget, from 6% in 1987 to 19% in 1996, but to unprecedented levels, from $99 million in 1987 to $600 million in 1996 (see figure 10)
The pipeline industry

With the help of the visual metaphor, Bloch was so successful in delivering the pipeline message to Congress that his idea of creating the Task Force on Women, Minorities and the Handicapped in Science and Engineering was passed into law by Congress in 1987.\footnote{Many other task forces, specific to certain population groups in specific disciplines such as "Women in Engineering" were formed around this time. However, the significance of the one mentioned here is that it was the only one given authority by Congress and established under public law (99-383).} Congress established this Task Force to examine the current status of women, minorities, and the handicapped...
in science and engineering and to coordinate existing federal programs to promote their education and employment in these fields. The Task Force had the authority to "develop a long-range plan to advance opportunities for women, minorities, and the handicapped in federal scientific and technological positions and in federally assisted research." (PL 99-383) Without precedent in the history of science education, this Task Force was co-chaired by a hispanic and a woman, directed by another woman, and composed mainly by female and minority representatives from government, industry, and academia. The Task Force published the report Changing America: The New Face of Science and Engineering with specific recommendations for many sectors of American society to implement programs and policies.

Invoking the image of nation in economic competitiveness with Japan and using the pipeline as its foresight methodology, the Task Force identified specific groups (Blacks, Hispanics, American Indians, People with Disabilities, and White Women), established their current participation in NS&E fields, and, by means of group-specific pipelines, outlined group-specific attraction and retention strategies. Furthermore, the Task Force gave the responsibility of increasing the representation of underrepresented groups in science and

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Task Force Co-Chairs: Jaime Oaxaca, Vice Chairman, Coronado Communications, and W. Ann Reynolds, Chancellor, California State University System. Executive Director (appointed by Erich Bloch): Sue Kemnitzet who eventually became Deputy Division Director for Engineering Education at NSF.
engineering to "key players in American society."23 By making the representation of underrepresented groups in science and engineering everybody's business and a "goal for the American nation", this Task Force opened the door for the pipeline industry.

One of the most important features of the pipeline model was that it provided a foundation for longitudinal analyses of behavior of key subsets of the general population, i.e., women and minorities (see figure 11). This was accomplished with the use of desegregated flow diagrams which focus on one particular subset of stock such as "black women in engineering" or "hispanic men in physics." Also these group-specific models made it possible to pinpoint "leaks" in the flow of that particular group at specific points in the educational pipeline. These "leaks" came to be understood as "behaviors" requiring institutional fixes, such as offices of recruitment and retention established at colleges and universities and sponsored by the federal government and industry. As such, the pipeline became a technology of government that helped government and industry to keep track of the science-and-engineering bound student population beginning as early as middle school. Also, it helped to incorporate women and minorities into the economy, making them once again social citizens but now in accordance with the national context of the 1980's.

23 According to the Task Force, those players are: the President, industry, state legislators, school boards, parents, the media, governors, federal government, universities and colleges, pre-K-12 educators, professional societies, and all americans.
Figure 11. Pipelines for Women and Minorities in Science and Engineering
The Task Force recommendations established a new dimension in the relationship between the federal government and educational institutions, from kindergarten to research universities. By recommending that the federal government "provide stable and substantial support for effective intervention programs that graduate quality scientists and engineers who are members of underrepresented groups", the Task Force called upon the federal government to become involved in the problem of underrepresentation of women, minorities, and disabled persons in science and engineering. By encouraging academia "to set quantitative goals for recruiting and graduating more U.S. students in the sciences and engineering from underrepresented groups...[and] to improve retention programs aimed at underrepresented groups..." (Task Force 1989:11), the Task Force also called upon academia to vigorously take up the task of increasing the representation of women, minorities, and disabled persons in science and engineering. Educators at all levels began to see themselves, and what they did, as part of the pipeline.24 In sum, the Task Force established an exchange of federal monies for numbers of underrepresented science and engineering students. Universities now received federal funds as they implemented programs to attract and retain women and minorities.

Previous to the Task Force recommendations, calls for increasing women and minorities in science and engineering were for the most part unsuccessful. Advocates of social justice and equal opportunity fought the Reagan administration's decision to cut science education programs after women and minorities had made some strides in the 1970's. However, they invoked an image of nation that was no longer within the limits of what was sayable in the early 1980s. While trying to save science education programs at NSF in 1982, for example, Charles Meredith, Chancellor of Atlanta University Center, claimed that "it is extremely significant to realize that the production of minority professionals [in s/e] is essential to the entire framework of achieving both social and educational equity [for minorities]." (USHR 1982: 481) His attempts were unsuccessful. Other failed attempts include those of John Slaughter, the first black to become NSF director, and Dr. Sheila Pfafflin, president of the Association for Women in Science Educational Foundation and chair of the Subcommittee on Women of NSF's Committee on Equal Opportunity in Science and Technology, who tried to further develop programs for minorities in science at NSF in 1982 based on claims of social justice. The point here is that these advocates were using arguments from the 1970's when Congress gave access to women and minorities to science and engineering as a means to solve domestic national problems, including social and educational equity. However, in the early 1980's the nation's needs were being redefined in terms of
economic competitiveness, and any group hoping to further their participation in science and engineering would have to speak to these new national concerns. Calls for education programs, even if they were in science and technology, had to be redefined in terms of economic competitiveness.

No one understood this better than Shirley Malcom, who worked her way up from a research assistant position at AAAS in 1975 to become director of AAAS Office of Education and Human Resources and a member of NSB. Malcom, who in the 1970’s successfully argued that “diversity of cultural and other backgrounds was good for science” (Malcom et al. 1976), understood that the legislative gains of the 1970’s would no longer ensure the representation of women and minorities in science and engineering education in the 1980’s. With the Administration committed to fiscal reorganization and the nation focused on economic competitiveness, Malcom shifted her strategy; to build into the rhetoric of competitiveness a need for women and minorities. This shift in strategy came very early in the Reagan era when Malcom wrote in the editorial of Science magazine: “We must protest cuts in programs for developing the capabilities of women and minorities, not only for the sake of these groups, but also for the sake of science and for the sake of our nation.” (Malcom 1981) She explained this strategy as follows:

I remember the day [Reagan got elected]...we decided to become more pragmatic...we shifted [the language] to describe the problem of underrepresentation in terms of economics and national security...our
universities were graduating more foreign nationals in many areas of strategic interest. But you realize that those people couldn't work in our defense industry...we were kicking the legs out from under our own industry in terms of the talent issues and so there were national security aspects as well as strategic economic interests.  

Malcom tried to link the issue of underrepresentation of women and minorities to the problem of economic competitiveness in a way that would resonate to everyone regardless of political affiliation. U.S. Representative Margaret Heckler (R-Mass), a member of the House Subcommittee on Science, Research and Technology, realized the need to link underrepresentation to the issue of manpower for competitiveness within NSF:

I feel we are frightfully behind. We had to fight very hard to save women and minorities last year. Now we know that on the one hand we have the technology problems, the personnel problems, the academic training needs, the productivity lag between the U.S. and Japan, all these enormous difficulties facing the industry and the jobs affected by it, and here we have an enormous resource in the population of women and minorities and we do not really seem to be making the right linkages. I would hope that there would be a development of a sense of urgency within the NSF on this subject, not only in terms of programs, but on the whole picture. I think we are dealing with fringe issues and not centrally attacking what could be a major resolution of national problems (USHR 1982: 534)

Neither Malcom nor Heckler had at their disposal at the beginning of the 1980s the certified knowledge that came later with the pipeline. The Task Force had this knowledge at its disposal and used it to recommend policy and programs.

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25 Phone interview, November 18, 1994
"The Sputnik of the Eighties"

In 1983, seeking a national crisis that would focus government support into education, Charles Smith, chancellor of the University of Tennessee, asked in the popular media "Sputnik II -- Where Are You When We Need You?" (Smith 1983) In 1987, NSF's pipeline became the Sputnik of the 80s. According to Sue Kemnitzer, executive director of the Task Force and Deputy Division Director in Engineering Education at NSF, after the Task Force final report was presented to Congress "the budgets for education in science and engineering went up tremendously, at least a three or four fold increase." (Kemnitzer 1995: 5) As we have seen, NSF's funding for education and human resources increased from $110 million in 1987 to $600 million in 1996 (see figure 12).

Figure 12. Funding for NSF Education and Human Resources: 1980-93
The impact of the Task Force report was so significant that Richard Ellis, director of the Engineering Manpower Commission of the AAES, testifying during congressional hearings on oversight of the pipeline numbers said: "The Task Force used the scarcity arguments to dramatize its push to open up technical professions to underrepresented people. The Chronicle of Higher Education then proceeded to focus as much on the scarcity aspects of this story as on the need to encourage women and minorities. From there, NSF's numbers went out to thousands of college public relations people and then to the media." (USHR 1993: 246)\(^26\)

By the end of 1980s, NSF had redefined its mission around economic competitiveness and the pipeline. In its Long Range Plan FY1989-1993 (NSF 1988), NSF outlined its contribution to the nation's economic competitiveness and security by supporting activities in three categories: education, generation of new knowledge, and transfer of new knowledge from producers to users. Among the three themes to develop this plan, one was to "enhance the quality of science and engineering education and of human resources development, and broaden participation in science and engineering."\(^27\)


\(^{27}\) The other two are improving academic science and engineering facilities, and developing science and technology centers and group research activities.
given to the development of educational and human resources, particularly
those of women and minorities, was clear: "Among the key NSF themes and
strategies, this will be the top priority" (Ibid: 9)²⁸

The distribution of the budget and funding of continuing and new
programs is conceptualized along the pipeline. Specific locations for funding
along the pipeline are established: elementary/secondary level; undergraduate
level; graduate level; postdoctoral level; young investigators; and senior
scientists and engineers. Special provisions to increase the participation of
women and minorities in each one of these levels were also established. In
sum, the pipeline had become a good business for NSF. The pipeline helped
NSF become the nation's premier agency in the making of scientists and
engineers by significantly increasing its budgets and legitimizing its position
within academia and with respect to underrepresented groups.

**Women and minorities to save the nation**

During invited lectures, Erich Bloch positioned NSF at the center of the
pipeline industry. Always opening with the pipeline argument and outlining
NSF's programmatic solutions²⁹, he invited academia to participate in these

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²⁸ It is clearly stated that the rate of growth in support of education and human resources will be maintained at a
level at least 50% higher than that in other strategic areas (disciplinary research and facilities, centers and groups).

²⁹ Examples of these programs include Visiting Professorships and Research Opportunities for Women, Minority
Research Initiation Grants and Minority Research Centers of Excellence, Minority Graduate Fellowships, and
Research Assistantships for Minority High School Students.
efforts, also creating partnerships with industry, all in the name of economic competitiveness:

NSF has set in place a number of programs to meet the challenge... but these programs are only a place to start. Their success depend on you.... I encourage you to become involved. Reach out to students in your local schools... and encourage them to take the prerequisite math and science courses... Talk to your colleagues in industry and state and local government about the problems and ask them to help you improve engineering training and to recruit and retain women and minorities in engineering... Your success will help determine whether the U.S meets the challenges of a new world environment. (Bloch 1989)

During speeches to audiences of underrepresented groups in science and engineering, Bloch showed the growth of NSF programs for women and minorities after 1985, the year that he began using the pipeline argument in Congress to secure appropriations for such programs (see figure 13).

<table>
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<tr>
<th>FY 1985 ($12.8M)</th>
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<td>Minority Research Initiatives</td>
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<td>Facilitation Awards for Handicapped Scientists and Engineers</td>
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<td>Research Assistantships for Minority High School Students</td>
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<td>Career Access (SEE)</td>
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<tr>
<td>Support Through Non-targeted programs $80.1 M</td>
<td>Support Through Non-targeted programs FY 1987 $108.3 M</td>
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Figure 13. Growth in NSF Programs for Women, Minorities, and the Disabled: 1985 to 1988
By 1988, the pipeline, economic competitiveness, and the importance of underrepresented groups came together as a mission for NSF as imparted by the National Science Board (NSB).\textsuperscript{30} In determining the role of NSF in economic competitiveness, the NSB, in a report titled \textit{The Role of the National Science Foundation in Economic Competitiveness} (NSB 1988), stated that:

If compelled to single out one determinant of US competitiveness in the era of the global, technology-based economy, we would have to choose education, for in the end people are the ultimate asset in global competition.... But an especially important further step will be to extend the pool from which the pipeline draws by bringing into it more women, more racial minorities, and more of those who have not participated because of economic, social, and educational disadvantage... Thus not only is providing a better grounding in math and science for all citizens a matter of making good on the American promise of equal opportunity. It is a pragmatic necessity if we are to maintain our economic competitiveness (Ibid)

With that in mind, one of NSB's final recommendations to Congress was that

From the perspective of economic competitiveness... NSF programs and management efforts designed to help bring women, minorities, and the economically, socially, and educationally disadvantaged into the mainstream of science and engineering deserve continued focus. (Ibid)

if in the 1970s, as Malcom told us, "you are what gets studied," in the 1980s we can say "you are if your kind can provide enough numbers to the pipeline."

\textsuperscript{30} In 1984, before the pipeline studies created women and minorities as significant categories for economic competitiveness, the only existing program in NSF's science education budget for underrepresented minorities was the Minority Graduate Fellowships. At that time, only 10% of the total (60) NSF fellowships were awarded to minorities and women. By 1989, "education programs...to strengthen the quality, diversity, and number of U.S. scientists and engineers" become the special focus of NSF's mission (NSF 1989). Unprecedented in the history of NSF are the kind and number of programs specifically targeted to minority populations. These include pre-college activities, such as "Escalante's Work Expands" and Detroit Area Pre-College Engineering Program, and college-level activities, such as Undergraduate Research Opportunities for Minorities, Minority Scholars Program, "Women in Engineering Fellowships..."
Conclusions

In the 1980s a discourse about the nation in terms of economic competitiveness with Japan emerged. Pro-technology groups, including industry leaders and "technophiles" such as Lewis Branscomb, rushed to define this new national problem and its solutions in their own terms. They defined the problem as that of a failing productivity. Furthermore, they defined the solution in terms of the development of technological innovation and education and training of human resources, mainly engineers. Both congressional attempts to advance a national manpower policy and Reaganomics' redefinition of the role of government in education defined the limits of what was acceptable about education and the nation. Within these limits, NSF emerged as an institutional solution to the political problem of educating scientists and engineers for competitiveness.

Erich Bloch came to replace the last of scientific academists to direct NSF in an effort to transform it for the needs of economic competitiveness through the development of technological innovation, infrastructure, and workforce. To conceptualize the new needs of the nation for scientists and engineers, he implemented and successfully institutionalized an engineering flow model: the science and engineering pipeline.

More than becoming the guide of NSF's education programs, the pipeline became the "Sputnik of the Eighties." First, it gave form (a visual
representation) to the problems of education (quantified "leaks" from kindergarten to Ph.D). Second, it showed the potential contributions of large numbers of scientists and engineers (quantified future production of scientists and engineers) to economic competitiveness. NSB, Congress, the President, and educators embraced the message of the pipeline and established a new social contract between those groups that were to feed the pipeline, mainly women and minorities, and the federal government. This new contract created what I have called the pipeline industry where pipeline-based claims allowed educators and NSF administrators to request federal monies to bring students into the pipeline by means of recruitment and retention efforts.

After disappearing in the early 1980's, women and minorities in science and engineering re-emerged in the late 1980's as significant categories for economic competitiveness. The pipeline successfully connected selves and nation within the discourse of economic competitiveness.
CHAPTER 5
Science and Technology Policymaking in a Tripolar World:
Making Flexible Selves for Global Competition

...the time has come, for the first time in U.S. history, to establish clear, national
performance goals that will make us internationally competitive. By the year 2000,
U.S. students will be first in the world in mathematics and science achievement...

...we need human resources that will be flexible enough in terms of their training so that
if they don't quite match what is at that time the need for their skills, they can be
retooled very quickly. (Fechter quoted in U.S. Congress 1985: 84-5)

There is an apparent contradiction between the call for national
performance standards from the first of these quotes and the call for flexibility in
training of human resources from the second quote. However, as I show in this
chapter, standards and flexibility are features of distinct but concerted efforts at
NSF to educate and train U.S. scientists and engineers for global competition
as the single economic threat of the 1980's becomes multidimensional and
complex. The complexity is due in part to new understandings of Japan, not in
terms of numbers but in terms of quality, flexibility, and capacity to innovate, at
the same time that two economic blocks, the Pacific Rim and unified Europe,
have emerged as new economic competitors. With this complexity comes
uncertainty and ambivalence in redefining American institutions and policies.
NSF and its programs for research and education are certainly no exception.
Wondering between isolationist competitive attitudes, like the protectionist
policies adopted in the 1980s, and partnerships in multi-national alliances, the
U.S. government is seeking ways to reconceptualize its scientific and
educational institutions, programs, and policies conceived during the Cold War to match the requirements of a new global political and economic space. This has certainly been the case of NSF and, especially of its education programs. This closing chapter traces the emergence of a new national discourse in terms of global competition in a multi-lateral world into NSF and its programs. Particularly in its education and human resources policies and programs, NSF is shifting from producing large numbers of scientists and engineers "to beat the Japanese" towards making flexible scientists and engineers capable of rapidly adjusting to changes in knowledge production, dissemination, and application in new global scenarios. Focusing on two emerging visions for education and human resources in science and engineering --systemic reform and competitive flexibility--, this chapter shows how these two visions and their advocates are coming together in a marriage of convenience to educate and train a highly skilled workforce to help the U.S. compete in new global scenarios. These visions of education redistribute power in U.S. science and engineering education, from groups based on gender and race to groups based on their ability to improve market penetration of U.S. businesses in a global economy. This chapter questions the impact of such redistribution on the fashioning of selves in science and engineering. That is, it poses the question: what kind of students, and for which kind of future jobs, are programs like those at NSF hoping to produce?
The making of a multiple threat: From "bipolarity" to "tripolarity"

In the 1990's theorists from different fields are redefining the global marketplace from a tug-of-war for market-share of consumer products between Japan and the U.S. to multi-lateral "battlegrounds" where other growing economies have become significant competitors and unexploited markets. Since the late 1980's, both media and academic writers have described this new global scenario, remapping the world from a place where only two opposing sides (e.g., U.S. vs. USSR or U.S. vs. Japan) define the geopolitical context to a place where three or more interconnected sides share or compete for global political and economic space. For example, popular media representations include: the U.S. competing with the rest of the world, the U.S. competing with emerging small but powerful economies of South East Asia, and the U.S. being threatened by European unification.¹ Academic representations include: a world made of three economic centers, Europe as the "next battleground" where Japan and the U.S. compete, and a global space continuously changing according to ongoing redefinitions of competing or collaborating alliances between U.S., Europe and Japan.² Among these representations, two locations

¹ See for example, "America vs. the World" (Fortune 1992a), "Snapshot of the Pacific Rim" (Fortune 1991), and "Europe 1992" (Fortune 1992b).

² Examples of academic representations are: Bergsten, C. Fred's (1990) account on Japan, the United States and Europe forming a tri-polar world, Tim Jackson's (1993) analysis of the European market as the next battleground where Japan and the U.S. compete, and Theodor Leuenberger's and Martin E. Weinstein's (1992) study of cooperation and competition among Europe, Japan and America in the 1990s.
the Pacific Rim and a united Europe--have emerged as favorites of both media and the academy.

Representations of the Pacific Rim show a block of emerging economies, imagined as smaller versions of Japan, which through a combination of industrial policies, cultural values, and human resources are becoming serious competitors in different world markets.\(^3\) Although reports on Japan and other Asian countries show differences in macro-economic indexes among these nations, when trying to come up with answers to these countries' economic and technological successes, most theorists provide one answer: Confucian culture. As one leading engineering journal put it: "...the Confucian ethic of toil, respect for authority, and preference of cooperation over confrontation, has inspired [in these countries] achievements far out of proportion to those of [Western] nations." (IEEE Spectrum 1991) This narrow view of cultural, political, and historical diversity has led scholars to an exaggerated preoccupation with Japan as the exemplar of what "Confucian ethic" can achieve. For example, in a 30-page special report on "Asia's Competitiveness Formula", all books reviewed focus on Japan, including T.W. Kang's (1989) Is Korea the Next Japan? (see IEEE Spectrum 1991).

\(^3\) Depending on the source, they are four countries (South Korea, Taiwan, Hong Kong, and Singapore) or seven countries (South Korea, Taiwan, Hong Kong, Singapore, Malaysia, Thailand, and Indonesia) considered part of this emerging economic block. Generally, the first four are granted the label of "little dragons" or "tigers" while Malaysia, Thailand, and Singapore have been assigned the label of "tiger cubs." Japan is still the only country who has earned the full title of "Dragon." (see for example, IEEE Spectrum 1991)
In the 1990's, it has been difficult for American policy makers to escape numerical comparisons that highlight Japan's superiority in most economic indexes. For example, an extensive review of numerical comparisons led Nester (1993) to conclude that "during the 1980s, the United States was transformed from the world’s greatest creditor to the worst debtor country" while Japan has become "the world's banker" and nowadays "Japan has replaced the United States as the world's most dynamic economic power...[including] twelve emerging technology sectors [where] Japan leads in ten and is running neck to neck in the other two." However, quantitative analyses have been scrutinized by revisionist scholars who have concluded that Japan's success is the result of something inherent to its culture and/or to its modern domestic and international policies. In the areas of education and human resources, this obsession with the superiority of Japan's technological workforce lead Earl Kinmonth (1991) to question the assumptions of most number-based studies. Kinmonth claims that "unfortunately, the notion of Japanese numerical superiority is entirely a myth. Every component of it can be shown to be the product of differences in definition and methodology between U.S. and Japanese data sources.

Nevertheless, because Japanese engineering success remains a fact, attention must shift to qualitative differences in engineers and how they are used in industry." (Ibid:329) But qualitative differences extend beyond professional labels and job descriptions. American scholars are focusing now on Japanese
culture and industrial policies to explain its successes. As Gail Cooper (1993) explains, "in the now bulky literature that seeks to explain Japan’s postwar 'economic miracle,' two broad explanations have emerged. One is that Japan’s success is due to its cultural base...recently dubbed 'Confucian Capitalism', an explanatory model relevant for all Asian industrialization... A second group maintains that cultural explanations prevent us from seeing that specific modern policies rather than a centuries-old culture nurtured Japan’s economic growth." Both cultural and policy dimensions of competitiveness theorizing have influenced recent conceptualizations of U.S. education.

Flexible education for a world with 3 centers

Whether analyzing U.S. competition with Europe or with the Pacific Rim, scholars of competitiveness place education and human resources as significant elements of global competition. They recommend investment in education and human resources as safe policy that enjoys political support at home and that is non-confrontational, as some industrial and trade policies are. For example, recommending education and training to any of today’s global competitors, Jackson (1993) claims that "whether in Washington, in Brussels, or in the different national capitals of the European community...governments [should] foster good human capital, by turning out a highly educated and skilled worked force from national schools." (Ibid: xiv)
Recent theorizing about Japan sees this country as a cultural space where family-rooted values such as high regard for the group, hard work, diligence, and perseverance are reinforced through education and eventually translate into educational performance, loyalty to the company, teamwork, and quality. That is, these values translate into Japan's economic competitiveness. As a U.S. Department of Education report titled *Japanese Education Today* states, "Japanese education is a powerful instrument of cultural continuity and national policy. The explicit and implicit content of the school curriculum and the manner in which teaching and learning are accomplished impart the attitudes, knowledge, sensitivities, and skills expected of emerging citizens of Japanese society. These lessons are further reinforced in the context of family and society." (U.S. DOE 1987:2) This has shifted the attention of American education policymakers towards those values to see how they can be taught within the context of American education. As former Secretary of Education, William J. Bennett asked, "What lessons might we draw for ourselves from a close look at Japanese education? It is scarcely a novel query. Japan, after all, has increasingly become a reference point or gauge by which Americans appraise our own education system." (Ibid:69) For example, by contrasting Japanese collectivism with American individualism, some educators have begun to incorporate collective traits, such as teamwork, in American curricula. Other numerical and cultural comparisons between the U.S. and Japan have led
influential business and academic leaders to conclude that the key to Japan's productive performance lies in the quality and flexibility of its workforce, hence these traits must be transferred to U.S. education and training of scientists and engineers. The most influential work of this type has been conducted by MIT's Commission on Industrial Productivity (1989) about developing the human resources for technological advance and competitiveness. This work was eventually incorporated into Michael L. Dertouzos et al's (1989) Made in America: Regaining the Productive Edge. During my tenure at NSF from 1989 to 1991, this book was held up as the bible of competitiveness through flexibility and was very influential in the conceptualization of the Engineering Education Coalitions. Broadly speaking, the problem of education and training of human resources as conceptualized by these scholars is how to transfer and institutionalize those "cultural tricks" in order to improve the performance of new capitalist modes of production while preserving individualism to maintain a ever-growing consumer market. As scholars envision all kinds of iterations of cooperation and competition (see Leuenberger et al 1992), they see flexibility in human resources as a desired trait for any of the new global scenarios. Scenarios of cooperation usually call for a broad view of flexibility understood as mutual cultural and national understanding to share global markets. Scenarios.

of competition usually call for a narrow view of flexibility as an ability to create
new markets or penetrate existing ones through the deployment of
circumstance-specific (just-in-time) skills and traits, including one's gender and
race. In the U.S. where cooperation is viewed as a means to competition
(GUIRR 1995), the concept of flexibility refers to both education and training in
multicultural/national understanding and the development of circumstance-
specific (just-in-time) skills. We can already see how NSF is responding to
these needs by redefining its education and human resource programs in the
1990's around flexibility. Curriculum projects at NSF already aim at producing
engineers who can help American industry conquest new global markets in
technology and services. In the promotional brochure of the Engineering
Education Coalitions, NSF justifies this program since "the need to improve
market penetration of U.S. industry...require that engineers have not only
disciplinary depth but also strong integrative qualities if they are to participate
fully in leading innovation in the next century. (NSF 93-58)

Redefining NSF's mission around global competition

Along with theorizing the emergence of Pacific Rim in terms of the
Japanese success, both popular and academic theorists also are attempting to
redefine a unified Europe as a multi-national/cultural space coming together and
becoming not only a competitor of the U.S. for world markets but an unexploited
market that both Japan and the U.S. will have to fight for. With Europe rapidly becoming a single economic market and "the world's largest market and largest trader" (Bergsten 1990; Jackson 1993), a world defined around two rival sides was no longer sufficient. Bergsten (1990) has given this new global arrangement the name of "collaborative tripolarity" where "the Big Three of economics will supplant the Big Two of nuclear weaponry on the issues that will shape much of the early twenty-first century. Japan, a uniting Europe and the United States will become full partners in managing the world economy." Others have redefined the new relationship among nations as a confrontation where two sides fight for the quest of markets in the third.

Some theorists have focused on the relationship between state and society in Europe, Japan, and the U.S. and its effect on economic competitiveness. Some political scientists have analyzed state-societal arrangements, particularly in Japan and Germany, in order to explain their recent successes in international competitiveness. For example, according to Hart (1992) "the Japanese system is well organized for joint state and business efforts to bring Japan to the technological frontier in strategic industries and keep it there." (Ibid: 284) To account for Germany's success, Hart argues that "the strength of the German system is built on the high skill level of German workers... Although the German government plays a minor role relative to others, it is responsible for the educational system that transmits skills to the
workforce and helps to assure the transmission of university-created knowledge to business." He concludes that "state-societal arrangements are the key to explaining recent changes in international competitiveness." (Ibid) (see figure 14)

![Diagram of State-Societal Arrangements in Five Industrialized Countries]

Figure 14. State-Societal Arrangements in Five Industrialized Countries

The message for the U.S. is that if it wants to compete with Japan and Germany, it has to replicate some features of their state-societal arrangements. That is, the U.S. would have to move away from the business vertex simultaneously towards both the state and the labor vertices. In Hart's own words, "If [the U.S.] chooses the Japanese model there will have to be a major
upgrading of government agencies and centralization of industrial policy-making in a single agency...If the U.S. chooses the German model...a significantly increased commitment to the training and retraining of workers will be needed." (Ibid.291)

These new visions on how the U.S. must redefine its state-societal arrangements are having an impact on the way the federal government positions NSF. We have seen how since the 1980's different pro-technology groups from industry, academia, and government have tried to make NSF the American version of Japan's MiTI. Although NSF has not, and probably never will, become an agency that dictates centralized industrial policy, it has become instrumental in orchestrating partnerships between government, industry, and academia for the funding of major research and education programs. Also, in an almost German-like fashion, NSF is becoming more involved in initiatives to educate and train the American labor force into a highly skilled workforce while ensuring the transmission of university knowledge to business. In education, NSF is trying to address both the policy and cultural dimensions of the Asian and European challenges by means of two major programmatic initiatives: systemic reform and competitive flexibility.

On March of 1993, the Subcommittee on Science of the House Committee on Science, Space, and Technology held congressional hearings under the title "The Mission of the National Science Foundation." The
Subcommittee's chairman, Rick Boucher (D-Va) seek to redirect NSF's mission towards new national needs for global competition. Boucher recognized that "as new opportunities and challenges have been created by the end of the cold war, the rise of multilateral economic competition from abroad, and the emergence of global environmental problems," NSF's mission needed re-evaluation. (USHR 1993: 1-2) The main guide for NSF's new mission was the testimonies of three powerful groups: the President Council of Advisors on Science and Technology (PCAST), the Carnegie Commission Task Force, and the Government-University-Industry Research Roundtable's (GUIRR) Working Group of the National Academy of Sciences. All of them have published reports on the future of U.S. science and technology in the new era of multilateral competitiveness and Boucher wanted to address their recommendations for the future mission of NSF. One strong common message comes out from these proposals: technoscientific knowledge production, and the development of scientists and engineers to produce it, are fundamental for ensuring the competitive position of the U.S. in the new global scenario. As the President's Council of Advisors on Science and Technology (PCAST) puts it: "advancing the frontiers of knowledge is not, as it once may have been, a matter of

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intellectual luxury. In an era of relentless global economic competition, it is a
national imperative." (Ibid:90)

Most of these proposals call for the production of technoscientific
knowledge to take place in multinational settings beyond the walls of U.S.
research labs and U.S. national borders, and is to be produced by multinational
research teams. For example, the GUIRR Working Group, with former NSF
Director Erich Bloch now as its chairman, propose a "Global Research System"
in its report Vision for the Future. They argue that as "international research
cooperation will become a pervasive feature of the U.S. academic research
enterprise in the next century, multinational research arrangements will be
essential for studying large-scale [scientific and technological] problems. The
research communities of both industrialized and developing countries will rely
more and more on cooperative ventures to address these and other research
problems" (GUIRR 1992 quoted in Ibid: 257) However, these calls for
cooperation are not a departure from an attitude of competitiveness towards
one of mutual understanding and collaboration. It is very clear that scientific and
technological cooperation is just a means towards strengthening the U.S.
competitive position. In justifying multi-national cooperation, the GUIRR report
states

Global competition in science and technology will require that the United
States pay close attention to the research activities of other countries,
especially those targeting economic growth as their primary research
goal. This will be particularly true for the Western European and Pacific Rim countries, which have become fierce competitors in the knowledge-intensive global marketplace... Just as Japan in past decades capitalized on discoveries made in this country, during the next century, U.S. universities and industries will benefit from the growing base of knowledge and technology produced elsewhere. (Ibid: 258)

Following recommendations such as those made by GUIRR, NSF is already acknowledging the need to establish international partnerships. In its 1995 report *NSF in a Changing World*, NSF recognizes that "our goal of world leadership requires that we carry our partnerships across national boundaries, working with comparable organizations in other countries to promote international cooperation wherever mutually beneficial." To promote this sort of competitive cooperation, NSF proposes two kinds of funding: institutional and individual. Through institutional support, NSF "enables and encourages U.S. scientists, engineers, and their institutions to avail themselves of opportunities to enhance their research and education programs through international collaboration." By means of individual support, NSF "provides future generations of U.S. scientists and engineers with the experience and outlook they will need to function productively in an international research and education environment through support for traveling fellowships and research activities at overseas sites." (Ibid: 19-22)

We see here how proposals such as GUIRR's are redirecting NSF's mission of funding basic research and education in science and engineering,
from funding them inside the U.S. to compete with Japan to funding them in Western Europe and the Pacific Rim to compete with everybody. If in the late 1980's NSF tried to help American competitiveness mainly by producing large numbers of scientists and engineers following the recommendations of the pipeline, its mission now seems to be promoting research and education for a global economy. But how is NSF going to accomplish this new educational mission?

Developing intellectual capital for global competition: Systemic reform and competitive flexibility

One of NSF’s main strategies to enhance America’s global competitiveness is the development of human capital through a series of programmatic initiatives listed as: systemic reform K-12, developing workforce education in science and technology, flexibility in advanced training for scientists and engineers, and scientific and technological literacy. (NSF 1995). These four initiatives are really part of two distinct but interrelated visions of education that are replacing the pipeline: systemic reform and competitive flexibility. Workforce development and scientific and technological literacy are programmatic themes that collapse into both systemic reform and competitive flexibility. Advocates of the last two have included the development of America’s workforce and technioscientific literacy as parts of their overall visions and programs.
Furthermore, after the pipeline, systemic reform is becoming the way to institutionalize changes throughout the entire educational system. With Cold War curriculum and delivery methods now being questioned, competitive flexibility is providing the new content and delivery of curricula in science and engineering for post Cold War/post-Fordist global scenarios. Let’s see how.

**Systemic Reform**

Born out of the "Goals 2000: Educate America Act" of 1993, systemic reform, according to NSF, is a “fundamental, comprehensive and coordinated changes made in science, mathematics and technology education through attendant changes in school policy, financing, governance, management, content and conduct.” (NSF 1995) These changes are to be achieved through three interconnected aspects of systemic reform: 1) unifying visions and goals, including high standards for learning expected from all students; 2) alignment among all parts of the system, including policies, practices and accountability mechanisms; 3) a restructured system of governance and resource allocation that places greatest authority and discretion for instructional decisions on school sites.(NSF 1996)⁶ Who constructs these new visions, goals, policies, and systems of governance and resource allocation will determine how and where

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power is located to make decisions over the future of U.S. science and
engineering education. Maybe U.S. Secretary of Education Richard Riley's
account on how the "Goals 2000" were established tells us something about
distribution of power in systemic reform:

...educators had not been in on the ground floor when the National
Education Goals were developed in 1989 and 1990. The goals were
viewed by many as a classic example of a top-down reform imposed on
localities. Some mistakes inevitably were made in developing the
goals...It would have been much more powerful to have had the
"Summit" after a grassroots, nationwide effort to agree on the goals. Little
effort was made to engage teachers or principals broadly in this very
important education development. (Riley 1995)

Competitive Flexibility

Recognizing the limitations of the current curricula for a post-Cold War
capitalist system, which requires both internationalization and flexibility in its
modes of production (of knowledge, products, services, etc), NSF has begun to
sponsor curriculum reforms to make flexible scientists and engineers for the
new global scenarios. Under a programmatic initiative known as flexibility in
advanced training for scientists and engineers, NSF aims at developing "broadly
educated people with the knowledge and skills necessary to address the needs
of the Nation in a rapidly changing world." (NSF 1995: 30) An example of this
initiative is the Engineering Education Coalitions (EEC's), a multi-million NSF
program to develop new engineering curricula, which aims at creating 21st-
century flexible engineers that America needs to stay competitive in a global
Having originated during the pipeline boom of the late 1980's at NSF's engineering directorate, the Coalitions' original goals were defined along flexibility in the curricula and diversity in the student body. To accomplish the first goal, the Coalitions' initiative offered funding to U.S. engineering schools to "produce new structures and fresh approaches affecting all aspects of U.S. undergraduate engineering education, including both curriculum content and significant new instructional delivery system." (NSF 90-122) To accomplish the goal of diversity, the Coalitions wanted the funded schools to "increase dramatically the quality of undergraduate engineering education as well as the number of engineering baccalaureate degrees awarded, especially to women, underrepresented minorities, and people with disabilities." (Ibid) The first group of Coalitions tried to achieve these goals by having elite research universities design process-driven curricula, instead of the traditional analysis-based curricula, while predominantly minority institutions, like the HBCU's, implemented recruitment and retention programs. The Coalitions aim at transforming engineering education not only through innovative curricular design and use of multi-media technology but by changing the beliefs, customs, and practices in engineering education, particularly those of the engineering faculty. For example, the Coalitions aim at changing the way engineering faculty view teaching as a lesser activity than research. When I asked Karl Willenbrock, one
of the founding fathers of the Coalitions, how the U.S. was going to change and disseminate this new vision of engineering education based on flexibility, he replied: "That's exactly what the Coalitions program at NSF is aimed to do: cultural change. They want to develop a systemic change of how engineering education is done." (Willenbrock 1995)

The end of the pipeline?

On April 1992, the Subcommittee on Investigations and Oversight of the Committee on Science, Space, and Technology, U.S. House of Representatives, held congressional hearings to determine "How Good are the Numbers?" of the projections made by NSF's Division of policy Research and Analysis (PRA) in their pipeline studies. (USHR 1993). House Representative Howard Wolpe (D-Mich), chairman of the subcommittee, stated that "the purpose of the hearings is to review how a study so flawed survived for so long in the nation's premier scientific agency. The subcommittee's investigation has revealed that valid criticism was ignored and even suppressed within the Foundation." (Ibid: 2) Wolpe is referring to PRA's claim of a shortfall of

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7 Karl Willenbrock was one of the most influential figures in engineering education in the last 30 years. His professional contributions included service as Provost at the State University of New York-Buffalo; Director of the Institute for Applied Technology of the National Bureau of Standards; Dean of Engineering at Southern Methodist University; Executive Director of the American Society for Engineering Education; and Assistant Director for Scientific, Technological, and International Affairs of the NSF. In 1999 he organized and chaired a NSF-sponsored task force that produced the report, *Imperatives in Undergraduate Engineering Education: Issues and Actions*, which serve as the foundation for the EEC's.
scientists and engineers that would put the U.S. behind in the competitiveness race.

Wolpe and many critics claimed that the media, both popular and academic, took PRA's projected shortfall of 675,000 scientists and engineers by the year 2006 and made it into a crisis of national proportions. However, after dozens of witnesses from both sides of the issue presented their testimonies, and even the recommendations from an "impartial" expert were brought in, this controversy had no major impact on NSF's credibility or in its budgets appropriations. Actually, its education budget went from 16% of NSF's total in 1993 to 19% in 1994. In the end, all NSF had to do was to correct the record stating that "shortages are not the same as shortfalls and demographic projections are not the same as market analyses." (NSF 1993)

This controversy over the pipeline did not have major consequences because a different notion of nation had already developed, one that called for flexibility of the workforce instead of for large numbers. Around 1993-94, advocates of both systemic reform and competitive flexibility had already made their entrance in NSF. These new visionaries, and even some important advocates of the pipeline in the 80's, were beginning to criticize the pipeline model for promoting specialization in times of flexibility. The first criticism came from advocates of systemic reform who propose to engage and reform all parts of the educational system simultaneously. Systemic reform advocates criticize
the pipeline for elitism, only focusing on the best and brightest. Like its predecessors, the pipeline focuses on those who stay in and how to keep them in while recognizing "leaks" or "drop-outs" as failures. These limitations have been recognized by people like Daryl Chubin, now director of the Division of Research, Evaluation, and Dissemination of the Directorate for Education and Human Resources at NSF, who is trying to change the ways in which NSF views it educational goals. Explaining the limitations of the pipeline, he says

the pipeline metaphor is not a very useful metaphor...because it restricts at various entry points and there aren't too many of them. There are still more people flowing out than people flowing in. It restricts the pool of people who could eventually go on and take degrees in science and engineering. So if you fix the pipeline, if you were to seal the leaks, you are still dealing with a very small minority of all the students and that's the reason that systemic reform is a different kind of approach... (Chubin 1995.7)

Also aware of these limitations of the pipeline are people like Sue Kernnitzer, who made their careers at NSF constructing official knowledge and implementing pipeline programs. Kernnitzer argues, for example, that the pipeline ignores non-linear paths into science and engineering education:

there is one big flaw of the pipeline....There are a lot of people who do not go on a linear path through school, especially after grade 10. I know an American Indian woman who drops out of school in 10th grade and has finally come back at age 35 and gets a GED and goes to the community college and at age 40 has an associate degree and by age 43 has a bachelor's degree...we have more and more of those kind of people...If you look at the average student in the California State University System or the Texas A&M system, they are not 18-year-old white men. The average profile is that of a woman who is 25-35 and that
doesn't jive with the pipeline analogy. That is a big problem for science. (Kemnitzer 1995:8)

People in non-linear paths were ignored under the assumptions of the pipeline of the 1980's which focused on the 18-22 year old college population. The goal then was to enlarge the fraction of this population group going into science and engineering. Systemic reform is now being proposed as a more inclusive approach to education for it takes into account all kinds of students that NSF's programs, specially those based on the pipeline, have traditionally neglected. Arguing for the inclusiveness of systemic reform and the limitations of the pipeline, Daryl Chubin says that

the pipeline became a problem of how do you retain identified and self-selected students at the undergraduate level so they can complete a degree and maybe go on to graduate school. In some ways the pipeline is a far easier problem than the one that EHR is addressing. Our commitment is to all students. We are looking at the 95% that NSF traditionally has not worried about. We are now trying to address the needs of all students regardless of what they are going to do both educationally and occupationally...(Chubin 1995:5)

But more than a concern with elitism, these critics are also concerned with the overspecialization of students produced by the pipeline. As Chubin points out, another problem with the pipeline is that it only projected one model of what to do with a Ph.D in science, namely research....It is our responsibility to diversify what a doctoral program does. Just the way we have been talking about entering the workforce at earlier points, when you end up with a Ph.D you should be versatile not over specialized. You should be able to go into industry...into administration...into research...into teaching...And the problem here [at
NSF] is that we haven't been very creative about preparing students for a range of possible futures after they have a Ph.D.... Even if you can get the Ph.D awarded, you still are not ready to do anything that society at the present time knows how to utilize. I find that to be, 30 years later, a supreme irony. (ibid:14)

Concurring with this view, Sue Kemnitzer views the product of the pipeline as less important for economic competitiveness than technoscientific literacy of potential high-skilled workers. She puts it this way: "Ph.D's don't matter much to economic competitiveness...I rather have a much higher literacy in technology and science from people that graduate from high school than get 10 more Ph.D's." (Kemnitzer 1995)

Despite these criticisms there are still many NSF administrators at research directorates, mainly in life, physical, and mathematical sciences, who still the view the pipeline as serving one of NSF's main goals: the production of Ph.D's. After all, this has been the most everlasting education function of NSF, exemplified by its graduate fellowship programs which have always persevered at NSF even when science education was zeroed out. When asked if, after the questioning of the pipeline in 1993, there were still people at NSF who believed that the mission of the agency was the production of Ph.D's for research, Daryl Chubin responded: "The vast majority. The only way you are going to hear things you are hearing from me [systemic reform] is if you talk to few other in EHR [Education and Human Resources Directorate]... There are even people who are in this directorate who are still firm believers in the pipeline and think
that's what we are all about. So metaphors work. It's a grip that is hard to break." (Chubin 1995)

John Jordan (1994) describes metaphor as a tool that "creates consensus that would be impossible if participants had to reach explicit agreement on definitions." This characteristic of metaphor allowed the pipeline argument to disseminate and achieve high levels of consensus that in order to compete with the Japanese workforce, America needed to recruit and retain large numbers of students, mainly from underrepresented groups in science and engineering. We have seen how the pipeline metaphor helped NSF administrators to disseminate this message and in doing so to further establish the limits of what was sayable about education and human resources in science and engineering. The pipeline metaphor helped them do this without, as Kinmonth later argued, reaching agreements on whether Japanese defined engineers the same way that Americans do. Systemic reform advocates recognize this strength of the pipeline metaphor and understand that they need a metaphor of their own to convey their message and begin establishing the limits of what is sayable about education in America in the 1990's. Although crystallized in the visions that many have about science and engineering education, the pipeline metaphor does not work for systemic reform because it goes against their goal of developing life-long skills in human resources in science and technology. In a white paper, proposing a framework for national
policy to the NSB, systemic reform acknowledges that

while we discard the [pipeline] metaphor here, we have nothing yet to replace it. Continuing use of "pipeline," however, is inimical to what a national policy is trying to achieve, namely, an emphasis on how to draw students to SMET as a major or a set of life skills, not how many "leak" out of the pipeline or opt for majors and careers other than SMET. (NSF Study Group 1994)

Systemic reform advocates presented this paper to NSB to be adopted as NSF policy but NSB rejected the proposal. A member of NSB and an advocate of systemic reform, Shirley Malcolm maybe provides the clue as to why systemic reform is having difficulties reaching the consensus of NSB. She acknowledges the drawback of not having a metaphor that would create a coherent vision within NSF as to how systemic reform works:

I don't think that systemic reform has probably gotten over to any of the directorates yet down at the program officer level. I don't think there is a coherent vision of systemic reform even in the places where it happens to exist. I don't think that any of us have a complete picture of what it means. We have an intuitive sense that it's right because of the approach that we used to apply -- a little over here, a little over there-- didn't work. (Malcolm 1995:14)

What Malcolm is telling us is that systemic reform has been unable to set the limits of what is sayable. Coming up with the appropriate metaphor, one that speaks to the emerging image of the nation in the 1990's, is an important element of setting those limits. Since systemic reform is about interrelating all parts of the educational system, "interrelatedness" seems to be an important
characteristic for a possible metaphor of systemic reform. For example, while Shirley Malcom proposes an "ecosystem", claiming that people move a lot out of science and engineering and should be allowed back in, Alan Fechter, also a systemic reform advocate, proposes an "aquifer, a system of water underground that flows from various places to other places, and it comes from many places. The point is that the educational system is not the only source of talent." (Fechter 1995:10) Fechter also claims that efforts should be made to bring students into science and engineering from the most unexpected places. Hence, he proposes a metaphor that would reflect these efforts: "Another alternative is the cultivation model where you take an entire set of resources, minerals, oil, or whatever and you cultivate. If you don't find resources [where you expected], you look for nuggets in places where you don't expect to find them and you work with them." (Ibid:13)

To sum up, the pipeline metaphor maybe lost credibility after the 1993 questioning of PRA's numerical projections, but it still persists as the preferred way to conceptualize and even criticize education. Systemic reform advocates are struggling to find a metaphor to achieve consensus for their programs and policies. Actually, this struggle between the pipeline and systemic reform advocates reflect an ongoing battle to define the limits of what is sayable in America about science and engineering education. However, as we have seen, actors and groups alone do not set those limits. They also have to speak to the
existing image of the nation. In the 1990’s, those who speak to an image of a nation under global competition in need of flexible human resources will more likely be able to set the limits. We have seen how GUIRR is doing that with respect to defining the limits of how research is to be carried out in multinational arenas. Within NSF, it appears that systemic reform advocates are finding the language to invoke this image of nation through the advocates of competitive flexibility. At the same time, the latter are finding in systemic reform the mechanisms to achieve a nationwide dissemination of their curricular reforms. Both are teaming up to develop the flexible intellectual capital that the U.S. needs for global competition.

**Systemic flexibility?**

On July 1995, NSF sponsored a workshop on "Systemic Engineering Education Reform: An Action Agenda" aimed at achieving consensus among industry, government, and academia leaders on the need for institutionalizing and disseminating curricular changes achieved by the first groups of Coalitions throughout all U.S. engineering schools by means of systemic reform. (Peden, Ernst, and Prados 1995) This workshop is a clear example of how advocates of competitive flexibility are endorsing systemic reform to achieve comprehensive institutionalization of new curricula such as the one developed by the Coalitions. During the workshop, engineering leaders from NSF, industry,
and academia defined the "challenges and opportunities" (the problem) that
today's engineering students will face in the 21st century as follows:

The shift from defense to international competition as a major driver for
engineering employment:opportunities offered by intelligent technology to
be more creative and "work smarter;" an expanding social infrastructure
that demands a talent for complexity; an eclectic, constantly-changing
work environment, calling for astute interpersonal skills; and massively
integrated populations placing environment, health, and safety at the front
end of design will require engineers whose intellectual skills include, but
extend well beyond, the traditional science-focused preparation that has
characterized engineering education since World War II. (Ibid: 1)

Once again, who defines these demands (the problem) and how they will be
addressed in the content and delivery of curricula (the solution) will determine to
a great extent how selves in science and engineering are shaped by means of
future curricular reforms. Apparently, all the groups represented at the
workshop (government, industry, academia) participated equally in the definition
of the problem. However, institutional changes taking place at NSF can tell us
more about the distribution of power in the definition of the problem, its
solutions, and hence the shaping of future selves. For example, John Prados,
former president of the Accreditation Board for Engineering and Technology
(ABET), was hired by NSF to align ABET's accreditation criteria with the new
demands for flexibility in the engineering curriculum. He is now NSF's Senior
Education Associate in charge of supervising the EEC's. Prados came to NSF
to align ABET with the new image of the nation under global competition. In the
past, industry and engineering schools have criticized ABET for resisting change towards flexibility in the curriculum by trying to protect Cold War criteria which focused on analytic skills obtained through basic and engineering sciences. They want ABET to respond to the new needs of the nation. In the words of a senior manager at NSF: "Prados came to NSF to change ABET from an organization that used to be seen as a barrier to the development of engineering education into an organization that becomes the catalyst for new change in engineering education." But who wants ABET to become a catalyst for these new visions of engineering education? Prados explains to me how corporate America is defining the demands for flexibility, the "new paradigm" as Prados calls it, and, through ABET, ensuring the dissemination of corporate demands into engineering schools. Using Boeing as an example, he says:

Boeing is trying to do two things. First of all, to make sure that they have a common understanding within the company of what they're looking for. And then to make sure that the schools understand it. They let this to be known and try to identify some partner schools which are going to be their major target schools for recruitment.... And then they will say, "if you turn out graduates who can do this, you can keep being one of our partner schools. If not, we will look else where"...Eventually ABET will focus entirely on what you might call "outcome-driven accreditation process" [with] characteristics very similar to the characteristics that Boeing puts in their list. (Prados 1995)

But how is ABET, an accreditation board still using criteria and evaluation mechanisms from Cold War curricula, going to ensure "outcome driven accreditation process" for the needs of global competition? it appears that

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through people like Prados, ABET will adopt evaluation mechanisms from systemic reform and curricular criteria from the Coalitions. As we have seen, systemic reform emphasizes on outcomes, measurement, and evaluation of student performance, ensured by a system of policies, governance and resource allocation. Through dissemination of its outcome-driven assessment metrics, systemic reform could help ensure that companies like Boeing get the kind of student they want from any engineering school in the nation. Advocates of competitive flexibility initiatives are beginning to embrace systemic reform as the mechanism to carry out national dissemination of assessment criteria to ensure proper implementation of new curricula changes such as those developed by the EEC’s. Prados tells us how the Coalitions can and will benefit from systemic reform:

The Coalitions have the potential, certainly, of making some major contributions. However, they got problems...[if] you are trying to generate sustainable systemic reforms, to devise workable strategies, to support diversity and linkage goals, you’ve got to demonstrate... and this is one thing that people are having great difficulty doing: setting up valid metrics to show that the things you are doing are indeed producing the effects that you say you are trying to produce. The sorts of things that you are trying to assess are not simple knowledge kind of things that you can assess on a true false, or multiple choice test [such as] a standardized test. You are trying to assess much higher order skills, and so you tend to move to things like evaluations of portfolios. You are trying to assess whether the students are really developing the skills you want them to. But it’s a very complicated process, and all the coalitions are struggling with that. (Ibid)

Systemic reform advocates also embrace competitive flexibility in their
efforts to educate and train America's workforce for the 21st century. Systemic reform envisions a fundamental transformation of America's workforce by having an impact on the 95% of non-elite students that NSF has traditionally neglected. When I asked Shirley Malcom, nowadays an advocate of systemic reform, if as part of its grand vision of completely transforming the educational system, systemic reform also aims at instilling flexibility in the general workforce, she said:

Absolutely!! We absolutely have to have the people who are able to respond to the changing requirements of the global marketplace. They have to be able to deal with issues such as customization, working smarter, etc....they are going to have a different job in five years whether they stay on the same job or if they move...The technology basically affects and permeates the structure of all work... Systemic reform holds out a new goal for everyone, a basic level of literacy in science, mathematics, and technology, that gives them a foundation for further life-long learning, and for further training in jobs where that are being affected by science and technology. (Malcom 1995: 12)

Alan Fechter's statement in the opening quote of this chapter neglected in the mid-1980's when the needs of the nation were those of producing large number of scientists and engineers, shows that since the mid-1980's some have perceived the demand for human resources flexible enough to adjust to new forms of capital formation. As David Harvey (1989) reminds us, these new forms of capital formation "rest on flexibility with respect to labor processes, labor markets, products and patterns of consumption. [They are] characterized by the emergence of entirely new sectors of production, new ways of providing
financial services, new markets, and, above all, greatly intensified rates, commercial, technological, and organizational innovation." What neither Fechter nor Harvey told us in the 1980's is how flexible workers will be educated and trained. It appears that NSF education programs based on systemic reform, as the mechanism for dissemination and institutionalization, and on competitive flexibility, as the content of curricula, are current examples of how flexible selves in science and engineering will be educated for new forms of capital formation.

Flexible selves for global competition: genderless/colorless performers or re-engineered gender/racial identities?

One of the most important aspects of systemic reform is that it intends to redefine categories of potential scientists and engineers, from groups based on gender and race to groups based on performance, thereby disempowering population groups created by the pipeline studies of the 1980's. Aiming at reforming all parts of the educational system simultaneously, systemic reform is a significant departure from the pipeline framework which only considers the limited population group on the path towards scientific and engineering careers. Systemic reform criticizes the pipeline for basing policy and practice on the "innate ability" paradigm, hence, "often [making] judgements about children...on the basis of educationally irrelevant criteria, including socio-economic status,
ethnic group, and gender" (NSF 1994: 55). Systemic reform shifts the focus from these "irrelevant" criteria to "performance" criteria between disadvantaged and advantaged students, irrespective of their gender and ethnic group. If performers, regardless of gender and race, will be supplying science and engineering workforce, an understanding of this new economy of performance is critical for those groups that gained access to science and engineering education as underrepresented groups based on gender and race. If, as we have seen, there is the possibility of corporations like Boeing determining what counts as performance criteria, what are the implications of these criteria for women and minority groups who are now in the pipeline?

We need to ask similar questions about technoscientific literacy which is considered an essential element of systemic reform and has become one of the measuring sticks of economic competitiveness. Evidence of this is the emergence of the new *Indicators of Science and Mathematics Education* at NSF under a separate cover from the traditional *Science and Engineering Indicators*. These new indicators "address, in more detail than any other report, the progress made towards the U.S. national goal of ranking first in the world in mathematics and science by the year 2000." (NSF 1992) Technoscientific literacy has been defined under systemic reform as flexibility in using one's skills to apply technoscientific knowledge in different contexts. As Daryl Chubin points out:
Literacy is not a matter of what you know, it's a matter of what kinds of skills you have that would allow you to apply knowledge that we would call math and science knowledge in this context and be able to apply it in another context. So in that sense it does become a work skill, becomes a competency. And we don't measure that very well, by the way, as you know, most of our literacy measures have to do with what is DNA?... what we need to be able to measure is how people use the content that comes out of science and mathematics. And do they understand the processes involved and how you get that knowledge, and how you refine it, and advance it... (Chubin 1995: 5)

If measured achievement in this kind of literacy or just-in-time skill deployment, not gender and race, determines your access to the science and engineering workforce, will systemic reform disempower those underrepresented groups that the pipeline of the 1980's empowered? If metrics and assessment, as required under systemic reform, determine your level of achievement, do these evaluation tools shift power away from recruitment and retention efforts towards systemic reform experts who set the standards? Would experts such as those at the Office of Systemic Reform at NSF or at the National Science Education Standards at NRC be setting performance standards for access to science and engineering? Or would women/minority program administrators continue to influence who enters science and engineering programs at U.S. colleges and universities?

One of the ironies of the pipeline of the 1980's is that although it aimed at promoting economic competitiveness, not equal opportunity, women and minorities groups wanting access to science and engineering reaped most of
the benefits of the pipeline industry. As a result, the pipeline of the 1980's became an instrument of power for those groups, such as National Association of Minority Engineering Program Administrators (NAMEPA), that became committed to the diversification of U.S. scientific and engineering institutions by means of recruitment and retention efforts.

If systemic reform creates new statistical groups to supply the science and engineering workforce based on educational performance and levels of technoscientific literacy then it will disempower those groups that the pipeline of the 1980's created. An understanding of the consequences of this power shift in the formulation of educational policy is essential for those groups that are committed to the diversification of our scientific and engineering institutions.

We have seen the struggle between pipeline and systemic reform advocates within NSF. This struggle has extended beyond NSF into national forums on science and engineering education for underrepresented groups. Tensions already exist between those who made their careers in the pipeline industry and those who advocate systemic reform. Referring to her appearance at the 1994 NAMEPA conference "Partners in the Pipeline" where she advocated systemic reform to an audience of administrators of minority programs in U.S. colleges of engineering, Shirley Malcolm described the audience's negative reaction as

fear because they don't know what it means to lose the minority tag...
they don't think that they would be the first people consulted about how to make things work for everyone. They might be right, but I think that the question they have to ask themselves at some point is: is this about my job? Or is this about this effort?...these programs [MEP's] are unlikely to remain in this kind of environment...I would hope that they basically start to become offices of student support and instructional improvement...They don't understand that their value is even greater [under systemic reform]...they are the ones who have a better sense of the problems and possibilities. (Maicom 1995: 16)

But as U.S. Secretary of Education Riley reminded us, it is not clear yet who will be setting the standards, organizations like NAMEPA or systemic reform experts such as those at NSF?

Increasing recruitment and retention efforts at colleges and universities have become problematic at a time when industry is downsizing and restructuring its workforce. The emphasis industry is placing on flexible modes of production, which includes downsizing, instead of recruitment efforts, can already be seen in competitive flexibility programs at NSF. For example, the Coalitions have emphasized the making of flexible engineers over their recruitment and retention goal. A senior advisor to the assistant director for engineering at NSF confirmed this. After the "wrong message got out" in the early 1990's when NSF and universities were still focused on the pipeline problem --i.e., recruitment and retention of women and minorities-- instead of curricular reform, he claims that now the Coalitions "got it right"

They are now pursuing diversity as it pertains to what their main objective is which is to reform the curriculum... What they are doing is
"just-in-time" education from the Japanese "just-in-time" factory thing. Number one [restructuring the engineering curriculum] comes first, and number two is while you are doing that keep an eye on the diversity issues.

This redefinition of the Coalitions from both flexibility and diversity in 1990 to only flexibility, nowadays when global competition calls for flexibility and downsizing, shows how the new needs of the nation have permeated into program criteria at NSF. While the first four Coalitions founded in 1990-1992 (ECSEL, SYNTHESIS, SUCCEED, GATEWAY) emphasized both curricular reform towards flexibility and increasing the representation of women and minorities in engineering, the most recent Coalitions illustrate a shift towards flexibility and away from recruitment and retention. For example, the Academy Coalition (circa 1994) aims at "Integrating Manufacturing Concepts in the Curricula for All Engineering Disciplines." The Greenfield Coalition's (circa 1993) theme is "A Coalition for New Manufacturing Education." The SCCEME Coalition (circa 1994) focuses on "Developing a Comprehensive System of Inter-university Programs of Undergraduate Manufacturing Engineering Education." (NSF 95-62)

Through criteria for new educational programs, global competition also defines criteria for a new kind of self. After explaining to me how global competition put new emphasis on flexible curricula, Prados tells me how flexibility has become a marketable skill in today's job market:
...in the post Cold War there is a change again in the driving forces for engineering education. There is a great deal of emphasis now on, among employers at least, trying to develop structures that will make them more competitive on the international markets, so now there is more emphasis and focus on teamwork, communication, external constraints on design, continuous improvement...that's the context into which this is taking place...In a tight job market, engineers who have skills that follow this new paradigm are more likely to be employable. They will have a competitive advantage. (Prados 1995: 19-20)

So what are the skills that global competition requires students to develop?

What kind of student is competitive flexibility trying to produce? Referring to a process known as "Continuous Quality Improvement", Willenbrock can only give us a hint as to how systemic reform and competitive flexibility programs can ensure the kind and quality of the product --the flexible student-- that corporations want nowadays. However, he is unable to give us a complete picture of such a student:

...what has happened is that a bunch of companies have beat on universities and said, "we want people who can work in a new sort of environment." They beat on engineering schools and business schools, particularly. One of the fellows who was sort of a crusader here was David Kerns, CEO of Xerox at the time...They decided, "well, we have a different work environment in our companies than we had before...we need our employees to work quite differently. We need different people coming in"....[so] NSF, operating as a lever, [has] in its curriculum development program announcements, "we want change...we want systemic reform of the undergraduate curricula...a curricula that is more sensitive...to engineering as it is currently practiced, to the current industrial scene"....The industrial community, both manufacturing and service sectors, ...they need a different type of person... (Willenbrock 1995: 16)

Maybe we can look for representations of this flexible self in present calls
found in popular and academic media to redefine students around global
competition. For example, in a special issue of Graduating Engineer magazine
devoted to minorities, Edward Valdez, an MIT-trained hispanic engineer at
Motorola, encourages Hispanic engineers to "re-engineer" their image to fit the
new realities of corporate America. He says

In the case of re-engineering the image of Hispanics, we must
differentiate ourselves. The best products differentiate themselves from
other products in the marketplace. That's why advertising is so crucial.
They seek to identify the key competitive advantage. We can view
ourselves as a product and ask the question, 'What is my key
competitive advantage?' (Valdez 1995)

Also, in a recent issue of Black Enterprise (BE) magazine focusing on how BE's
100 companies are making inroads into the global market, the cover article
emphasizes that successful companies have channeled the characteristics of
their workforce into the marketing and selling of their products: "BE 100s
companies are trading on their inherent edge -- their ethnicity." (Black
Enterprise 1996) A re-engineered ethnicity is not the only trait that corporate
America is looking for in their global workforce. They are also looking for people
with so called "multicultural competence." For example, a recent article of
Careers and the Engineer (1995) dedicated to globalization reports that "our
workplaces are becoming diverse, multicultural environments that demand
tolerance and teamwork." The article quotes a corporate vice-president stating
that "we need a workforce that mirrors the international scope of our sites and
the international character of the global customers we work for. We can’t do this with culturally homogenous teams of professionals."

Ibid: 36) Furthermore, the article cites a RAND Corporation study titled Global Preparedness and Human Resources: College and Corporate Perspectives which found that "the need to understand and interact with individuals from different cultural backgrounds has become increasingly location-independent...[companies] have moved to make diverse workgroups a part of the way they do business everywhere." (quoted in Ibid) So what does this multicultural person look like? The same article provides an example of an engineering student who after an international internship and study abroad came to identify herself with several distinct cultures. She summed up her experiences by saying, "I had always considered myself sort of a cultural misfit. That is to say, I craved the opportunity to belong to any and all cultures other than my own. Now, after working in different parts of the world, I realize that I am a culture all my own. My culture is the sum of all of my experiences. I am Italian, Swiss, Spanish, Norwegian and American." (quoted in Ibid) To reproduce this kind of student, NSF is already sponsoring the Global Engineering Education Exchange program.

We have seen how both systemic reform and competitive flexibility are becoming integral parts of the same objective, that is providing the nation with the technoscientific workforce for the 21st century. We have seen how both reconceptualize the making of scientists and engineers around the problem of
global competition and have redefined categories established by the pipeline. Systemic reform redefined categories based on race and gender into new ones based on performance. Competitive flexibility redefined race and gender from demographic potential that could contribute numbers to the pipeline into race and gender as flexible potential that could be exploited to reach broader markets in a global economy. Together they redefine women and minorities in science and engineering, not according to the domestic social problems they can solve, or for the number of bodies they can contribute to the pipeline, but for what they can sell in global markets where their counterparts are the customers. Sadly enough, if in the 1970s, as Malcom told us, "you are what gets studied," maybe in the 1990's we can say "you are what gets sold in the global markets."

Conclusions

In the 1990's a new discourse about the nation is emerging. Global competition between the U.S. and its Asian and European competitors has become the most dominant narrative to describe images of the nation. NSF's mission is already being redefined around a new image of nation that calls for internationalization and flexibility in the creation, dissemination, and application of technoscientific knowledge. Within the narrative of global competition, flexibility emerges as the most desirable characteristic for the future.
technoscientific workforce to have. Theorists in academia, media, and NSF have begun to define flexibility in terms of integrating "just-in-time" skills, including multicultural/national understanding, to create knowledge as well as to identify and solve problems in any global setting.

With a new image of nation calling for a flexible workforce to compete globally, two new visions of education have emerged at NSF which aim to develop flexibility in U.S. scientific and technological workforce for the 21st century: systemic reform and competitive flexibility. With the pipeline rapidly losing its authority as certified knowledge, but as a metaphor, these new visions are finding space within NSF to become the models that will guide education and human resources in science and engineering for the years to come. In addition, with the discourse of global competition calling for fiscal responsibility, these two new visions, and their advocates, have come together into a marriage of convenience. For example, the Coalitions find in systemic reform the mechanisms to disseminate and institutionalize curricular changes, ensuring a nationwide quality of flexible students. Through nationwide dissemination, the Coalitions can justify how their huge initial investments ($200 million in five years), localized in few sites, will benefit the overall population of engineering students. On the other hand, as an offspring of the Goals 2000 educational initiative, systemic reform is encountering increasing resistance in a conservative Congress. However, by ensuring the dissemination of competitive
flexibility efforts, systemic reform at NSF finds the legitimation it needs to ensure its existence. Both initiatives are redefining the categories the pipeline created, from gender and race to performance and flexibility.

The flexible self that these new initiatives are trying to create is not defined along its ability to solve social and environmental problems, nor its gender and racial characteristics. The new flexible self is defined according to its ability to help the U.S. create and conquer new markets in a global economic space.
CONCLUSIONS

The making of policy for making scientists and engineers at the National Science Foundation is a history of national culture. We have seen how cultural images of nation are constructed and invoked again and again by social actors during the processes of their effort to make policies and programs to educate and train scientists and engineers. Hence, what we understand for "scientist" and "engineer" at any particular time is inseparable from these images of nation. At the same time, when the national narratives that develop from time to time position scientists and/or engineers as saviours of the nation under threat, the images of scientific and technological selves become integral parts of what we understand as American nation. Nowhere is this two-way cultural relationship between nation and technoscientific selves more evident than around the policymaking processes at NSF.

Images of nation in science and technology policymaking

We have seen that as discourses emerge and become a contested space, groups and actors rush to define images of nation, national problems and solutions. The appropriation of this space, particularly as it relates to the making of scientists and engineers, takes place through claims made by actors and groups in the media, forums, and official statements. We have seen that
the success of these claims in setting the limits of what is sayable and acceptable in the education and training of U.S. scientists and engineers depends mainly on two factors. First, how well the claims resonate or speak to the dominant narrative about the nation. Second, the positions of groups and actors making these claims relative to established locations of economic and political power.

NSF and the making of policy

Throughout the last 15 years, NSF has increasingly become an actor that appropriates national narratives and defines images of nation in need of specific kinds of science, technology, scientists, and engineers. NSF has evolved from a responsive role in the 1960s, when actors like James Conant used it as a mechanism to materialize their visions for quality science education, to a maker of national images through its sources of certified knowledge such as the science and engineering pipeline. The pipeline is one of the most dramatic examples of how NSF constructed an image of a nation in need of recruiting and retaining thousands of scientists and engineers to beat Japan in the competitiveness race. More recently, NSF is constructing images of an American nation being challenged by the scientific and technological resources of Pacific Rim competitors¹ or by the "cognitive achievement" of Western

¹ See for example, NSF's (1993) Human Resources for Science and Technology: The Asian Region
European students.\textsuperscript{2} If 40 years ago the media relied on pictures of Sputnik and interpretation of the events by influential scientists to show the American public how the Soviet threat looked like, today the media relies on NSF’s images of the nation and interpretations of the technological threats from other industrialized nations to tell Americans how the latest Asian and European threats look like.

But more than a builder of national images, NSF has emerged in the last four decades as an institutional solution to the political and economic problems of supplying scientists and engineers required for specific notions of nation. In the 1960’s NSF responded to specific calls for top quality scientists and second rate scientists and engineers to save the nation from the Soviet threat. In the 1970’s, NSF resisted calls for applied scientists from a nation plagued with domestic problems, but, after continuous pressure, it eventually came to address those calls. NSF recognized women and minorities as significant categories of scientists capable of solving some of the nation’s problems that white males could not solve. In the 1980s, NSF provided the institutional mechanism to help produce the large numbers of scientists and engineers required by a nation under economic threat from Japan. Here, NSF made women and minorities in science and engineering significant categories for

\textsuperscript{2} See NSF’s (1992) Indicators of Science and Mathematics Education, especially the section on International Mathematics and Science Achievement. Although four or seven countries of the Pacific Rim are seen as significant competitors in most economic indexes, Japan is the only Asian country included in the cognitive achievement comparisons.
economic competitiveness. In the 1990s, NSF is coming up with institutionalized programs and policies to provide flexible scientists and engineers required by global competition.

To accomplish the task of producing scientists and engineers for national needs, in both appropriate numbers and characteristics, NSF constantly redefines its education and projection models according to the image of nation it is trying to provide for. We have seen how in the 1960s both education and manpower studies program embodied a notion of nation to be saved by top-quality scientists from the Soviet threat. In the 1970s, after long resistance from its administrators, NSF incorporated in its education and manpower programs an image of nation in need of mobile scientists to solve social and environmental problems. In the 1980s, NSF's education programs and the pipeline contained an image of nation in need of lots of scientists and engineers capable of technological innovation to beat the Japanese in the competitiveness race. More recently, NSF is including in its education programs a notion of nation in need of flexible scientists and engineers for global competition. Proponents of old and new visions of education are still struggling to define the metaphors and projection models for the 1990's and beyond.

It is not my intention here to assess the success of NSF's programs in education and human resources. Some could argue that NSF was successful in helping create the scientists and engineers that produced national triumphs
such as Apollo. Others could argue that it failed in its mission of producing the required scientists and engineers for, after all, the Japanese still dominate the automobile and electronic markets. My intention, though, is to argue that, given its instrumental role in the making of selves and knowledge in science and technology in the last 45 years, NSF should be included in any contemporary STS account dealing with the construction of knowledge and persons in science and technology in the U.S.. For STS, the importance of NSF extends beyond its instrumentality as an institution responding to specific national needs in science and technology. One of the most important aspects of NSF is its unique location within the structure of political power where official knowledge about science and technology resources is constructed, shaping the direction of all kinds of federal policies. What NSF says about the education and training of scientists and engineers affects immigration, tax, and, of course, educational policies.

**NSF and the making of selves**

Recent analyses of the making of selves have shown mainly two dimensions of this process: "the shaping of the private self" through the interaction between technologies of government and individuals (Miller and Rose 1993; Barry, Osborne, and Rose 1993; Burchell 1993; Rose 1993; Rose 1990; Cruikshank 1993); and the fashioning of "cyborgs" through the interactions between humans and machines (Downey et al 1995, Gray et al
1995). My analysis of science and engineering education in the U.S. during the last 40 years shows still another dimension in the making of selves: the making of selves in science and engineering for time-specific notions of the Nation.

Through its education programs, projection models, and data-gathering techniques, NSF has constructed images of selves that have come to rescue the nation from different threats: highly scientific selves for a nation under threat by Soviet science, mobile interdisciplinary selves for a nation under threat by its own domestic problems, selves for technological innovation for a nation under threat by Japan's technological success, and flexible scientists and engineers for a nation engaged in global competition. Through the making and dissemination of these images, NSF has shaped what we understand for "scientist" and "engineer" in the U.S. during the last 40 years of national life.

We have seen that in defining national problems and its solutions, groups and actors including NSF, usually call for specific characteristics or traits in the science and engineering workforce. In the 1960's, scientific academism called for "quality." In the 1970's, advocates of applied science for national needs called for "mobility." In the 1980's, corporate and academic technophiles called for "technological innovation" embodied in large numbers of scientists and engineers. In the 1990s, corporate America and NSF are calling for "flexibility." Within these traits, underrepresented groups, such as women and minorities, have found and created space for participation in science and engineering. This
is what happened in the 1970s when "mobility" provided the opportunity for women and minorities to claim their participation in the solution of national problems. With the help of powerful actors like Senator Edward Kennedy, they pushed NSF to recognize them as categories worthy of budget allocations in science education. In the 1980s, when NSF defined the problem of human resources for competitiveness as a matter of numbers and recognize the demographic potential of underrepresented groups, women and minorities claimed that they could contribute numerically to the solution of this problem. More recently in the 1990s, while corporate America and NSF are calling for "flexibility" as the workforce's most desired trait, groups of different ethnic and racial backgrounds are beginning to find space in a global economy where such backgrounds might be part of what is understood as "flexible."

Recommendation for STS

The concept of nation as a construct and constructor

Most of the attention in constructivist STS case studies has been on defining relevant social groups and looking at the process of negotiation until closure is reached. However, future STS research must pay attention to the concept of "nation" as an important element in the construction of knowledge,
artifacts, and people. Throughout this dissertation, we have seen how groups invoked images of nation to ensure participation in the definition of problems and solutions through science and technology. We also saw how notions of nation shaped the different manpower projection models that NSF used for different national needs. We need further research to understand how notions of nation also shape the content of other areas of scientific knowledge. On the other hand, we also need to focus on the concept of nation as a scientific construct, as it is the case with scientific notions and modelling of the nation that emerge from NSF.

Economic competitiveness as a problem for STS

Unfortunately, economic competitiveness, and in particular its reliance on science and engineering, has been ignored as an area for STS analysis and critique. One of my goals in this dissertation has been to open a window for critical intervention into the narrative of economic competitiveness by exposing its influence on education and human resources programs in science and engineering. By looking at how NSF redefined itself around economic competitiveness in the 1980's, I shed light onto one way in which economic competitiveness has redirected the funding of science and technology. However, we need to understand better in which ways economic
competitiveness determines what counts as valid areas of research, how research is done, where research is done, and who are considered legitimate partners in the process of knowledge production and dissemination.

We should not, however, view economic competitiveness as just one more narrative among many. I believe that it has become the most dominant expression of recent changes in capitalism. Hence we need politically engaging theoretical and methodological frameworks that help us locate it in today's global capitalism and that allow to critically intervene in it. Unfortunately, STS, with its overdependence on social constructivism, lacks such a framework. I have found historical-geographical materialism as proposed by David Harvey (1989) particularly inviting as a framework to help us understand how recent changes in capitalism, including the emergence of competitiveness as narrative within ongoing changes from Fordism to flexible accumulation, affect education and human resources in science and engineering. I believe this framework provides important conceptual and methodological advancements over constructivism. For example, it helps us theorize how quantitative and qualitative changes in modes of production translate into quantitative and qualitative changes in the education and training of scientists and engineers. Also, it will help me bring a class dimension to my future research as I explore how flexibility means different things for different classes. STS should devote more attention towards the processes of making flexible selves, for it will be in
the making of these people where the knowledge and power dimensions of science and technology education will be played out in the future.

Equally important for STS is to understand redefinitions of what counts as valid knowledge brought by rapid changes in flexible modes of production and consumption. Current emphasis by government and industry on flexible curricula in science and engineering already reveals a departure from Cold War curricula based on basic scientific concepts and analysis. However, we need to understand how flexibility shapes the knowledge content of areas such as biology and physics. In sum, historical-geographical materialism, contrary to constructivism, brings the structural dimensions of capitalism development to the forefront. It reminds us that after all, education and human resources in science and engineering are embedded in a capitalist structure.

The making of selves as a cultural/political problem for STS

STS needs to look more carefully at cultural studies. Not only does cultural studies provide us with conceptual and methodological advancements over constructivism in the understanding of cultural representations, but it also contributes to reinvigorating the political project of the left by questioning the politics of cultural hegemony in representation. The story in this dissertation reveals how science and engineering education in the U.S. has been a captured space by the cultural hegemony of a mostly white-male-middle class
while the "other" has remained for the most part marginalized. My use of
cultural studies, although minimal, helped me understand not only how
representations of the nation are constructed but, more importantly, how they
are used to marginalize or bring the participation of underrepresented groups.
Further research is needed to shed light onto the institutionalization of policies
and programs in science and engineering education under the banner of the
nation which have been for the most part discriminatory on the basis of gender,
race, and class. For example, why did the federal government fail to implement
programs to bring women to participate in the "Age of Science" when there was
overwhelming evidence (DeWitt 1955, 1961) that 50% of all Soviet scientists
and technologists were women? I have provided a partial answer by showing
how scientific academism defined the problem of education in terms of quality
instead of numbers. As such, the numerical superiority of the Soviets, even if
made up of women, was not the driving factor that shaped science education
programs in the 1960s. Hence, American women, even if they could provide
lots of potential scientists, were not invited to participate in quality-oriented
programs. My research of popular media found images of women
conceptualized as passive consumers of labor-saving devices, embodying the
values of the "American Way of Life" of the 1950s, participating on the civil
defense programs against communist expansion. This is how media depicted
images of women carrying out their civic duties and patriotic responsibilities.
Still, we need further research into the role that government assigned to women in other areas of the "Age of Science" such as the massive efforts under the National Defense Education Act of 1958. Similarly, more research needs to be done to further explain the reluctance of the federal government to include working classes and racial minorities in the efforts of the "Age of Science" when congressional hearings on Soviet technoscientific education revealed significant contributions of different racial and economic groups to the Soviet scientific success.

STS must also look into post-Foucauldian studies on governmentality in order to understand how the management of populations, especially those made of technoscientific experts, have become one of the most important issues of modern governance. By looking at the history of the development of technologies of government, such as those developed at the NSF, and by analyzing how they have helped government, industry, and academia visualize, inventory, normalize, and correct populations of past, present, and future technoscientists, we gain new understanding into the knowledge/power dimensions in the making of scientists and engineers in contemporary liberal democracies. For example, this approach can bring to the surface the knowledge/power dimensions in the reconfiguration of gender and race categories in education as surveillance mechanisms are implemented as early as kindergarten in the educational pipeline. The construction of gender and race
as categories in science and technology is an important area for further STS research, for it highlights how images of nation, science and technology, shape selves at the same time that it discloses power relations among those in policy making position and those being shaped by policies and programs. Some STS scholarship has come to include gender and race dimensions in the construction of knowledge and artifacts (Cowan 1983, Wajcman 1991, Longino 1989, Haraway 1991). With some exceptions (e.g., Harding 1993, Hacker 1990), it has not dealt with the construction of these categories in science and technology. Furthermore, we have seen how race and gender categories in science and engineering education have not remained fixed in time. As notions of the nation change, categories of gender and race in science and technology also change. For example, categories which remained invisible in the 1960s emerged as significant categories for domestic national problems in the 1970s, and re-emerged differently as categories for economic competitiveness in the 1980s. It remains to be seen how they will re-emerge in the 1990s as categories for global competition.

Further questions need to be explored on the consequences for women and minorities becoming recognized as significant categories in science and technology. Even when the economic benefits for these groups after gaining access to science and engineering seem obvious, women and minorities have to begin asking themselves about the political, social, and cultural
consequences of being categorized as a significant categories in science and engineering, especially if science and engineering are defined under the umbrella of economic competitiveness. Referring to the shift in arguing for the inclusion of women in science, from the 1970s to the 1990s, one feminist scholar recently stated in a conference on Women in Science and Engineering: "we did the social thing [in the 1970s] and it did not work. Now [in the 1990s] we are doing the economic thing." A similar attitude of "whatever works" is taken by minority program administrators at national conferences. This attitude reflects how women and minorities in science have dealt unproblematically with the significance of their numerical representation in the pipeline. The question is still more pressing now when women and minorities are being reconceptualized one more time, not for what they are entitled to, nor for the number of bodies they contribute to the pipeline, but for what they can sell in markets where their counterparts are the customers.

We also need further research on the differences between women and minorities in their attempts to be included in science and engineering. For the most part, we have assumed that the efforts of women and minorities to participate in science and engineering have been unified and concerted, without conflict and differences among themselves. However, we began to see how in the 1970s their political strategies were different as were their perceptions of social problems. Regardless of these differences, they were lumped together in
the Science and Technology Equal Opportunity Act of 1980. We need to further research those conflicts and differences. In the 1980s as their presence in science and engineering increased so did conflicts among themselves.

Examples of these differences are reflected in organizations like NAMEPA which for the most part have remained committed to programs targeting African Americans without commitment to programs for white women and other racial minorities. Similarly, organizations of and efforts for women in science and engineering have remained mostly for white women. Are these differences and disputes merely a reflection of contestations for other spaces in society such as participation in government or corporate structures? More importantly, are these differences and disputes hindering efforts to democratize science and technology? And if so, what sorts of concerted efforts should be made between these and other groups to increase participation not only in the creation and diffusion of scientific knowledge but in the policy making that shapes both knowledge and selves?
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VITA
Juan C. Lucena
Science and Technology Studies Program
Center for the Study of Science in Society
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0247

EDUCATION

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Dissertation: Making Policy for Making Selves in Science and Engineering: From Sputnik to Global Competition

Committee: Gary Downey (chair), Ellisworth Fuhrman, Steve Fuller, Richard Hirsh, Langdon Winner

M.S. 1990 Rensselaer Polytechnic Institute (STS)
B.S. 1988 Rensselaer Polytechnic Institute (Mechanical Engineering)
B.S. 1987 Rensselaer Polytechnic Institute (Aeronautical Engineering)

EMPLOYMENT

1995 - 1996 Lecturer and Teaching Assistant
"Engineering Cultures", HST/STS Program
Virginia Polytechnic Institute & State University

1991 - 1996 Researcher and Staff Director
Engineering Curriculum Project (NSF sponsored grant, $210K)
Center for the Study of Science in Society
Virginia Polytechnic Institute & State University.

1990 - 1991 Assistant Program Manager
Division for Engineering Infrastructure Development
Directorate for Engineering
National Science Foundation, Washington, D.C.

1989 - 1990 Science and Technology Professional Assistant
Ethics and Values in Science (EVS) Program
National Science Foundation, Washington, D.C.

1988 - 1989 Graduate Research Assistant
STS Project on University/Industry/Government Research
Department of Science and Technology Studies
Rensselaer Polytechnic Institute, Troy, NY
PUBLICATIONS


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