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Democratization of Ocean Research: A Model for the Post-Cold War Era?

Maureen A. Kennelly
University of Rhode Island

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A Model for the Post-Cold War Era?

by
Maureen A. Kennelly

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Abstract

Since the end of World War II the field of oceanography has enjoyed the generous patronage of the federal government under the "social contract" model for the support of science. This model is based on the principles of freedom and autonomy for scientists, insulation of science from politics, and emphasis on basic research. With the recent ending of the Cold War, the simple science policies of the post-World War II years are being philosophically and politically challenged and the rationales for the support of science are being questioned. National security is no longer the driving force behind science funding in the United States. With a heavy dependence on the federal government for support and strong roots in the Cold War, oceanographic science is particularly vulnerable at this time to shifts in national priorities. Calls have been made for the negotiation of a new social contract between scientists and the federal government. In this paper a model for a new social contract is suggested based on the democratization of science. Indicators of democratization are presented and data relevant to the oceanographic field are analyzed. It is concluded that a shift is underway toward the democratization of academic oceanography in the United States in the post-Cold War era.

Acknowledgments

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Thank you also to my parents. You provided my with the drive to follow my dreams. I only wish my father, now stricken with Alzheimer's disease, could read these words and know of my deep appreciation and love.

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List of Acronyms

AAAS	American Association for the Advancement of Science
ARCSS	Arctinc Systems Science
ATOC	Acoustic Thermometry of Ocean Climate
CoOP	Coastal Ocean Processes
CORE	Consortium for Oceanographic Research and Education
DOD	Department of Defense
DOE	Department of Energy
DSDP	Deep Sea Drilling Project
EPA	Environmental Protection Agency
ESH	Earth System History
GLOBEC	Global Ecosystems Dynamics
IDOE	International Decade of Ocean Exploration
IGY	International Geophysical Year
JGOFS	Joint Global Ocean Flux Study
JOI	Joint Oceanographic Institutions, Incorporated
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
LMER	Land Margin Ecosystem Research
MIT	Massachusetts Institute of Technology
MMS	Minerals Management Service
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASCO	National Academy of Sciences Committee on Oceanography
NOAA	National Oceanic and Atmospheric Administration

NSF	National Science Foundation
ONR	Office of Naval Research
OSRD	Office of Scientific Research and Development
OSRS	Ocean Science Research Section
R&D	Research and Development
RIDGE	Ridge Interdisciplinary Global Experiments
TOGA	Tropical Oceans, Global Atmosphere
USGS	United States Geological Survey
WHOI	Woods Hole Oceanographic Institution
WOCE	World Ocean Climate Experiment

CHAPTER 1. INTRODUCTION

Scanning recent science and social science periodicals, one is likely to encounter pronouncements about the dire situation now facing the science community in the United States. *Physics Today* asserts "Science in the United States is in a time of pain and uncertainty."[1] Recent events such as the end of the Cold War, industrial downsizing, government deficits, and demographic trends have lead to uncertainty about the duration and outcome of the current situation. Although budget difficulties and lack of jobs plague most of the sciences, the atmosphere of uncertainty about the future is different from one discipline to the next. With a heavy dependence on federal funds for support and strong roots in the Cold War, oceanographic science is particularly vulnerable at this time to shifts in national priorities, resulting in increasing stress for many ocean researchers.

Although one could trace government support for ocean research in the United States to the days of Matthew Fontaine Maury (early 1800s), it was not until World War II that significant federal resources were committed to oceanography. Since World War II, important advances in oceanography have been made with federal support, most of which have taken place in the context of pure curiosity-driven basic science, as funded initially by the Office of

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1 S.M. Gruner, J.S. Langer, P. Nelson, and V. Vogel, "What Future Will We Choose for Physics?" *Physics Today*, December 1995, p. 25.

Naval Research (ONR), and later joined by the National Science Foundation (NSF). Much of marine science has been funded implicitly for its perceived military implications. In particular, the existence of a Soviet submarine fleet generated an extensive U.S. antisubmarine warfare program. In support of that effort, the U.S. government used research grants and contracts to transform the small number of tiny, prewar civilian oceanographic institutions into a much larger number of major laboratories, both university-operated and independent. Corresponding to the increase in oceanographic institutions has been a significant increase in the number of ocean researchers. It is estimated that a decade before World War II, American oceanography required fewer than 100 scientists.[2] By 1990, it was reported that there were 1,674 Ph.D.-level oceanographers employed at academic institutions in the United States.[3]

The growth in ocean science following World War II is not unique. Science in general has benefited from the "social contract" model of supporting science which was negotiated between the government and the scientific community following the war. This model is based in large part on the work of Vannevar Bush and the principles enunciated in his now famous and often cited report, *Science*

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[2] W.W. Shannon and D.D. Palmer, *The Federal Funding of Academic Marine Science, Final Report*, (Storrs, CT: University of Connecticut, 1982), p.31.

[3] Ocean Studies Board, Commission on Geosciences, Environment, and Resources, National Research Council, *Oceanography in the Next Decade: Building New Partnerships,* (Washington, D.C.: National Academy Press, 1992), p. 128.

- *the Endless Frontier.*[4] The Bush report was interpreted as suggesting that generous federal support of basic science would lead almost automatically to useful downstream technology which in turn would underwrite an ever-growing standard of living for the American people as well as a strong defense and improved health for the American people.[5] The "social contract" model is based on the principles of freedom and autonomy of scientists, insulation of science from politics, and emphasis on basic research. Moreover, it stresses determination of the direction of science by scientists.

Science, particularly oceanography, has been in a relatively privileged position in the U.S. since the end of World War II. Under the social contract, science has enjoyed the generous support of the federal government for over 50 years. However, the political and economic context has changed from the time at which the social contract was first negotiated. Furthermore, the Cold War is over and national security is no longer the driving force behind U.S. science funding. Thus, the simple science policies of the post-World War II years are now being philosophically and politically challenged and the rationale for the support of science is being questioned. Without national security concerns at the

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4 V. Bush, *Science - the Endless Frontier, A Report to the President on a Program of Postwar Scientific Research*, (Washington, D.C.: Government Printing Office, 1945), 184 pp.

5 H. Brooks, "Can Science Survive in the Modern Age?" *National Forum*, Fall 1990, p. 31.

forefront, economic security and health care are now receiving greater attention.

Policy analysts now maintain that elements of the social contract model are no longer appropriate, such as the insulation of science from politics and elite control of science.[6] To better fit the concerns of a new era, arguments are now being made that a new "social contract" is necessary. Just what form will this new social contract take? It is suggested in this paper that science is becoming more vulnerable to the principles of democracy, i.e., that the new social contract will be based on the "democratization" of science.

This paper will explore the idea of democratization of science as a model for the federal support of academic oceanography in the United States in the post-Cold War era. First, the background of post-World War II federal support of science in the United States will be investigated. Specifically, the "social contract for science" model will be described. Next, the implementation of the social contract in a general sense will be discussed, followed by an examination of its implementation in ocean sciences. Differences between the ocean and general science cases will be highlighted. Next, the changing context for the social contract will be described. A model based on the democratization of science will then be developed. Elements

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[6] D.H. Guston and K. Keniston, *The Fragile Contract: University Science and the Federal Government* (Cambridge: MIT Press, 1993), p. 23-30.

of the democratic science model will be contrasted with the social contract model. Relevant data will be presented to test the democratization of ocean science. Conclusions will be drawn based on the data presented to determine if democratization is an appropriate model for the support of ocean science in the post-Cold War era. Finally, recommendations will be made for the ocean science community for operating in today's social environment.

CHAPTER 2. BACKGROUND ON SCIENCE FUNDING

2.1 Introduction

The event of World War II changed forever the character of U.S. scientific research and its relationship with government. Prior to World War II, the federal government's role in scientific research was relatively limited. The prewar research community was small in size, based largely on private resources and aloof from politics. Wartime and postwar research however, became an enormous enterprise, financed mainly by government and inextricably involved in political processes.

During World War II, scientists were mobilized and given federal funding in support of the war effort. In fact, the federal government became the dominant sponsor of research during the war, funding three quarters of all research by fiscal year 1944.[7] The government contract became an important means of supporting this research. Indeed, between 1940 and 1944 the federal government went from doing most of its own research to contracting out most of it.[8] The contract was important as a funding mechanism in itself and its use established the principle that the government should fund research carried out by non-governmental bodies, especially universities.

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7 D.L. Kleinman, *Politics on the Endless Frontier - Postwar Research Policy in the United States* (Durham: Duke University Press, 1995), p. 72.

8 *Ibid.*

Administering the nation's massive wartime research program was a group of elite scientists, mostly associated with the physical sciences. Prominent among these scientists was Vannevar Bush, who headed the wartime agency of the Office of Scientific Research and Development (OSRD) which coordinated academic and industrial research programs. Based on policies employed at OSRD, Bush and his colleagues helped establish the principle that science should be governed by scientists.

Science in World War II meant radar, sonar, the proximity fuse and ultimately the atomic bomb. In terms of saving lives it also meant blood plasma, sulfanilamide, and penicillin. The success of scientists during the war generated the widespread belief that scientific research was the key to progress, national welfare, and security and should be continued after the war with government support. Moreover, it was obvious to military planners that a permanent revolution had occurred in the relationship of technology to warfare and continuous mobilization of scientific and technical resources became a priority. It was anticipated that future wars would be won or lost by technological superiority, and funding scientists in universities was seen as a relatively inexpensive way to maintain the technological and intellectual basis of military readiness.

Following the war, two opposing views for the organization of postwar science emerged. The first was that advanced by Vannevar Bush and the scientific vanguard. The other viewpoint was that of advocates of a New Deal agenda for science, led by Senator Harley Kilgore.

Bush's views were embodied in his report to President Roosevelt entitled *Science - The Endless Frontier*. Bush used the phrase "The Endless Frontier" to characterize the open-ended process of scientific exploration that would replace the western frontier in the American consciousness.[9] Bush and his scientific supporters advocated a program that emphasized basic research, from which they asserted economic benefits would obviously flow. However, the benefits from basic research would be realized too far in the future for business to undertake. Therefore, Bush asserted that government resources would be necessary to support basic research. Furthermore, Bush maintained that both the civilian and the military needs of the nation would be well served by large investments in university-based research. To administer and coordinate the nation's science program, Bush advocated the establishment of a national research foundation.

Kilgore envisioned a postwar structure under the control of nonscientists and directed toward practical ends. Kilgore's populist view was that the public had a right to the material benefits from publicly funded research. In paticular, Kilgore believed that patent rights from publicly

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[9] B.L. Smith, *American Science Policy Since World War II* (Washington, D.C.: The Brookings Institution,1990), p. 5.

funded research should be given to the government rather than to the individual investigator undertaking the research. Kilgore advocated a program that would directly link scientific research with economic development. Thus, his proposal focused not only on basic research, but also on the transformation of basic research into publicly usable results. Furthermore, Kilgore's proposal called for an equitable distribution of federal resources based on a formula concept following the model of the agricultural research system and the broadest possible circulation of the results of federally sponsored research. Kilgore also proposed the creation of a federal science agency to promote and coordinate basic and applied research.

Science - The Endless Frontier proved to be persuasive enough to deflect the ideas advocated by Kilgore in favor of those recommended by Bush and his colleagues. Although the principles proposed by Bush were not adopted in total, his report set the tone and the boundaries of the postwar organization of scientific research in the United States.

In this chapter, the "social contract for science" model which evolved from the postwar debate over the organization of science, will be presented. Discussion of the implementation of the social contract will follow, first in terms of science in general, then specifically for ocean science.

2.2 "Social Contract for Science"

As the debate over the postwar organization of science continued, the outlines of a social contract for science began to emerge. With blueprints provided by Bush's *Science - The Endless Frontier* and John R. Steelman's *Science and Public Policy*,[10] the social contract between the federal government and the scientific community was forged. This contract is not a formal agreement, rather, it is a set of arrangements and understandings accommodating the interests of both the federal government and scientists. Under this contract, special privileges and freedoms were conferred on scientists in the expectation that they would deliver great benefits to society as a whole. Today, the "social contract for science" has come to refer to the constitution of the post-World War II research system.[11]

As maintained by Bush and colleagues following World War II, the purposes of the social contract were to strengthen national security, fuel national economic growth, and provide better public health.

> Progress in the war against disease depends upon a flow of new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. Similarly, our defense against aggression demands new knowledge so that we can develop new and improved weapons. This essential

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10 President's Scientific Research Board, *Science and Public Policy: Administration for Research.* J.R. Steelman, chairman (Washington, D.C.: Government Printing Office, 1947)..

11 Guston and Keniston, 1993, p. 5.

> new knowledge can only be obtained through basic research.[12]

Among the major tenets of the social contract was that basic research would be the foundation of the system, providing the advances that would sustain the pace of inventions and applications. Since the benefits would be too far in the future for industrial support and the costs too great for philanthropy alone, the government would have to assume responsibility for nurturing the effort which would take place primarily, but not exclusively, in universities. To describe the relationship between basic research and applications, Bush used the metaphor of a bank from which deposits may be withdrawn:

> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.[13]

Bush further elaborated that:

> Today, it is truer than ever that basic research is the pacemaker of technological progress. In the nineteenth century, Yankee mechanical ingenuity, building largely upon the basic discoveries of European scientists, could greatly advance the technical arts. Now the situation is different.
>
> A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.[14]

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12 Bush, p. 1.

13 *Ibid.*, p. 13-14.

14 *Ibid.*, p. 14.

Bush's argument was that America could no longer rely on importing knowledge but had to make strong efforts in basic research a centerpiece of national policy. Furthermore, Bush maintained that basic research is a long-term process. He asserted that research ceases to be basic if immediate results are expected on short-term support.

Industrial representatives from firms with research capacity agreed with Bush and colleagues that basic research was an important foundation of national economic welfare and they advocated government support for such research. Because no one could predict where, when, or to whom the benefits of basic research would flow, no single firm could justify adequate levels of investment in basic research Moreover, such research was not profitable for firms to support since they could not prevent "free riders" from benefiting from the research they funded. However, Bush and his colleagues saw no need for government to support applied or technology research. Indeed, they believed support for such research would be an inappropriate use of government resources because it would put government into direct competition with industry.

Growth provided the glue for the research system. People supported the social contract in part because all expected to share the benefits of expansion. The research system was expected to grow rapidly and to continue to grow.

A main provision of the social contract was that basic research was to be conducted primarily in universities. Within universities, research funding would go to individual researchers or teams rather than institutions, to cover the direct costs of a project. Proposals would compete on their merits and be judged by other scientists knowledgeable in the particular field (The judges came to be known as peers and the system as peer review). Bush believed that the best science would thereby be supported and the national interest most effectively promoted. Thus, "excellence" rather than "equity" was the criteria stressed for funding.

By the peer review system the source of the funds was effectively separated from their disposition. This was a remarkable delegation of authority and resulted in freedom from political direction and control. Researchers themselves, would determine how to conduct their research. Moreover, institutions would not have to give up any autonomy despite receiving federal funds.

The awarding of grants or contracts, as provided by the social contract, allowed scientists to work at their home institutions, rather than work in some central government laboratory. Decentralized research, in many universities, guaranteed a dispersed, competitive scientific community.

The training of future scientists was also an integral part of the social contract. As Bush stated:

> The most important ways in which the government can promote industrial research are to increase

> the flow of new scientific knowledge through support of basic research, and to aid in the development of scientific talent.[15]

Guston and Keniston suggest that the "social contract for science" can be summarized in a few words: "Government promises to fund the basic science that peer reviewers find most worthy of support, and scientists promise that the research will be performed well and honestly and will provide a steady stream of discoveries that can be translated into new products, medicines, or weapons."[16]

Although the blueprint laid out by Bush and his colleagues was not followed in every detail, the overall effect was to quickly give the federal government a dominant position in funding basic research in universities. In fact, following World War II, the federal government became the principal patron of university research.

2.3 Implementation of the Social Contract

Implementation of the social contract proved to be less than straightforward. As the debate over Bush's proposed national research foundation continued year after year, the responsibilities envisioned for this organization were progressively broken off and taken over by other agencies. The organization Bush proposed was finally established in 1950 as the National Science Foundation. Historians agree

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15 *Ibid.*, p. 16.

16 Guston and Keniston, 1993, p. 1-2.

that the five-year delay in establishing NSF following World War II left the U.S. with a fragmented system for federal funding of research and the domination of American science by the military.[17]

The mission of NSF is to promote the progress of science, to advance the national health, prosperity and welfare, and to secure the national defense. NSF uses the peer review system to determine which scientists should receive federal funds. Although established in 1950, NSF did not dispense significant funds until the end of the decade.

While the creation of the NSF was still being debated, ONR, created by statute on August 3, 1946, took the lead in funding basic research in the universities on a wide variety of subjects related to naval missions. Public Law 79-588 stated that ONR was established to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power and the preservation of national security. ONR had an unexpended $40 million appropriation left from wartime construction funds as an initial budget, a strong staff built up for its wartime predecessor office, and excellent leadership.[18] Using a simple contract mechanism of institutional awards, ONR quickly moved to support investigators in universities across the country and to

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17 Kleinman, p. 149.

18 H. M. Sapolsky, "Financing Science After the Cold War," in *The Fragile Contract: Contract: University Science and the Federal Government* , ed. by D.H. Guston and K. Keniston (Cambridge: MIT Press, 1993), p 167.

inaugurate in the navy a program of support for basic research. The other services followed suit and established similar offices, most of whose funds were also devoted to basic research in the universities. ONR played a major role in funding basic research for almost a decade after World War II and received consistent support from Congress.

2.3.1 General Science Case

With federal agencies (ONR and later NSF) in place to support and coordinate science, academic research in the United States began to expand rapidly following World War II. During the two decades that followed the war, research in the United States was driven by national security considerations to almost the same extent as during the conflict itself. The powers of science and technology that were manifest in the victories over Germany and Japan were called upon to meet the widely proclaimed threat of Soviet expansionism.

University research benefited greatly from the Cold War. Although universities were allocated but a minor portion of defense research and development (R&D) funds, the amounts they received were never trivial relative to those available to them for the support of research from other sources. In the initial years of the Cold War especially, the military financed much of the university-based basic research and a considerable amount of graduate training in the sciences. But what Sapolsky believes was even more significant, was that the military helped define a government-university relationship which granted significant freedom and autonomy to scientists that extended beyond defense-related work and that persisted largely intact and unchallenged until quite recently.[19]

In the early 1950s, ONR was the dominant agency supporting basic research in universities. The level of funding of NSF did not become significant until after the Soviets launched their Sputnik satellite in 1957. Guston and Keniston assert that the impetus given by Sputnik to NSF funding demonstrated the extent to which the hope for military benefits lay behind government support of basic research even in areas not immediately related to military applications.[20] Thus, in the 1950s, there was an enormous expansion of both the number of university research personnel and the financial resources available for the support of university research. Between 1953 and 1961, federal support for R&D grew 14% annually in constant dollars.[21] Federal support for academic R&D continued to grow in the 1960s (Figure 1), peaking in 1968. The year 1968 is considered to be the end of the "golden age" of American science, a period which began shortly after the end of World War II.[22]

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19 Sapolsky, p. 165.

20 Guston and Keniston, 1993, p. 7.

21 Smith, p. 38

22 L.M. Lederman, *Science the End of the Frontier?*, (Washington, D.C.: American Association for the Advancement of Science, 1991), p. 14.

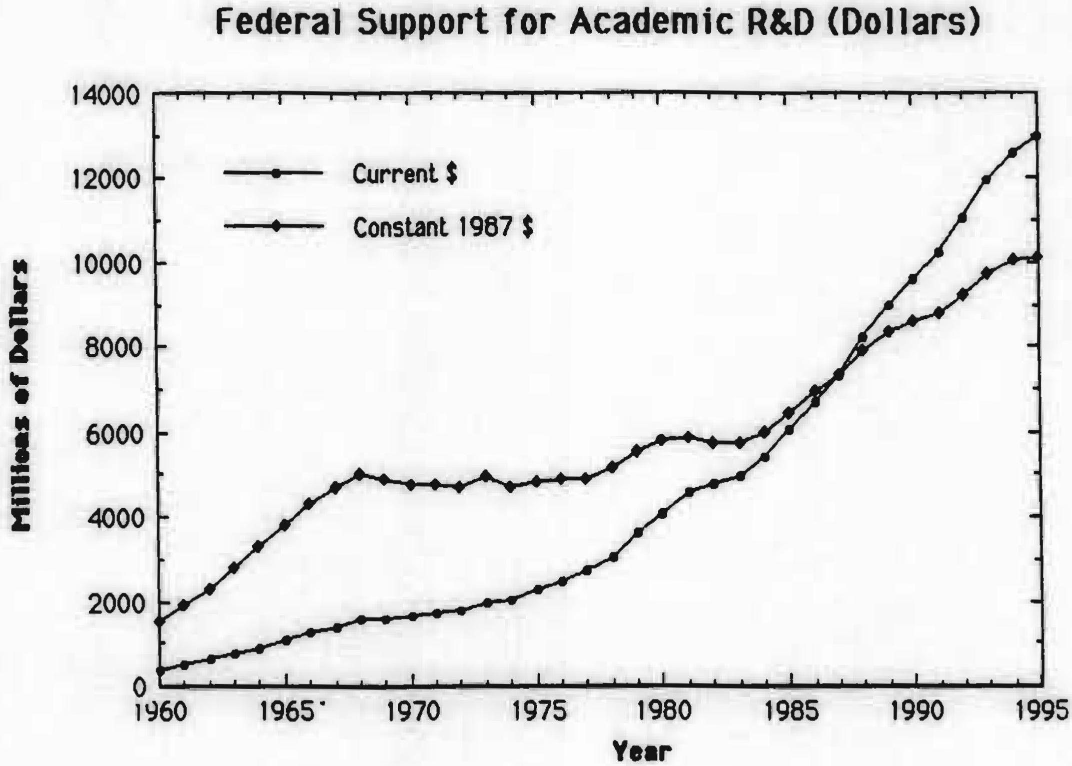

Figure 1. Federal Support for Academic R&D. Data are from National Science Board, 1996, Appendix Table 5-2, p. 166. Data entries for years 1994 and 1995 are estimates.

The late 1960s witnessed a crisis in the relationship between government and science. Even those who continued to have faith in scientific progress and defended scientists against the critics found it more difficult to believe that all the nation's problems could be solved through science. Smith suggests that the Vietnam War symbolized the dilemma: the most powerful and technologically advanced nation on earth was unable to subdue a technologically backward enemy.[23] The events of the war seemed to indicate that some problems had no technological fix.

Society's support for science had been based on the assumption that progress in the various scientific disciplines would ultimately lay the foundation for a better life for all Americans. As promoted by Bush, social improvements of all kinds would follow when the nation's collective intelligence was brought to bear on the most pressing problems. But as Americans lost confidence in this promise, the foundations of society's support for science eroded. The new mood challenged the beliefs underlying the social contract for science. Subsequently, the growth of federal support slowed (Figure 1).

The decline in academic R&D funding during the late 1960s and early 1970s, especially in the physical sciences, was accompanied by a public demand, particularly among young people, for greater "relevance" of academic research to

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[23] Smith, p. 76

societal problems such as the environment and the Great Society. The funding situation was exacerbated by rapid inflation and constraints on the federal budget.

During this period, there was also increased federal emphasis on "targeted" research. One event important in promoting targeted research was the passage of the Mansfield Amendment (section 203) to the Military Procurement Authorization Act of 1970, which specified that "none of the funds authorized to be appropriated by the act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation."[24] The Mansfield Amendment restricted the scope of Department of Defense (DOD) research funding to areas of obvious importance to the missions of the services.

In the second half of the 1970s there was a new period of growth in both the number of R&D scientists and engineers (Figure 2) and in federal support for academic research (Figures 1). However, in constant dollars, support growth was slow until approximately 1983. Between 1983 and 1989 there was a sharp increase in federal support for academic research which grew by about 30% when adjusted for inflation. The slope of this growth period (Figure 1, in constant dollars) is approximately the same as during the golden age period of science, 1960 to 1968. Growth in

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[24] Smith, p. 81.

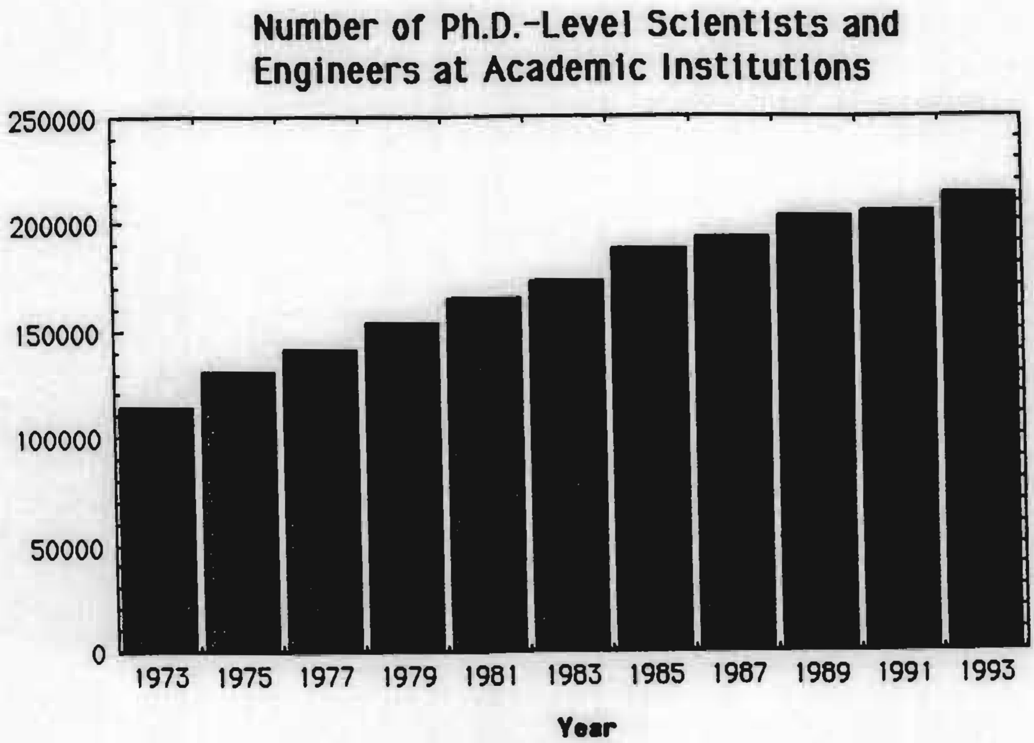

Figure 2. Number of Ph.D.-Level Scientists and Engineers at Academic Institutions. Data are from National Science Board, 1996, Appendix Table 5-20, p 190.

federal obligations for academic R&D again slowed in the beginning of the 1990s, to half the rate of the late 1980s.[25] At that time, concerns began to be voiced by the scientific community about the adequacy of federal support for academic research. Inadequacy was thought of in monetary terms as senior researchers began to lose long-term grant support and young investigators were unable to secure funds to initiate research.

The issue of adequate funding for academic science was given prominence in 1991 by Leon Lederman, then president of the American Association for the Advancement of Science (AAAS). After an informal survey conducted by AAAS, Lederman found that American science showed signs of extreme stress.[26] He noted that morale was declining and students were turning away from science. Lederman concluded that the depressed state of the academic scientific community resulted from inadequate federal support of research. Lederman argued that federal support of academic research, adjusted for the inflation of R&D costs had risen only 20% since 1968, the end of the "golden age" of American science.[27] Over the same period, the number of doctoral scientists and engineers at work in colleges and universities had doubled. Meanwhile, the cost of doing research increased greatly due to a variety of factors,

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25 National Science Board, *Science and Engineering Indicators - 1996*, (Washington, D.C.: U.S. Government Printing Office, 1996), p. 5-7.

26 Lederman, p. 5.

27 Lederman, p. 5.

ranging from more sophisticated instrumentation to higher overhead rates.

Today, at the federal level, demand for financial support for research activities is outpacing recent increases in research funding by federal agencies. Also, as pointed out by Lederman, the price of research has gone up much faster than inflation. For this reason, scarcity is felt even in the midst of generous funding. As a consequence, although the absolute number of federally supported researchers is now higher than at any point in history, competition for research funding is increasing, for both established and younger investigators. The increased demand for financial support comes at the same time as persistent deficits in the federal budget are limiting federal spending. Discretionary programs, of which science programs are a part, have been a shrinking part of federal spending for many years, now accounting for 35% of the total outlays, only half the share they had back in the early 1960s.[28] In the early 1960s, the government spent more than two dollars on discretionary programs for every dollar of mandatory spending, today it spends almost two mandatory dollars for every discretionary one.[29] This shift in federal spending now constrains the system in which science is supported.

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28 A. Schick, *The Federal Budget - Politics, Policy, Process* (Washington, D.C.: The Brookings Institution, 1995) p. 7.

29 *Ibid.*, p. 189

Sapolsky believes that overall, the ending of the Cold War will not have a great effect on university research.[30] Indeed, for the 1993-1995 period, no more than 10% of all U.S. university research is currently supported by the Department of Defense.[31] However, Sapolsky suggests that some segments of the academic community will feel the effects of a declining national concern about defense.[32] Fields such as oceanography and aeronautics, where the military involvement was intense are likely victims of changing priorities. Ocean science is especially vulnerable. For the 1993-95 period, DOD still financed 38% of oceanographic research.[33]

Funding for fiscal year 1996 brought uncertainty for science for many months as the longest stalemate in U.S. history over the budget occurred. Funding levels for fiscal year 1997 were resolved just prior to the start of the fiscal year. In light of the persisting federal deficit and the struggles of Congress to achieve a balanced federal budget, funding difficulties and stressful times are likely to continue for the scientific community.

2.3.2 Ocean Research Case

Prior to World War II, support for oceanography was provided almost exclusively with private funds. The Scripps

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30 Sapolsky, p. 160.
31 National Science Board, 1996, p. 181.
32 Sapolsky, p. 160.
33 National Science Board, 1996, p. 181.

family founded the Scripps Institution of Oceanography. The Rockefeller Foundation, in response to recommendations by the National Academy of Sciences (NAS), awarded grants totaling $16 million to establish oceanographic laboratories at Woods Hole and at the University of Washington and to aid the Bermuda Biological Station and Scripps.[34] Oceanographic activities were also endowed by private individuals at the University of Southern California and Yale University. Outside the Navy, no federal agency had broad-based interest in the marine sciences.

World War II thrust the United States into global affairs and its many sea campaigns not only drew public interest to the oceans, but also highlighted ignorance of it. During the war, most members of the small marine science community turned to military-oriented work in uniform, in the civil service, or at universities and related institutions. Academic ships, as well as those of the federal government, were put to work on Navy research and surveying tasks. The Navy needed and received oceanographic help in all areas from submarine warfare to amphibious landings. Although this assistance contributed to the war effort, the Ocean Studies Board asserts that even more importantly, it impressed on the nation the fact that marine

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[34] R.A. Abel, "The History of the United States Ocean Policy Program," in *Making Ocean Policy*, ed. by F.W. Hoole, R.L. Friedheim, and T.M. Hennessey (Boulder: Westview Press, 1981), p. 4.

science was not an abstract endeavor, but could contribute to the public good in many fields.[35]

Ocean research benefited greatly from the implementation of the social contract. Following World War II, ONR recognized the need for greater public sector involvement in the oceans. The growing Cold War and the threat from both surface and particularly, submarine vessels led ONR to conclude that expanding and generally strengthening the basic science of the oceans were in the national interest. With ONR's financial backing, existing marine research centers were expanded and new ones created. The Navy also set the tone for U.S. academic oceanography by providing ships to the academic community after World War II. This resulted in a mode of distributed ship operations that has proven remarkably effective over the years.

Along with new facilities for ocean research came new personnel. By 1950, the number of oceanographers had increased from a pre-war level of approximately 100 to between 200 and 250 individuals.[36] The oceanographic community continued to experience an influx of personnel in the 1950s. By 1958, a NAS study estimated that there were slightly more than 400 oceanography-related Ph.D.s working in the U.S.[37]

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35 Ocean Studies Board, p. 19.
36 Shannon and Palmer, p. 31.
37 *Ibid.*

In 1956, Rear Admiral Rawson Bennett, acting on behalf of ONR and other federal agencies, requested the President of the National Academy of Sciences to appoint a scientific committee to provide advice and guidance on the opportunities for oceanographic research to be supported by the federal government. In February 1959, this committee, called NASCO (National Academy of Sciences Committee on Oceanography) released a report entitled *Oceanography, 1960-1970*. NASCO recommended that the federal government assume responsibility for accelerating a national program of research, surveys, education, and construction of facilities by approximately doubling the level of effort in oceanography over the next 10 years.[38] At approximately this time, marine science interest grew from the coastlines to the globe, leading to such major ocean-related programs as the International Geophysical Year (IGY) of 1958-1959. With the IGY, NSF became a significant supporter of oceanography.

During the period 1959-1969, there was congressional pressure on the executive branch to expand its support for oceanography and to improve the federal organization for addressing national ocean concerns. President Kennedy responded with a special message to Congress in early 1961 which pledged that his administration would give "concerted attention to our whole national effort in the basic and applied research of oceanography" and that he would initiate

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[38] T.A. Kitsos, "Congress and the Oceans: Shaping Marine Policy for Three Decades," *MTS Journal,* 22(1), 1988, p. 34.

a national program for oceanography.[39] Kennedy stated that in 1962 he would nearly double the government's investment in oceanography, expand construction of oceanographic vessels, increase shore facilities, funding for basic and applied research, and training for oceanographers. King and Jennings note that President Kennedy's initiatives were significant because they marked the first time that the oceans, defined primarily in terms of oceanographic research, were the subject of presidential rhetoric buttressed by requests for real spending increases.[40] Table 1 shows the results of this increased attention on the ocean.

Table 1.[41]
Funding for University Ocean Research
Millions of 1963 Dollars

	1958	1963	1968	% Change 1958-63	% Change 1963-68
NSF	1.6	9.4	13.9	488%	48%
ONR	4.5	15.1	20.9	236%	38%
Total Federal	8.3	33.7	41.9	306%	24%

39 L.R. King and F.O. Jennings, "The Executive and the Oceans: Three Decades of United States Marine Policy," *MTS Journal* , 22(1), 1988, p. 18.

40 *Ibid.*, p. 19.

41 F.N. Spiess, "Up Periscope! Observations on Ocean Research Policy and Administration (as Seen from Below)," *MTS Journal*, 23(2), 1989, Table 1, p. 41.

Funding for ocean research increased by a factor of four between 1958 and 1963, even after correcting for inflation. However, the subsequent five year period showed an increase of only 24%.

In the early years of marine science, there were no formal mechanisms for coordinating academic institutions' activities. The Joint Oceanographic Institutions for Deep Early Sampling (JOIDES), established in the 1960s to provide formal advice to the Deep Sea Drilling Project (DSDP), was the ocean community's first attempt to build a true national program. NSF decided to back the DSDP, formally proposed under the scientific sponsorship of JOIDES in 1966. Evolving from JOIDES was JOI, a formal not-for-profit corporation, consisting of 10 U.S. ocean science institutions that operate many of the large ships in the oceanographic fleet, employ the majority of U.S. academic ocean scientists, and receive the majority of the research funding. The JOI institutions are:

Scripps Institution of Oceanography, University of California
Lamont-Doherty Geological Observatory, Columbia University
School of Ocean and Earth Science and Technology, University of Hawaii
Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
College of Oceanography, Oregon State University
Graduate School of Oceanography, University of Rhode Island
College of Geosciences and Maritime Studies, Texas A&M University
Institute for Geophysics, University of Texas
College of Ocean and Fisheries Sciences, University of Washington
Woods Hole Oceanographic Institution (WHOI)

Oceanography along with U.S. science in general, entered a steady-state funding situation in the late 1960s. In 1969, NSF launched the the International Decade of Ocean Exploration (IDOE). This program resulted in substantial increases in NSF Ocean Science Funding. In fact, since the 1960s, NSF has been the principal supporter of academic oceanography in the U.S.

About the same time that the IDOE was extending academic marine science, the National Sea Grant College Program was created to provide an added dimension to university marine programs. Sea Grant provided support for kinds of marine science commonly neglected at that time by ONR and NSF, for example, the study of estuaries, fisheries, and pollution. It also provided support for research in areas where there had been none before, such as political science, law and economics. Sea Grant was, and is, different from most other government funded research programs. It is a federal-university partnership. For every two dollars of federal funds there must be at least one dollar of matching funds. A key element of Sea Grants is its public service or extension component.

In 1969, the Stratton Commission published its seminal report entitled *Our Nation and the Sea: A Plan for National Action.*[42] The Stratton Commission's report provided

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42 U.S. Commission on Marine Science, Engineering and Resources, *Our Nation and the Sea: A Plan for National Action*, J.A. Stratton, chairman (Washington, D.C.: Government Printing Office, 1969).

encouragement to the entire federal government to develop and pursue new initiatives related to the coastal and oceanic environments. Upon the recommendation of the Stratton Commission, the National Oceanic and Atmospheric Administration (NOAA) was formed in 1970 from a combination of existing government entities.

By 1970, there were 540 Ph.D.-level academic oceanographers in the United States (Figure 3).[43] The average annual rate of increase for Ph.D.s in academic oceanography was 6.4% from 1970 to 1980.[44] However, funding levels throughout the 1970s for academic research were relatively flat, when corrected for inflation. In fact, the Shannon and Palmer survey indicated strong discontent in the academic marine science community with the existing level of support for basic research during that period.[45]

The 1980s were characterized by slow growth in federal support for oceanography. Figure 4 shows that the total federal spending on oceanographic research grew 3.5% from fiscal year 1981 to fiscal year 1993, an increase of about 0.3% annually. However, during this time, the federal share of support for academic oceanography was declining, from a high of 78% in 1980 to a low of 68% in 1991 (Figure 5). The federal share rebounded slightly in 1991 and 1992 to approximately 72%.

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43 Ocean Studies Board, p. 128.
44 *Ibid.*, p. 123.
45 Shannon and Palmer, p. 65.

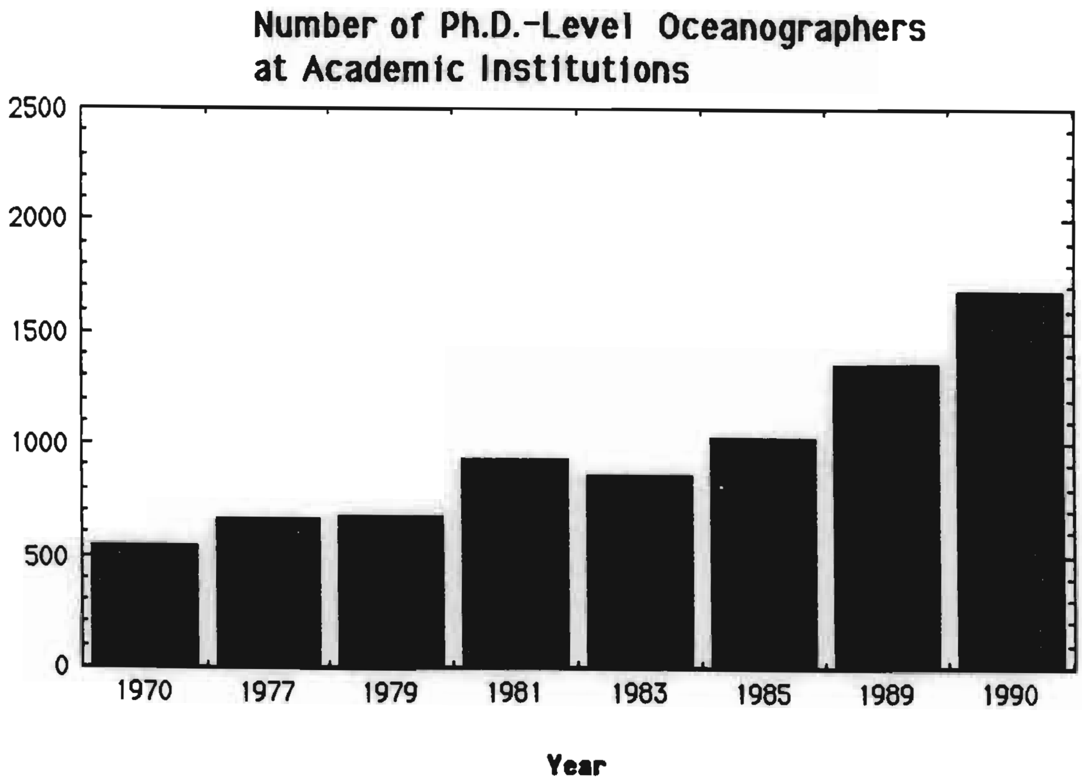

Figure 3. Number of Ph.D.-Level Oceanographers at Academic Institutions. Data are from National Science Board, 1996, Appendix Table, 5-10, p. 274 and Ocean Studies Board, 1992, p. 128 and p. 137.

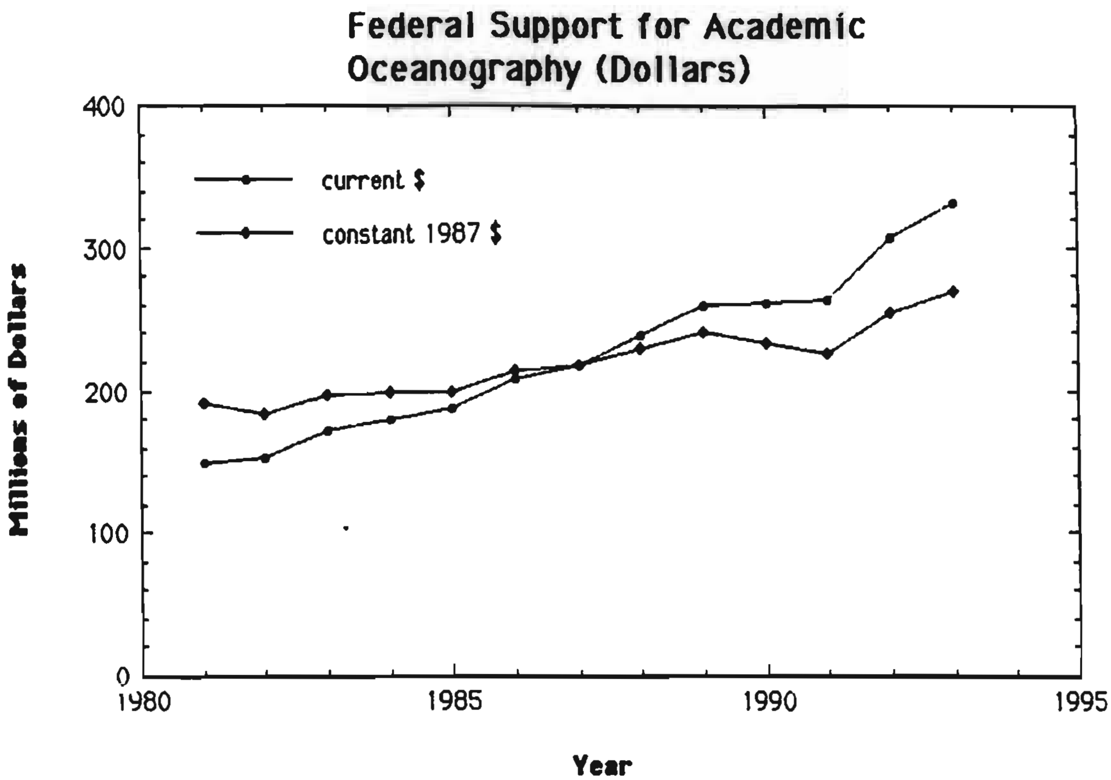

Figure 4. Federal Support for Academic Oceanography. Data are from National Science Board, 1996, Appendix Tables, 5-6 and 5-7, p. 173-175 and National Science Board, 1993, Appendix Tables, 5-7, p. 397.

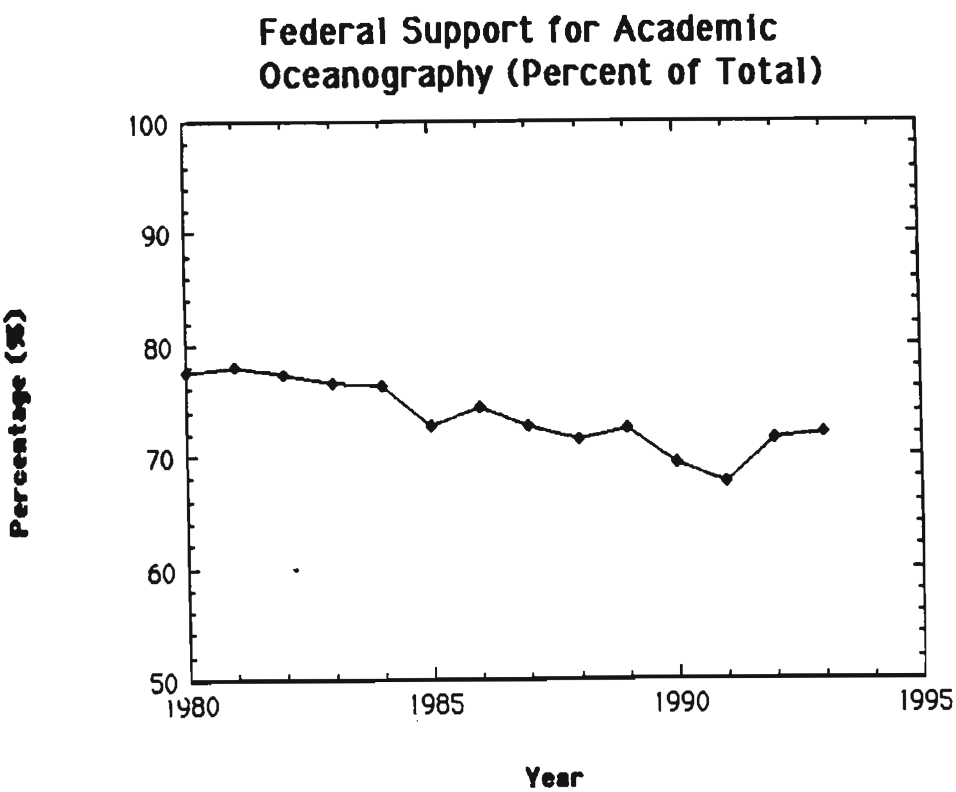

Figure 5. Support for Academic Oceanography- Federal Percentage. Data are from National Science Board, 1996, Appendix Tables, 5-6 and 5-7, p. 173-175 and National Science Board, 1993, Appendix Tables, 5-8, p. 399.

Throughout the 1980s, the number of scientists competing for funds continued to grow (Figure 3). The average annual rate of increase for Ph.D.s in academic oceanography was 5.2% from 1980 to 1990.[46] Thus, there were about three times as many Ph.D.-level oceanographers in 1990 as there had been in 1970. In comparison, over roughly the same period, the number of Ph.D-level scientists in all sciences at academic institutions had not quite doubled (Figure 2). The slow growth in federal funding, characteristic of the 1980s and early 1990s, has not been enough to keep pace with the proposal pressure by the academic ocean science community. During the period 1983-1994 for which there is uniform data, the number of proposals submitted to NSF's Ocean Science Research Section (OCRS) annually increased from approximately 800 to greater than 1,100. Over the same period, success rates fell from approximately 40% to 29%. It was noted with concern that 1994 was the worst year in the period, with the highest number of proposals (1,147) and the lowest success rate (29%).[47] Moreover, the median size of awards, when adjusted for inflation, in most OSRC programs over the 1983-1994 period declined.[48] It is obvious that as proposal demand has grown at a relatively high rate and awards have grown at a

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46 Ocean Studies Board, p. 128.

47 R. Duce, S. Chisholm, T. Kinder, P. Liss, T. Moore, and M. Scranton, "Report of a Review of the NSF Ocean Sciences Research Section," *Oceanography*, 9(2), 1996. p. 125.

48 *Ibid.*, p. 126

much lower rate, the average success rate for proposals has declined.

Today, NSF and ONR still provide the majority of federal support for university-based basic oceanographic research. In addition, several mission agencies (i.e., NOAA, the National Aeronautics and Space Administration (NASA), the United States Geological Survey (USGS), the Minerals Management Service (MMS), the Department of Energy (DOE), and the Environment Protection Agency (EPA)) support ocean science research through extramural funding to the academic research community. Figure 6 shows the distribution of federal support for ocean science by agency for fiscal year 1992.

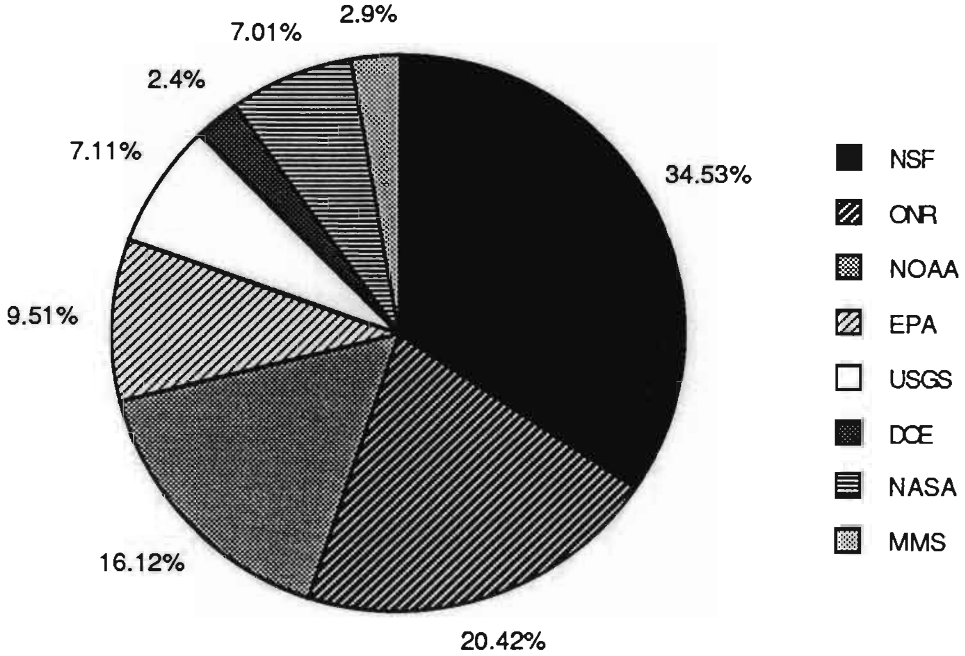

Figure 6. Distribution of federal support for ocean science in fiscal year 1992. Data are from Ocean Studies Board, p. 160.

CHAPTER 3. A MODEL FOR THE POST-COLD WAR ERA

3.1 Introduction

The policies set up after World War II were not inevitable. A choice could have been made to concentrate federally supported research within government laboratories, or to procure research under contracts with rigid specifications, or to create a central authority with power over research budgets and priorities. Morin believes that none of this was done, that the U.S. has retained a loosely organized, undirected, pluralistic research system over the past five decades, is testimony to its success.[49] Indeed, whether measured in terms of people, products, patents, publications, or prizes, the American system of science has been the most successful in the world. However, almost five decades into the social contract for science, there are signs that its pattern of partnership and harmony has eroded. Scientists and politicians have serious complaints about each other. The issues are by now familiar: the adequacy of science funding, administrative burdens in science, indirect costs of research, scientific priorities, big science, pork barrel, scientific fraud and dishonesty, and so on. Harvey Brooks,a leading science policy analyst, notes that there are signs of growing resentment against scientists whose pleas for more academic research support sound more and more like the special pleading of a

[49] A.J. Morin, *Science Policy and Politics* (Englewood Cliffs: Prentice Hall, 1993), p. 46.

relatively well-off interest group.[50] Guston and Keniston maintain that the contract between science and the government has entered a fragile state and is undergoing a rethinking such as it has not experienced since its inception.[51]

In this chapter the reasons for the fragile state of the social contract for science will be explored. The changing context for the social contract will be discussed and public attitudes toward science will be investigated. New rationales for the federal support of science will be examined. A paradigm shift from the social contract for science to a more democratized system will be suggested. Finally, a model for democratized science will be developed.

3.2 Changing Context for the Social Contract

A major impetus for reexamination of the social contract has been the ending of the Cold War. National security rationales, as provided by the Cold War, have been a primary force in sustaining the social contract for science. International military competition had come to be relied upon so much as the justification for the support of science that the case for support may be seriously weakened in its absence. Indeed, throughout history, military conflict has been a driving force behind the concern of

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50 H. Brooks, "Research Universities and the Social Contract for Science," in *Empowering Technology - Implementing a U.S. Strategy*, ed. by L. M. Branscomb, (Cambridge: MIT Press, 1993), p. 205.

51 Guston and Keniston, 1993, p. 2.

government with science and technology. Brooks claims that "The history of the relationship between science and politics can be interpreted as the struggle of the scientific community to retain and institutionalize in time of peace the public support and the institutional independence which have been granted to it in times of military emergency."[52] With the Cold War over, it is now being argued that pressing national needs deferred to meet security challenges need to be addressed.

A simple explanation offered by Guston and Keniston for the current scrutiny given the social contract is that the old contract was made between a kind of government that no longer exists and a kind of scientific community that has long since disappeared.[53] The original social contract for science was written in simpler days. Government has since increased in size, complexity and in its capacity both to support and to oversee science. Science too has grown from a small business to a multibillion dollar enterprise of extraordinary complexity that has links to every aspect of American society. Guston and Keniston assert that the contract is fragile today because the two parties that agreed to it have grown and changed enormously in nature.[54]

Guston and Keniston state that the postwar research system, even though highly successful so far, has become

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52 Morin, p. 2.
53 Guston and Keniston, 1993, p. 17.
54 *Ibid.*, p. 23.

less effective in today's environment because it was geared toward a different set of military, political, technological, and economic challenges.[55] They claim that the image of a time when government provided money and science provided results is oversimplified. That image, Guston and Keniston assert, applied best to the abnormal years immediately following World War II, when the contract was negotiated under the assumption of a near-identity of interest between science and the government.[56] Frank Press, science adviser to President Jimmy Carter and two-term president of the National Academy of Sciences, acknowledges that the era when Washington threw money at R&D to bolster defense, medicine, aeronautics and space, agriculture, computers and communication, and university science is ending, along with many other forms of discretionary spending.[57]

The world of today is different from that of the late 1940s and early 1950s in almost every way. The research community of the 1940s and 1950s enjoyed a funding situation very different from today's. Then, the research environment was characterized by fewer researchers, ample job opportunities, a more homogenous work force, fewer research universities with a greater concentration of federal

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55 D.H. Guston and K. Keniston, "Updating the Social Contract for Science," *Technology Review*, November/December 1994, p. 64.

56 Guston and Keniston, 1993, p. 28.

57 I. Goodwin, "To Limit Damage of Shrinking Science Budgets, Academies Panel Urges New Funding Framework," *Physics Today*, February, 1996, p. 47.

resources, and little international competition or concern about U.S. research performance.[58] Since World War II, numbers of researchers have increased dramatically in most scientific fields, job opportunities have decreased, federal support has grown little when corrected for inflation, and the U.S. is struggling in some fields to remain internationally competitive. The situation reached a critical point in 1991 when Leon Lederman, then president of the American Association for the Advancement of Science posed the question "Is science is at the end of the frontier?"[59]

3.3 Public Attitudes Toward Science

In light of the changes which have occurred since the social contract was first negotiated, it is instructive to examine public attitudes toward science for signs of change. After all, it is the public who supports science through tax dollars.

Understanding the public face of science is not a straightforward matter. Attitude surveys indicate that the public has generally retained a certain faith in science as important to social progress, but Nelkin points out that surveys reveal little substantively about the diversity of public views, and they quickly reveal that most people know

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58 D.E. Chubin, "How Large an R&D Enterprise?," in *The Fragile Contract: University Science and the Federal Government*, ed. by D.H. Guston and K. Keniston, (Cambridge: MIT Press, 1993), p. 121.

59 Lederman, p. 5.

very little about science until it affects there immediate interest.[60]

Over the past 16 years, the level of interest in science and technology in the United States has remained relatively stable, with approximately 40% of Americans expressing a high level of interest in scientific discoveries and new technologies.[61] Interest appears to be correlated with education level. Individuals with higher levels of formal education were significantly more likely to report that they were very interested in scientific and technological issues than were other citizens.[62] However, only approximately one in nine Americans thinks of himself or herself as being well informed about science discoveries or the use of new technologies. In comparison, approximately one in four American adults believes that he or she is very well informed about medical discoveries, economic issues and business conditions. As Epstein points out, people are much more inclined to have and assert opinions about medicine than about other scientific disciplines.[63]

Since 1979, the percentage of Americans attentive to science and technology policy issues has remained constant at approximately 10%.[64] Today, this attentive public

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60 D. Nelkin, "The Public Face of Science: What Can We Learn from Disputes?," in *The Fragile Contract: University Science and the Federal Government*, ed. by D.H. Guston and K. Keniston, (Cambridge: MIT Press, 1993), p. 102.

61 National Science Board, 1996, p. 7-4.

62 *Ibid.*, p. 7-4.

63 S. Epstein, "Democratic Science? AIDS Activism and the Contested Construction of Knowledge," *Socialist Review*, 91(2), 1991, p. 39.

64 National Science Board, 1996, p. 7-8.

includes approximately 18 million American adults. Comparatively, 15% of Americans were attentive to economic and medical discoveries in 1995.[65] Attentiveness to science issues has been shown to be correlated with an understanding of scientific concepts. However, only a small segment of the population has a strong grasp of basic scientific ideas.[66]

One of the oldest indicators of the public attitude toward science and technology is the General Social Survey, which has been conducted annually since 1973. This survey asks Americans to indicate whether they have a "great deal of confidence, only some confidence, or hardly any confidence at all" in the people running selected institutions. Approximately 40% of people asked expressed a great deal of confidence in the leadership of the scientific community, virtually the same confidence they revealed for the medical field.[67] This level of confidence in leaders in the scientific community has remained constant for the full two decades that this time series has been collected.[68] Comparatively, in 1995, approximately only one in ten adults expressed a great deal of confidence in leaders in Congress, the executive branch of the federal government, the press, television and organized labor.[69] Thus, the leadership of

65 *Ibid.*
66 *Ibid.*
67 *Ibid.*
68 *Ibid.*
69 *Ibid.*

the scientific community and the medical community are the two most esteemed groups in the United States.

In summary, the National Science Board survey data indicate that the public perception of science has not changed appreciably in the last two decades. Science and science leaders are well regarded. However, survey data also point out that most Americans do not have a deep understanding of science.

What do all these survey data mean for popular support of the social contract for science? It is suggested that in their esteem for science and scientists, Americans indirectly support the social contract. However, so few Americans understand science that it is unlikely many will become involved in debates about basic science priorities or budgets. Americans are much more likely to be vocal and supportive of the issues which they understand and most affect their daily lives, for example health care and their own economic plight. Without the protection of national security to keep science aloof from politics, support for science is now on a more equal footing with support for other concerns vying for federal dollars. Senators and Representatives have been warning scientists that unless constitutents tell legislators that science programs are important, scarce research dollars might be directed to other national and local concerns. Moreover, the voices arguing for support of science are likely to seem lower relative to the voices raised over health care and taxes.

Turning now to the more specific case of support for ocean research, the Mellman Group recently collected data from a survey on the public's attitude toward the oceans.[70] Their survey revealed that Americans have a latent concern about the oceans, which the Mellman Group suggests could be translated into significant political action.[71] The Mellman Group found that 85% of those surveyed believe that the government needs to do more to help protect the ocean.[72] It is noteworthy that the Mellman Group found an overwhelming number of those surveyed (72%) believe funding for ocean exploration is a more important priority than funding for space exploration (17%).[73] However, survey data revealed that the scientific community and the public may have differing opinions on which issues are most important to the health of the oceans. Over half (61%) of those surveyed believe that citizens and scientists disagree on which are the most important problems facing the oceans, and a plurality (42%) say that government should focus on citizen's concerns over those of scientists (37%).[74] From their survey, the Mellman Group concluded that the prerequisites are in place for ocean issues to become a

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70 The Mellman Group, Inc Results of Public Opinion Survey, (Memo to Sea Web, Washington, D.C.: July 10, 1996).

71 *Ibid.*, p. 3.

72 *Ibid.*

73 *Ibid.*

74 *Ibid.*

significant public issue.[75] Concern, they note, is high, but information is low.

3.4 New rationales

Guston and Keniston assert that of all the changes since the postwar negotiation of the social contract for science, the end of the Cold War is probably the most consequential.[76] Ever since 1945, the promise of military applications and the specter of Soviet competition has driven federal R&D expenditures in both military and civilian agencies. The expected usefulness of science and technology to the conduct of the Cold War, both in material terms of building effective weapons and in symbolic terms of conquering the new frontiers of space, the atom, and the cell meant that the governement and the public viewed science in a favorable light. But today, without the Soviet threat, Guston and Keniston believe that the instrumental value of science and technology has lost some of its urgency.[77]

Although Vannevar Bush and colleagues justified the federal support of science based on national security, economic, and public health rationales, the principal reason for public support of science since World War II has been national security. The enhancement of national security was

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75 *Ibid.*, p. 7.
76 Guston and Keniston, 1994, p. 64.
77 *Ibid.*, p. 64.

the rationale that convinced the nation to support with public funds a very large research and development enterprise in the years following World War II. Countering the Soviet threat was one central "public good" upon which almost everyone agreed. Today, other public goods are alleged, or more precisely revived, with new vehemence from the past.

Public spending is a reflection of the priorities that the country places on addressing important national goals. Guston and Keniston claim that today, with the dissolution of the Soviet threat and the absence of a coherent and exciting space program, there are no comparable goals for basic scientific research that have a strong national consensus.[78] Only in the general area of health care does a ready consensus exist for massive public spending on research.

In addition to health care, economic security is another rationale that is now garnering support for science instead of national security. When the social contract for science was first negotiated, the U.S. did not have an economic competitiveness problem because there was no competition. However, by the late 1980s, many Americans began to view national security in economic terms. In fact by 1988, almost 60% of Americans surveyed indicated that "our economic competitors like Japan are greater threats to

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78 Guston and Keniston, 1993, p. 18.

our national security than our military adversaries like the Soviets."[79] Lakoff maintains that in view of the persisting trade deficit with Japan, the specter of Japanese economic competition has for some come to replace the specter of the Soviet threat.[80] Moreover, Zinberg suggests that by the time the former Soviet Union unraveled, concerns about national security had shifted to anxiety about declining U.S. economic competitiveness.[81] For example, in 1988, only 23% of a national sample of Americans believed that the United States was still the key economic power in the world, while a startling 90% had some degree of "serious" concern about the country's ability to compete effectively in the world economy.[82]

Recently, there have been calls for less emphasis on basic research in favor of economic considerations. For example, in 1991, members of the Council on Competitiveness asserted that "When it comes to technology, U.S. public policy can no longer afford to be preoccupied with basic research and military issues; economic security and industrial competitiveness are also vital issues."[83]

Can scientists adapt to the new rationales of support for science? Many scientists argue that research funding

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79 D.S. Zinberg, "Putting People First: Education, Jobs and Economic Competitiveness," in *Empowering Technology - Implementing a U.S. strategy*, ed. by L.M. Branscomb, (Cambridge," MIT Press, 1993), p. 238.

80 S. Lakoff, "Science Policy After the Cold War: Problems and Opportunities," *Technology in Society*, 13, p. 32.

81 Zinberg, p. 238

82 *Ibid.*

83 Kleinman, p. 172

already benefits the public at large, economically. However, Martino states that today this argument may no longer be sufficient justification for taxpayer funding.[84] The social contract is now under heavy pressure, as Congress asks the scientific community to demonstrate the effectiveness of the mechanisms through which benefits to society flow.

3.5 Updating the "Social Contract"

What do new rationales mean for the support of academic research after the Cold War? Sapolsky believes that the problem for science is that in the long run economic and health care rationales protect the independence of academic science much less than do national security rationales.[85] As pointed out by Sapolsky, whereas politicians are willing to defer to the judgement of the military on most research matters, they have little hesitation to substitute their own for that of civilian officials in nearly all domestic affairs.[86] Thus, the autonomy that scientists had gained under the social contract may be at stake in the post-Cold War Era. In fact, Congressman George Brown (D-CA), a member of the House Science Committee, maintains that the scientific community must seek to establish a new contract with policy makers, based not on demands for autonomy and ever increasing budgets, but on the implementation of an

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84 J.P. Martino, *Science Funding - Politics and Porkbarrel* (New Brunswick: Transaction Publishers, 1992), p. 245.

85 Sapolsky, p. 171.

86 *Ibid.*

explicit research agenda rooted in societal goals.[87] Furthermore, Brown asserts that the simple science polices of the postwar years are now philosophically and politically unsupportable.[88] He believes scientists must view their efforts as part of a complex system and must justify the need for federal support in the context of broader vision.

Guston and Keniston also maintain that the old contract between science and government needs updating, in part because of the tensions between the principles of science and those of democratic government.[89] For example, the limited control that scientists have been given over the expenditures of some federal funds is an anomaly in the U.S. system of representative government. Morin points out that it represents an act of faith in the benefits to be derived from research that is directed by the researchers themselves, but it does not represent an abdication by Congress of its constitutional authority to decide when and how it should intervene in the formulation of policy or the allocation of resources for research.[90] This point was driven home by Congressman Brown in a stinging indictment of the American science community:

> Scientists were willing pawns in the Cold War game. They accepted the fruits of their role in the military, and the adulation that they received for preserving this country in a time a danger.

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87 Guston and Keniston, 1993, p. 6.

88 G.W. Brown, "Science Policy, Science Funding and the Science Community," *Academic Medicine*, 66(7), 1991, p. 377.

89 Guston and Keniston, 1994, p. 62.

90 Morin, p. 171.

> And they assumed that they were entitled to the largess that flowed from this because of their sterling character, moral integrity, and great vision. And that wasn't the case at all. They failed to see that this country has a number of high priorities, of which military security is just one. The research and development establishment has got to speak compellingly about these other priorities.[91]

Furtermore, Brown has pointed out that unlimited funding for basic research is no longer viewed by the U.S. Congress as a birthright of the scientific community.[92]

Guston and Keniston assert that the basic tensions between science and democracy must be confronted in updating the social contract.[93] Furthermore, unprotected by national security rationales, Sapolsky predicts that the democratization of science seems likely to lie ahead.[94]

Just what does updating the social contract by the democratization of science mean? It is suggested that the support of science in the post-Cold War era will take on more democratic characteristics. In fact, some scholars have argued that "democratic ideals imply that science policy be subject to greater public scrutiny and political control."[95] Morin contends that Bush's principle of an apolitical science, a system of federally supported research kept comparatively free of the policy controls of democratic government is no longer viable.[96] Furthermore, Guston and

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91 M. Carlowicz, "Communications Means Survival Policymakers say," *EOS, Transactions, American Geophysical Union*, 77(9), 1993, p. 82.

92 Brown, p. 377.

93 Guston and Keniston, 1994, p. 65.

94 Sapolsky, p.161.

95 Kleinman, p. 4.

96 Morin, p. 156.

Keniston claim that in a democratic society, citizens must be allowed to choose between supporting science and supporting other valued enterprises.[97] They maintain that even though science may be the pursuit of truth, it is still only one pursuit among many that citizens value. Furthermore, Epstein suggests that the struggle for democratization might be expressed in demands that scientific elites and institutions be responsive to societal concerns and that the public exercise greater participation in setting research priorities.[98]

The original social contract has often been described as a linear model. That is, science leads to technology which leads to markets. Congressman Brown asserts that the linear model of R&D was accepted by policymakers in large part because there was no need, in fact, there was no way to test it.[99] Gibbons believes that the traditional linear paradigm must be replaced by a model that recognizes multiple feedback loops between science and technology, and the nation's economic and social well being.[100]

A 1992 report written by the Government-University-Industry Research Roundtable (GUIRR) discusses the choices that affect the future of the U.S. academic research system. The findings of the GUIRR support the trend toward the

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97 Guston and Keniston, 1993, p. 26.

98 Epstein, p. 38.

99 Kleinman, p. 193.

100 J.A. Gibbons, "Science and Technology in Post-Cold War Era," *Forum for Applied Research and Public Policy*, Spring 1995, p. 119

democratization of science. As outlined in the GUIRR report, the funding criteria that will play an increasing role in support decisions are: relevance, that is having eventual application to human needs, economic promise, that is the potential for accelerating growth in the gross national product, and equity, or the degree to which funding agencies consider the geographic location, race and sex of grant applicants.[101]

The findings of the GUIRR suggests federal support for research will be increasingly tied to the U.S. economy.[102] The strength of the economy will be an important factor in setting the overall level of resources available for meeting national needs. Thus, academic research institutions will have an increasing interest in the economic vitality of the nation. Their public support will be closely tied to the country's ability to generate wealth through increased industrial competitiveness and work-force productivity. Furthermore, academic research institutions will benefit from a healthy economy only to the extent that the public believes in the social value of the work they perform. The GUIRR maintains that taxpayers will provide substantial financial support for academic research only if there is convincing evidence that research is helping to maintain or improve the quality of life and the standard of living.[103]

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101 Government-University-Industry Research Roundtable (GUIRR), Fateful Choices - The Future of the U.S. Academic Research Enterprise (Washington, D.C.: National Academy Press, 1992), p. 11.

102 *Ibid.*, p. 27.

103 *Ibid.*, p. 28.

In summary, Guston and Keniston suggest that the old contract between government and science was fragile because it denied the inevitable tensions between democratic government and scientific practice, attempting to keep politics and science as separate as possible.[104] The new contract as it evolves must take into account the blurred boundaries between politics and science, all the while recognizing the differences between them.

3.6 Paradigm Shift From the "Social Contract" to "Democratic Science"

The tensions between democracy and science boil down to conflicting values: democracy cherishes participation and the pursuit of justice, while science cherishes inquiry and the pursuit of truth. Guston and Keniston assert that because the gap between participation and truth can never be closed, the tensions will always exist.[105] They claim that an attempt to run science on democratic principles would destroy science, however, they maintain that does not mean that the existing institutions and processes of science are democratic enough.[106] The preceding section demonstrated that there are now calls to update the social contract with more democratic principles. It is suggested in this paper that there are indications that more democratic processes are

104 Guston and Keniston, 1994, p. 66.
105 *Ibid.*
106 *Ibid.*

becoming part of the U.S. scientific enterprise in the post-Cold War era.

What will the model of democratic science look like? From a synthesis of the concepts expressed in this paper thus far, a model for democratic science has been developed. Characteristics of the democratic science model are contrasted with those of the social contract for science model in Table 2. The characteristics enumerated in Table 2 describe the relationship between science and society under the two different models.

The social contract model for federal support of science, although expressed succinctly in *Science - The Endless Frontier*, took years to evolve. Many of the ideas advanced by Bush and his colleagues had precedent long before World War II. Moreover, many of Bush's ideas were hotly debated in the late 1940s before the social contract model finally emerged. So too, a shift in paradigm to a more democratic system will be a gradual evolution with considerable debate along the way. The model presented here has been developed to serve simply as a means to enter the debate over the organization of science in the post-Cold War era. Current practices and policies of the U.S. science enterprise are likely to lie between the two sets of characteristics presented in Table 2.

Table 2.
Federal Support for Science

Element	**Social Contract** (1945 to approximately 1989)		**Democratic Science** (approximately 1990 to present)
(1) WHAT are the goals for the support of academic science?	Emphasizes basic research and ensures academic freedom	-->	Emphasizes researach relevant to societal needs - research may be targeted by goal, agency, program, or institution
(2) WHO determines the direction of science and funding amounts?	Experts with a large degree of autonomy	-->	Broad segments of society at large
(3) WHO selects which projects to support?	Scientific peers who determine the "best" science	-->	In addition to peers, others such as Congressman and agency managers who will consider additional factors
(4) WHERE will supported research be conducted?	At sites most capable of conducting the best research, resulting in concentrated excellence	-->	At locations which take into consideration additional factors such as potential economic benefits, resulting in regional and institutional development
(5) WHEN are results of supported research anticipated?	With long term horizons	-->	With short term horizons

Each of the elements listed in Table 2 will now be briefly explained. (The convention used here is Table number - Element number). Element 2-1 concerns the goals for the support of academic research and the amount of freedom granted to scientists. The social contract model emphasized basic research, that is, pure curiosity driven research directed toward the increase of knowledge rather than a practical application. This emphasis has resulted in significant freedom for scientists to pursue their own ideas. A shift toward democratic science would be characterized by a greater emphasis on relevance to societal needs brought about by political intervention, resulting in less academic freedom. Political intervention can take on a variety of forms, for example, the setting of specific goals, the targeting of certain programs, or the designation of specific agencies to conduct research.

Today, a key component of academic freedom revolves around the debate over the balance between big science and little science. Little science has been considered the backbone of the U.S. scientific enterprise and is characterized by individual grants. Big science is described as highly capitalized efforts with steep start-up and maintenance costs.[107] Big science tends to emphasize the achievement of a few goals at the expense of gradual diffusion of scientific findings throughout society. Because

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107 Smith, p. 11.

of the large expenditures and long timeframes associated with big science, many big science projects are supported by large political constituencies extending beyond the scientific community. It has been argued that the government favors big science because it provides neat packages that administrators in the science funding agencies can manage readily and because it provides pork barrel opportunities for Congress.[108] Large science projects can make it appear that government is "doing something" about whatever is the current buzzword (e.g. global climate change), individual grants do not have the same publicity value.

Peter Likens, President of Lehigh University, expressed concern about the effects on little science of a trade-off in favor of big science. Speaking at the 1988 annual meeting of the AAAS, he claimed that there would be a shift toward more targeted research in the future.[109] In his view, it will be very difficult for scientists not connected with major research institutions or big projects to get funding. Likens remarked that given the pressure on Congress to "do something" about the budget and trade deficits, there will be less money available for basic research. He predicted that money will be available only for big projects that can be touted as helping to improve competitiveness, whether or not they actually do help.[110]

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108 Martino, p. 71.
109 *Ibid.*, p. 69.
110 *Ibid.*

Element 2-2 describes who determines the direction of science and funding amounts for scientific research. Thus, this element characterizes the degree of autonomy granted to scientists by the two models. The social contract model stresses governance of science by experts, while democratic science involves governance by the broad participation of society. Guston and Keniston assert that the requirements for membership in decision making within science are more exclusive, i.e., being a scientist or expert than for membership in democratic decision making in general.[111] Democratic science seeks to encourage and expand participation in decision making, while the social contract limits scientific decision making.

Conflict over the autonomy of scientists has led to a steady growth of legal and bureaucratic regulation of research in respect to the methods and techniques used in its conduct. Hackett has observed that principal investigators on federal research grants are increasingly accountable to their sponsors for keeping their research within the confines of the proposal and for producing substantial research results in the grant period.[112]

Element 2-3 describes the selection process used to decide which research projects to support. Under the social contract, peer review was chosen as the primary method for

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111 Guston and Keniston, 1994, p. 65.

112 E.J. Hackett, "Science as a Vocation in the 1990s - The Changing Organizational Culture of Academic Science," *Journal of Higher Education*, 61(3), 1990, p. 256.

determining which projects receive funding. Peer review is intended to ensure that the best science will be supported. However, peer review is only one method of resource allocation. Other methods exist, such as those based on equity rather than excellence, agency discretion, or Congressional earmarking. Morin argues that the elitism implied in the scientific emphasis on "excellence rather than "equity" is in contradiction to the egalitarianism embodied in the very structure of Congress.[113] An example of the equity method is the Department of Agriculture's pattern of support. Every land grant college or experimental station in the United States gets funds allocated by a formula intended to assure that each state and almost every Congressional district gets it share.[114]

The Office of Technology Assessment (OTA) has defined a Congressional academic earmark as a project, facility, instrument, or other academic research related expense that is directly funded by Congress, which has not been subjected to peer review and will not be competitively awarded.[115] Such allocations have also been called "pork barrel," designed to curry favor with constituents rather than a means to support well-conceived programs. It is suggested that under the democratic science model peer review will be used less in funding decisions in favor of the other allocation

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113 Morin, p. 171.

114 Martino, p. 21.

115 U.S. Congress, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade* (Washington, D.C.: U.S. Government Printing Office, May 1991).p. 87.

mechanisms just described. In short, political review will come to displace peer review in research support decisions.

Peer review, its critics assert, takes the decision making power out of the hands of elected officials and their appointees and puts it into the hands of people who are not accountable to the public.[116] Another criticism of peer review is the claim that the system is biased against researchers at less prestigious universities and that it concentrates federal funds in a small number of universities. Indeed, data for 1989 show that at the institutional level, 10 universities receive 25% of the federal research funding and only 30 universities account for 50%.[117] Some see earmarking as a way to "even up the playing field."[118] Defenders of earmarking emphasize that allocations are intended for the purchase of equipment and the construction of new facilities, not for individual research projects. The NAS, AAAS, and other mainstream groups have condemned academic earmarking.

Ruscio points out that many legislators use earmarks today because they prefer projects offering immediate, tangible returns benefiting only designated recipients over long-term projects promising intangible public benefits.[119] Furthermore, Sapolsky believes that the effect of the Cold

116 Martino, p. 47.
117 U.S. Congress, Office of Technology Assessment, p. 9-10.
118 *Ibid.*, p. 52.
119 K.P. Ruscio, "Policy Cultures: The Case of Science Policy in the United States," *Science, Technology & Human Values*, 19(2), 1994, p. 213.

War's end is seen most clearly in the effort of members of Congress to earmark portions of the federal research budget, especially that of the DOD, for colleges and universities within their districts.[120] However, with tight budgets, earmarked funds can come directly at the expense of regular peer-reviewed programs, and therefore represent a direct attack on the autonomous decision-making mechanisms developed by the scientific community as part of the social contract. Moreover, spending for pork barrel science may actually reduce the average quality of tax-supported science by diverting funds from higher quality projects. Martino notes that this clearly happened in a recent Department of Agriculture budget, in which Congress halted an expansion of the Department's competitive grants program and transferred the funds to earmarked programs.[121]

Element 2-4 describes where supported research will be conducted. Under the social contract, scientific excellence tended to be concentrated in a small number of institutions, which in turn has tended to concentrate some economic advantages in a few localities. Enhancing the research capacity over a wider geographic area or a greater number of institutions would be a goal of democratic science, because it would broaden economic opportunities. For example, new facilities can create jobs and attract new industries. Democratic science would therefore take considerations other

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120 Sapolsky, p. 169.
121 Martino, p. 9.

than existing scientific capability into account when deciding to fund a university facility. Ruscio suggests that foremost among these considerations is whether or not a new facility would contribute to the economic development of the area in which it is located.[122]

Element 2-5 deals with time horizons for the anticipated results of scientific research. The social contract stressed that basic research is a long-term process. Vannevar Bush believed that the pressure for quick answers to practical questions sometimes obscures the need for investing in the improvement of basic science and Bush therefore sought to ensure that decisions on the optimal allocation of resources be protected from short-term political interest. Democratic science would be driven more by political time frames which tend to be relatively short. An elected politician, if he wants to get reelected, strives to produce tangible results during his term in office.

Once the terms of the relationship between science and society are defined, the character of the scientific work force can be determined. Table 3 lists the characteristic elements describing the scientific work force for the two models. These elements will now be briefly explained.

Element 3-1 deals with the size of the scientific work force, specifically the numbers of Ph.D.s produced by graduate programs. The training of future scientists has

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[122] Ruscio, p. 212.

Table 3.
The Scientific Work Force

Element	**Social Contract**		**Democratic Science**
(1) What is the optimal size of the scientific work force?	Train more researchers - with the result that competition for funds increases	-->	Train fewer researchers to ease competition for funds
(2) What career paths should new Ph.D.s follow?	Emulate mentor's career path	-->	Encourage a deversity of career paths
(3) How should work force composition be achieved?	Rely on historic methods to build scientific work force	-->	Broaden the participation of traditionally underrepresented groups

been an integral part of the social contract. The simplifying assumption has been that the primary mission of graduate programs is to produce the next generation of academic researchers.[123] However, as science faculties have replicated themselves, they have generated not only future replacements but also current rivals for resources. Sapolsky argues that given this inclination to reproduce, university research is impossible to satisfy.[124] Democratic science would therefore attempt to better match supply and demand for new Ph.D.s to alleviate some of the competition for shrinking budgets. Some have referred to this process as "Ph.D. birth control."

Element 3-2 deals with the career paths encouraged or promoted during graduate education. Under the social contract model a graduate student was more or less expected to follow his mentor's career path into academic research. However, Chubin suggests that the model whereby a productive mentor would reproduce himself, ten, twenty or thirty times over may be dysfunctional for the 1990s and beyond if the career path of new Ph.D.s is intended to duplicate that of the mentor.[125] He notes that this is not the same as saying there are too many researchers. It may mean there are too many academic researchers, or researchers at Ph.D. granting

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123 National Academy of Sciences, Committee on Science, Engineering and Public Policy, *Reshaping the Graduate Education of Scientists and Engineers* (Washington, D.C.:, National Academy Press, 1995), p. 3.

124 Sapolsky, p. 170.

125 Chubin, p. 125.

institutions, which is the cadre that relies on the federal government for research support. Nelson and Romer believe that graduate programs should move toward training students to work in the private sector and away from the presumption that Ph.D.s or at least good ones, get recycled into academia.[126]

Under the democratic science model, universities and departments would consider the preparation of Ph.D.s for careers beyond academic research. For example, the movement of new Ph.D.s into industry would be encouraged where they can contribute to national competitiveness. Furthermore, much of the socialization of scientists occurs during graduate education. Democratic science would therefore stress broader curricula than are now currently available in graduate programs. Courses focusing on science policy would be good candidates to add to graduate programs.

Element 3-3 deals with how the composition of the scientific work force should be achieved. Under the social contract, the best and brightest students were trained to enter the work force. This resulted in a predominantly white male scientific community following World War II, a community which remains largely intact today. Under democratic science one would expect to see broader participation in the work force by members of underrepresented groups, such as women and minorities.

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126 R.R. Nelson and P.M. Romer, "Science, Economic Growth and Public Policy," *Challenge*, March-April 1996, p. 20.

Increased efforts to prepare more individuals from underrepresented groups would be initiated under the democratic science model.

Another part of the work force element is the participation of foreign students. Congress has criticized research universities for encouraging foreign nationals to participate in publicly supported academic research. Brooks notes that university policies concerning foreign students are alleged to result in the loss of "knowledge assets" paid for by U.S. taxpayers without fair compensation to the ultimate detriment of the economic interests of U.S. citizens.[127] Therefore, under the democratic science model it is anticipated that fewer foreign students would be found in U.S. graduate programs.

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127 Brooks, 1993, p. 204-205.

CHAPTER 4. TESTING THE "DEMOCRATIC SCIENCE" MODEL: THE CASE OF OCEAN RESEARCH

4.1 Introduction

Why is democratization important to a relatively small field like ocean research? After all, expenditures for oceanography constituted only 2.3% of total R&D expenditures at academic institutions in 1993.[128] However, ocean researchers are more dependent than most scientists on soft money. There are very few salaried academic positions for oceanographers. Ocean researchers rely on their research monies much more than traditional scientists and the primary source for those monies is the federal government. In fact, the federal government was the source for 72% of R&D expenditures for academic ocean scientists in 1993 and the federal share has declined approximately 6% since 1980 (See Figure 5).[129] In comparison, the federal government supported 60.3% of all science and engineering at academic institutions in 1993, down from 68% in 1980.[130] As the preceding chapter indicates, there are calls for a more democratic model for federal support of science. Thus, with such heavy dependence on federal funds, changes which affect the federal system of support for science are of paramount importance to the ocean science community.

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128 National Science Board, 1996, Table 5-5, p. 172.
129 *Ibid.*
130 *Ibid.*

In this chapter, the model developed in Chapter 3 will be tested using the ocean science case by examining recent events and current trends in oceanography for the signs of democratization described in section 3.6. Treatment of the democratic science characteristics will in no way be comprehensive. However, relevant examples have been chosen from which some preliminary conclusions can be drawn.

At the outset of this chapter, a point of distinction can be made. Democratization can come about in two different ways: either originating externally to the ocean science community, that is, outside forcing, or from within the community itself, that is, in response to outside forcing. Where applicable, that distinction will be made in the following discussion. The remainder of this chapter will follow the order of the elements listed in Tables 2 and 3.

4.2 Basic v. Relevant Research

Element 2-1 of the model deals with academic freedom, or the tension between the social contract's emphasis on basic research and democratic science's concentration on relevance. For this element, pertinent examples can be cited for both outside forcing and response by the ocean science community.

4.2.1 "Forcing"

"Forcing" will be discussed first in terms of the increased emphasis on large ocean science programs. A second example is provided describing recent legislation for a National Oceanographic Partnership Program. However, clear classification of this example as either external forcing or ocean science community response is somewhat gray. The National Oceanographic Partnership Program has been included as an example of forcing because it will be established pursuant to Congressional legislation. However, the Consortium for Oceanographic Research and Education (which will be described shortly) was instrumental in promoting this program. Thus, it is really a combination of forcing and response which brought about this new initiative. It is acknowledged that classification as either forcing or response can be further complicated by the participation of scientists who later become involved in policy decisions as program managers or agency heads. Although cognizant of these complexities, they will be largely ignored in the simple model suggested here.

4.2.1.1 Large Science Programs

As discussed in Chapter 3, an increase in the number of large science programs, targeted to achieve relevant societal goals, is considered a shift toward democratization. Large science programs are usually managed by international consortia that involve many scientists, multiple agencies, and often a number of countries. A number of oceanographic programs, such as the IDOE dating back to the 1970s, could be characterized as large science programs.

However, 1987 is considered the start of the support of large science programs by NSF's Ocean Science Research Section.[131] Large oceanographic science programs that NSF currently supports include: the World Ocean Circulation Experiment (WOCE), Tropical Oceans, Global Atmosphere (TOGA), Joint Global Ocean Flux Study (JGOFS), Global Ecosystems Dynamics (GLOBEC), Ridge Interdisciplinary Global Experiments (RIDGE), Earth System History (ESH), Land Margin Ecosystem Research (LMER), Arctic Systems Science (ARCSS), and Coastal Ocean Processes (CoOP).

Between 1986 and 1994, NSF's total Ocean Science Research Section (OSRS) budget increased from $57 to $92 million.[132] Most of the 61% growth in the OCRS since 1986 has come with the addition of the Large Science Programs (Table 4). These large, multinvestigator programs now account for approximately 40% of the OSRS budget. The rest of the individually funded programs (the core programs) have not kept up with inflation. In fact, the increases in funding levels of the large science programs have corresponded to decreases in core funding (in terms of constant dollars) in the last decade (see Table 4). Duce and colleagues point out that although the funding for large science programs goes in general to investigators who would otherwise be funded out of NSF's core funds, there is no doubt that these programs

131 Duce et al., p. 126.
132 *Ibid.*, p. 132.

have changed the character of research in oceanography.[133] Moreover, Duce et al., note that if growth continues in this direction without a concomitant increase in core funding it could change fundamentally the way oceanographers do science.[134]

Table 4[135]
NSF's OSRC Budgets
Millions of Current Dollars

	FY 1986	FY 1994	% Change
Core Programs	56.9	54.8	-3.7%
Large Science Programs	0	37.8	
Total	56.9	91.8	61%

Duce and colleagues point out that there are "quality versus coordination" trade-offs inherent in large science programs. For example, less highly ranked proposals were in some cases funded by NSF because they constituted a critical part of a larger program.[136] Thus, it would appear that less stringent evaluation criteria may be applied to proposals that are part of large science program than to proposals submitted to core programs.

Large science programs did not originate in the post-Cold War era. However, they have become a major part of NSF support for ocean science today. The 3.7% decline in core program funding listed in Table 4 translates to a 25%

133 *Ibid.*
134 *Ibid.*
135 *Ibid.*, Table 1, p. 126.
136 *Ibid.*, p. 129.

decrease when inflation is taken into account. Duce et al., conclude that the large science programs supported by NSF have resulted in increased funding in oceanography and may be critical to the maintenance of the level of research activity oceanographers have enjoyed over the last decade.[137]

4.2.1.2 National Oceanographic Partnership Program

Recent legislation was enacted that initiates a new oceanographic program stressing recognition of societal goals in research. On April 23, 1996, Representative Curt Weldon (R-PA) and Representative Patrick Kennedy (D-RI) proposed the National Oceanographic Partnership Act, a bill intended to "optimize oceanographic research and development efforts and accelerate delivery of ocean science products." The bill was passed by the House and Senate and was included in the National Defense Authorization Act for fiscal year 1997 which was signed into law by President Clinton on September 23, 1996 (Public Law 104-201). The new legislation calls for a National Oceanographic Partnership Program to be established by the Secretary of the Navy. A primary purpose of the new oceanographic program is to promote the national goals of assuring national security, advancing economic development, protecting quality of life, and strengthening science education and communication through improved knowledge of the ocean. The fiscal year 1997 appropriation

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137 *Ibid.*, p. 134.

for the National Oceanographic Partnership Program is $7.5 million. Although this program is in its infancy, this example indicates how the rhetoric of ocean science programs is changing. Here we see an acknowledgment of societal needs other than national security. In particular, the new program has as a goal the advancement of economic development.

4.2.2. "Response"

Scarcely a week goes by that *EOS,* the newsletter published by the American Geophysical Union for the entire geophysics community, does not deal with some aspect of the federal science system. Articles, ranging in content from current budget debates to the latest findings on the public's attitude toward science, were few and far between only a decade ago. The increased use of such informal articles represents an effort by the scientific community to inform itself about the external forces affecting the conduct of science today. The ocean research community itself has pursued a number of activities to make its members aware of the current climate for science.

4.2.2.1 The Oceanography Society

The Oceanography Society was established in 1988 to fill a niche left vacant by existing professional organizations. Since its creation, the Oceanography Society has tried to educate its members about the external forces acting on the ocean research community. For example, in

1991, D. James Baker, then president of the Oceanography Society remarked "We as the ocean community, must recognize that we represent only a small part of the federal budget - thus it is essential that we be heard as these [budget] decisions and compromises are being made."[138] Throughout Baker's tenure as president of the Oceanography Society he urged members to use one of the traditional lobbying methods, that is, writing to elected officials, to make them aware of the important contributions to the national interest in the environment that oceanographic programs make. In 1992, *Oceanography,* the journal published by the Oceanography Society, even included suggestions for how to write members of congress."[139] It is interesting to note that the author of that article, sensitive to the current mood in Washington, D.C., specifically suggested that scientists recognize the view of Congressman Brown (see Section 3.5) that "Scientists must view research funding as an opportunity that comes with a responsibility rather than a right."

4.2.2.2 Oceanography in the Next Decade

In 1992, a study was undertaken by the Ocean Studies Board of the National Research Council which culminated in the report *Oceanography in the Next Decade*. The Ocean

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138 D. J. Baker, "President's Report," *Oceanography*, 4(1), 1991, p. 46.

139 S. Horrigan, "Your Input Into the Federal Government - Suggestions for Writing Your Member of Congress," *Oceanography*, 5(2), 1992, p. 128.

Studies Board recognized the dependence by oceanographers on federal funds and the need to establish relevance:

> We cannot take for granted the continued excellence of oceanography in the United States because the foundation of facilities and human resources developed in the past must be renewed constantly. Excellence in oceanography also requires harmony between scientific aims and the pressing needs of society.[140]

Oceanography in the Next Decade explores the structure and support of ocean science research in the United States and provides a blueprint for more productive partnerships between academic oceanographers and federal agencies.

4.2.2.3. Formation of CORE

One of the recommendations of the Ocean Science Board in its report *Oceanography in the Next Decade* was that academic institutions, individually or through consortia, take a greater responsibility for the health of the field.[141] In response to the Ocean Studies Board's recommendation, the Consortium for Oceanographic Research and Education (CORE) was formed in 1994 to expand oceanographic academic community participation in implementation of science policy.

The President of CORE, Admiral James Watkins, highlighted some of the problems currently facing oceanographers in a speech in 1995:

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140 Ocean Studies Board, p. 18

141 *Ibid.*, p. 11.

> Unfortunately, policymakers at all levels of government, as well as the public at large, do not necessarily share the view (that the oceans are important to survival). In fact, in an era when government investment in any activity is very carefully scrutinized and weighed against other expenditures, the lack of understanding of the role oceans play in our evolving world could be devastating.
>
> As a consequence, the oceanographic community is being challenged to place its research agenda onto the same page, but next to, the political agendas, not to establish priorities, just relevance.[142]

Watkins maintains that the oceanographic community today has a heightened responsibility to ensure that oceans gain critical public attention at all levels. Included in CORE's goals are to enhance the visibility and appreciation of the oceans and oceanographic issues by the American public and to foster an environment wherein oceanographic science and education are recognized by the American public as integral to U.S. policy goals in national security, economic development, quality of life and education.

4.2.2.4. Formation of MIT/WHOI Alumnae Assocation

A final example of ocean community response to calls for relevance comes from the recently created alumnae association for the Massachusetts Institute of Technology (MIT)/WHOI Joint Program in Oceanography and Applied Ocean Sciences and Engineering. Members of that association have recognized the importance of the social contract to the

142 J. D. Watkins, "An Agenda for Ocean Sciences in a National Perspective," Doherty Lecture at University of Virginia School of Law, Center for Oceans Law and Policy, April 27, 1995, p. 1-3.

maintenance of oceanographic research. In minutes from an association meeting it was noted that "with the social contract constantly being revised, we need to be able to articulate our position on why people should be interested in ocean science. One of the goals of the association should be education of the public about oceanography."[143]

In summary, the ocean community is pursing a variety of avenues at many levels to establish relevance for support in the post-Cold War era.

4.3 Experts v. Broad Participation

Element 2-2 of the democratic science model concerns scientific autonomy. Democratic science seeks to broaden participation in science and weaken scientific autonomy. It was suggested that under democratic science, governance by experts would yield to governance by the broad participation of society. The example below describes a current oceanographic experiment in which public participation has influenced the conduct of the experiment. This example is illustrative of the forces acting on the ocean science community today.

4.3.1. ATOC

The Acoustic Thermometry of Ocean Climate (ATOC) is a controversial scientific program which illustrates the

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[143] MIT/WHOI Joint Program Alumni/Alumnae Committee, Minutes of the Meeting of October 14, 1995, (Woods Hole: WHOI, 1995).

increasing complexities of conducting a scientific experiment. The ATOC project involves nearly 100 researchers at 11 institutions in seven nations and is led by Scripps Institution of Oceanography. The purpose of ATOC is to measure climate changes in ocean temperature using sound transmissions across ocean basins. In today's bureaucratic environment, 12 permits were required, covering activities ranging from coastal development to the emplacement of equipment on the seabed, before the experiment could be carried out. Permits are a relatively recent requisite for conducting acoustic oceanographic research. Two permits, required by the Marine Mammal Protection Act because of ATOC's possible harmful effects on marine mammals, sparked considerable debate. Media attention was focused on the controversy, resulting in public outcry over potential harm to marine mammals. California's Senators and Representative became involved in the fray and ultimately public hearings were convened and Environmental Impact Statements were required. These requirements held up the program and ultimately resulted in a changed experimental plan. In this example, the conduct of science was fundamentally changed when the public and public officials became involved. Furthermore, this example illustrates the increasing number of bureaucratic requirements which must be met before science can be carried out.

4.4 Project Selection

Element 2-3 of the model lists who selects which scientific projects to support. The primary method of project selection under the social contract model has been peer review. As discussed in Section 3.6, other methods of distributing funds might be used with more frequency under the democratic science model. One of those methods, congressional earmarking will be discussed here.

Usually earmarks for academic institutions have been for facilities rather than programs. In the late 1980s, the federal government virtually stopped providing funds for academic construction projects. Seeking earmarks can be considered a response to combat the inequities some perceive in the system for receiving federal support. However, it is an individual response, usually initiated by an institution, rather than by the scientific community as a whole.

Identifying earmarked projects is often difficult, because of the dexterity of members of Congress in concealing them in spending bills, sometimes as "midnight riders" attached to continuing resolutions and omnibus appropriations. The use of academic earmarks has sky-rocketed since 1980. It is unclear if academic oceanographic institutions are seeking them more frequently in the post-Cold War era. However, the practice is clearly being used today. For example, for fiscal year 1997, an earmark was inserted into the conference report for the appropriations for the Departments of Commerce, State and Justice. Under the section on NOAA/National Ocean Survey it is stated:

> Within the amounts provided for tide and current data, $1,500,000 is provided for a one-time effort to establish a national coastal data center as identified in the Senate report.[144]

The earmark was inserted by Senator Pell of Rhode Island. Although no specific institution was named, the Senate report contains language that basically assures that the national coastal data center will be located at the University of Rhode Island.

4.5 Concentrated v. Disperse Support

Element 2-4 of the model deals with the differences between the social contract's emphasis on concentrated support and democratic science's underscoring of dispersed support. It is suggested that a shift to democratized science would be marked by more institutions receiving federal funding for ocean research.

Certainly federal ocean research was concentrated in a few institutions (such as Scripps, WHOI, and the University of Washington) in the early days of the social contract. Dispersion has occurred, but it is difficult to pinpoint its time scale. Today, CORE lists 37 member institutions with oceanographic programs.

The Ocean Studies Board analysis, reported in 1992, documents that fact that some decentralization of the

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[144] U.S. Congress, House, 104th Cong., 2nd session, September 28, 1996, p. H118655.

oceanographic field has occurred in terms of where Ph.D.-level scientists are employed and in turn where federal funds flow. During and after World War II, ONR and NSF support led to the expansion of the JOI institutions. In 1970, the faculty at Scripps and WHOI constituted approximately 40% of the field. By 1990, the faculty at these institutions comprised only 25% of the total. It is likely the share of federal funds received by Scripps and WHOI dropped proportionately over that same period as more funding was allocated to the other JOI institutions. Data for the more recent period of 1984 to 1991 indicate that concentration of funding for the JOI institutions has been relatively stable. In terms of financial support from NSF, JOI institutions received a relatively constant 45% between 1984 and 1991 and about 40% of ONR funding over the same time period.[145]

4.6 Time Horizons

Element 2-5 of the model deals with time horizons for scientific programs. The social contract stressed long time horizons. It is suggested that as democratic science is more closely linked with politics, scientific time frames would be shortened to the poltical time scale.

In recent years NSF's OSRS has made a conscious effort to increase the average duration of awards, and they have

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145 Ocean Studies Board, p. 133.

been successful (Figure 7). This effort was aimed at decreasing the amount of time that scientists needed to spend applying for and evaluating proposals relative to the amount of time that they could do research. As a result, over the past decade the mean award duration has increased from approximately 2 years to 2.3 years for Marine Geology and Geophysics and from 2.4 to almost 3 years for Physical Oceanography.[146]

4.7 Graduate Education

Element 3-1 of the model deals with the numbers of Ph.D.s produced by graduate programs. It was stated that under the democratic science model it would be anticipated that efforts would be made to better match supply and demand of new Ph.D.s to alleviate some of the competition for federal research funds. It is interesting to note that only a decade ago it was forecast that there would be a serious shortage of oceanographers because applications to enter graduate study in oceanography and ocean engineering had failed to keep pace with demand.[147]

Most graduate students in oceanographic programs receive some sort of financial aid. Traditionally, the primary source of support for that financial aid has been the federal government. Typically, support for graduate students is included in a research grant. Support of this

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146 Duce et al., p. 126.

147 "Running Out of Oceanographers?," *Technology Review*, November/December 1983, p. 80.

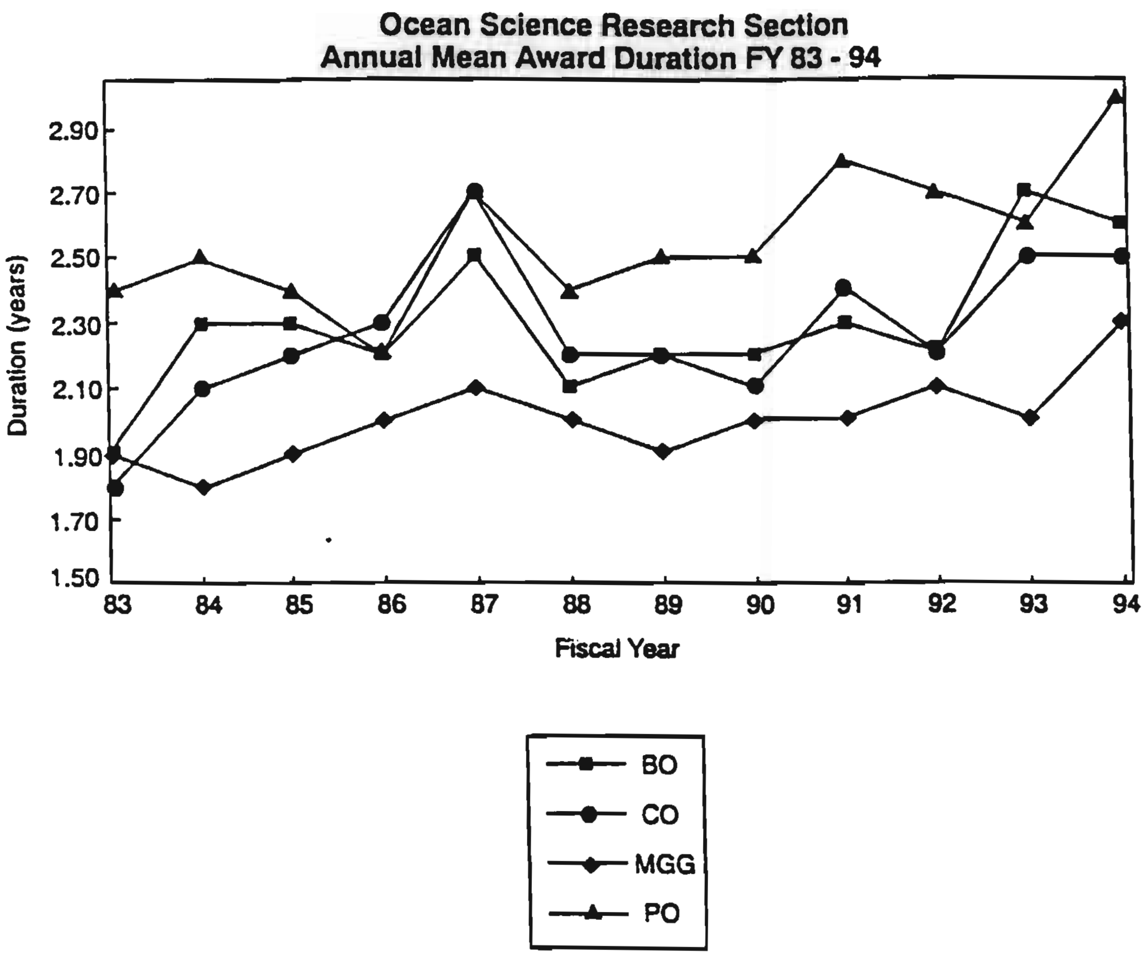

Figure 7. Mean award duration for proposals funded by OSRS disciplinary programs from FY 1983 to FY 1994.

type is called a research assistantship. To alleviate today's heavy dependence on federal research funds, it is hypothesized that under the democratic science model fewer opportunities would be available for research assistantships.

Table 5 presents recent data on the sources of graduate student support in ocean science programs. Twenty-four schools participated in the survey from which these data are taken. Ten of the schools are the JOI institutions, which are listed in Section 2.3.2. The other 14 institutions are: The University of Alaska - Fairbanks, the University of Connecticut, the University of Delaware, Duke University, Florida State University, the University of Maine, the University of Maryland, North Carolina State University, the University of North Carolina at Wilmington, Old Dominion University, Rutgers University, the University of Southern Mississippi, the State University of New York at Stony Brook, and the College of William and Mary (Virginia Institute of Marine Science). The upper portion of Table 5 is for the 14 non-JOI schools, while the bottom portion includes only data for the JOI schools.

Table 5.[148]
Sources of Student Support (%)

Year	RA	TA	IF	OF	Other	No support
			Non JOI			
1993	64.49	12.15	4.67	7.48	1.87	9.35
1995	49.07	12.05	16.40	3.33	15.52	19.25
			JOI			
1993	48	9	13	10	7	13
1995	58.86	6.5	7.5	7.78	9.10	9.65

RA = research assistantship
TA = teaching assistantship
IF = institutional funds
OF = outside fellowships
Other = other support including foreign support

Data for the non-JOI schools indicate a drop in the percentage of students supported by research assistantships and rises in the percentages of institutional funds and other fellowships, and also an increase in the percentage of students with no support. These data are consistent with what one would expect in a model of democratic science. Today, demand for federal financial support is outpacing funding increases. Under the democratic science model attempts would be made to match supply and demand. Decreasing the availability of federal funds for research assistantships would lead to fewer new ocean science Ph.D.s

148 R.W. Spinrad and A.R.M. Nowell, "Advising the Next Generation: Career Opportunities in the Ocean Sciences," *EOS, Transactions of the American Geophysical Union*, 76(3): OS46.

and presumably ease competition for scarce resources. If students receive no support they are more likely to pursue careers other than ocean research.

The data for the JOI schools do not support the same conclusions as the non-JOI school data. In fact, the percentage of research assistantships increased and the percentage of students with no support declined from 1993 to 1995. However, it must be noted that the number of new students enrolled in graduate ocean science programs decreased significantly between 1992 and 1995 (Table 6). In fact, the JOI school enrollment dropped 59% in three years. Thus, although the percentage of students supported by research assistantships increased, the number of students decreased.

Table 6.[149]
New Students Enrolled

	All Schools	JOI Schools
1992	450	250
1995	308	147
% decrease	32%	59%

Clearly, fewer Ph.D. oceanographers will be produced by ocean science graduate programs in the near future. There are other signs that changes are occurring in graduate

149 *Ibid.*

programs. A.L. Pierson, Associate Dean, at Woods Hole Oceanographic Institution, notes that there are no overt efforts to control the number of Ph.D.s produced by the MIT/WHOI Joint Program.[150] However, shrinking principal investigator research budgets are indirectly controlling graduate numbers. In the past, students could be accepted into the MIT/WHOI Joint Program and sources for funding determined after admission. Now however, funding to support graduate students must be guaranteed prior to a student's acceptance into the Joint Program. In fact, 1996 witnessed the entry of the smallest class into the Joint Program since 1974.[151]

One final point to note is the that decreasing class sizes are coming at a time when interest in graduate study in the ocean sciences is increasing. Since the end of the Cold War, the number of applications to graduate programs in ocean sciences has been rising (Figure 8). In fact, the JOI schools saw a 79% increase in the number of applications between 1988 and 1995.[152] With lack of support, good students will likely turn away from ocean sciences and pursue graduate study in other fields.

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150 A.L. Pierson III, Associate Dean, Woods Hole Oceanographic Institution, personal communication, October 4, 1996.

151 *Ibid.*

152 Spinrad and Nowell.

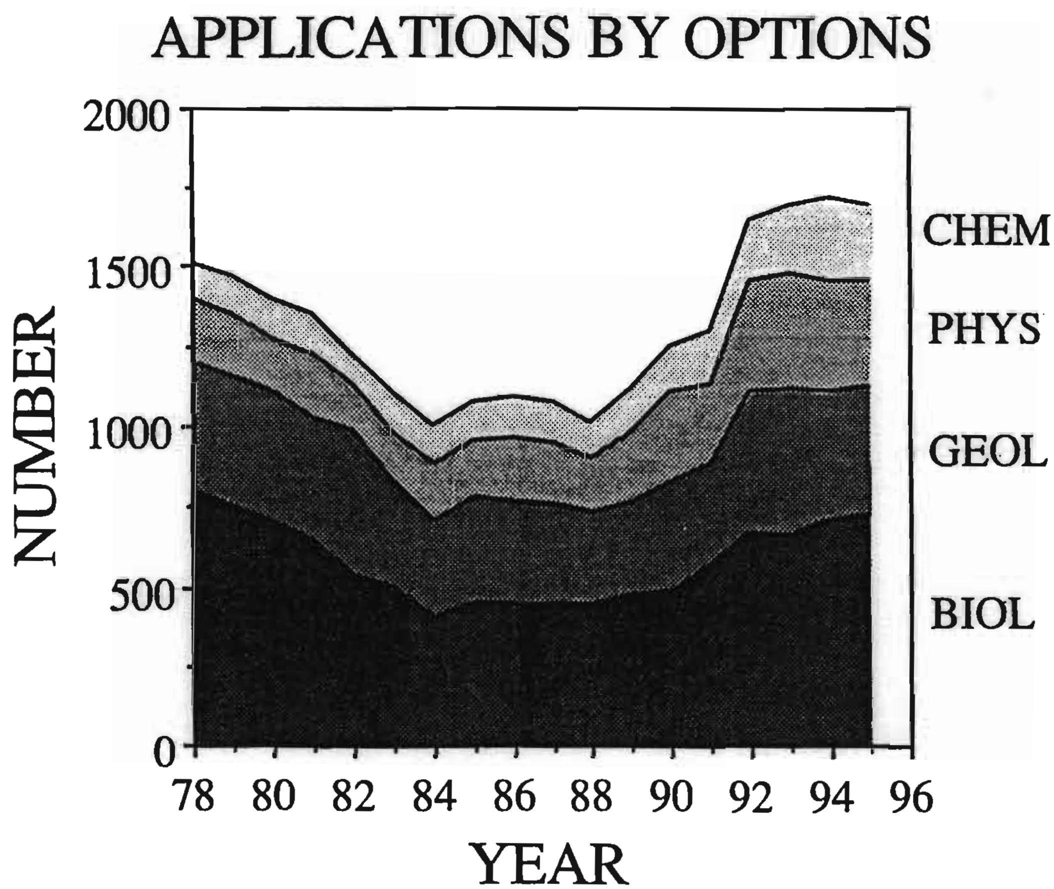

Figure 8. Applications to graduate programs in ocean science.

4.8 Career Paths

Element 3-2 of the model deals with the career paths encouraged or promoted during graduate education. Under the social contract, a student was expected to emulate his mentor's career path into academic research. It is suggested that the democratic science model would encourage a diversity of career paths in response to the declining availability of permanent research positions and the need to promote economic competitiveness.

Table 7 lists the career paths for Ph.D.s from graduate oceanographic programs. Data are taken from all oceanographic schools surveyed.

Table 7.[153]
Ph.D. Employment (%)

	1990-1993	1992-1995
University	67	55.55
Federal Agency	10	13.65
Commercial	10	9.53
State Agency	1	3.17
Other	1	.5
Non-U.S. who left country	7	10.17
Unknown	1	4.76
Unemployed	3	2.18

153 *Ibid.*

Table 7 does show a decrease in the percentage of Ph.D.s obtaining employment at universities, consistent with the prediction of the democratic science model. However, it was expected that there would be a percentage increase in Ph.D. recipients pursuing industrial careers. However, Table 7 shows that the share of Ph.D.s entering industry remained virtually the same over the period 1990 to 1995.

Pierson notes that for MIT/WHOI Joint Program alumnae there was a 4% decrease (from 58% to 54%) from 1993 to 1995 in the number of graduates employed in academic positions and a 4% increase in those with other types of employment.[154] Government and industry figures remained constant. Furthermore, Pierson notes that he has observed that over the last 8 to 10 years students have been considering a broader spectrum of career paths. In particular, more graduates are pursing opportunities at teaching schools rather than research institutions.

The topic of diverse careers has begun to receive increased attention in recent years. Pedlosky maintains that successful graduates of the MIT/WHOI Joint Program in Physical Oceanography go without exception into an academic or government research career.[155] However, others have begun to suggest different alternatives. For example, Sharp asserts that "We must be more open in our evaluations of

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154 Pierson.

155 J. Pedlosky, "Graduate Education in Physical Oceanography," *Oceanography*, 5(2), p. 119. 117-120.

what career paths are important and valid for our graduates to pursue."[156] Furthermore, Beagle asserts that "The challenge to the scientific community is to understand the importance of careers outside academia where scientists can make important contributions to science in forming public policy and societal priorities alongside research."[157]

At the 1995 fall meeting of the American Geophysical Union in San Francisco a special session was held on alternative careers in the ocean sciences. It was recognized that such a session was appropriate in view of current trends in science research funding and the relative scarcity of permanent positions. The convenor of the session acknowledged that information about alternatives is hard to find and the session was designed to provide attendees with opportunities to explore employment in areas other than traditional academic and teaching fields, such as policy, science journalism, environmental management, aquaculture and biotechnology. This topic of graduate education also received attention at the Oceanography Society's April 1995 meeting at a session entitled "Education in Ocean Sciences: Careers and Curricula."[158] Recently, CORE began a survey to answer critical questions about how well the oceanographic

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156 J.H. Sharp, "Diverse Career Possibilities and a Broad Oceanography Curriculum," *Oceanography*, 8(3), 1995, p. 107

157 C. J. Beagle "Fire and Funds: A Young Scientist's Perspective," *Oceanography*, 8(1), 1995, p. 34.

158 "TOS Fourth Scientific Meeting," *Oceanography*, 8(1), 1995, p. 40.

community is training graduate students for a variety of careers.

4.9 Composition of the Scientific Work Force

Element 3-3 of the model deals with the composition of the scientific work force. Traditionally, ocean science has been dominated, as has science in general, by white males. The democratic science model seeks to broaden the participation of traditionally underrepresented groups, such as women and minorities. Therefore, if ocean science is being democratized one would expect to see more women and minorities in the student populations and in the numbers earning Ph.D.s.

Table 8 lists the offers of acceptance to oceanographic schools for graduate study extended to men and women. The left half of the table is for all oceanographic schools. On the right are offers extended by the JOI schools.

Table 8.[159]
Offers of Acceptance (%)

	All Schools		JOI Schools	
Year	Male	Female	Male	Female
1991	62	38	61	39
1993	57	43	55	45
1994	49.28	50.72	49.11	50.89
1995	43.88	56.12	37.63	62.37

159 Spinrad and Nowell.

The share of offers extended to men decreased from 1991 to 1995. In 1994 offers were split approximately evenly between men and women. However, in 1995 more women than men were offered acceptance to graduate study in ocean science. The Ocean Studies Board found that the percentage of women earning doctorates in the ocean sciences rose from 10% in 1980 to almost 30% in 1991.[160] The trends shown by Table 7 indicate that the scientific work force will be more evenly made up of women and men in ocean sciences.

Table 9 presents a snapshot comparison between science overall and oceanography in 1993 of students in residence. This table shows that oceanography had a smaller percentage of minority and women students than science overall in 1993.

Table 9.[161]
Students in residence 1993

	% Minorities (U.S.)	% Women (U.S.)	% Non-U.S.
Science Overall	13.01	43.54	20.66
Oceanography	7.09	38.30	22.50

Another part of the work force element concerns the education of foreign students. Under the democratic science model one would likely see less foreign students in U.S.

160 Ocean Studies Board p. 134.
161 Spinrad and Nowell.

schools. However, Table 9 shows that in 1993 the percentage of non U.S. students in oceanography exceeded the share for science overall. The percentage of foreign students earning doctorates in oceaonography in 1991 was about 30%.[162]

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162 Ocean Studies Board, p.134.

CHAPTER 5. CONCLUSIONS

Science in general, and ocean science in particular, has entered a period of extreme stress and uncertainty. The stress arises from a variety of factors, ranging from inadequate funding levels to declining proposal success rates. Uncertainty can be attributed to the end of the Cold War and the loss of national security as a strong rationale for the support of science. To comprehend the current situation, one must understand how science is supported in the United States and how this system of support developed.

Prior to World War II, science in the United States was largely supported with private funds. The war mobilized scientists and made federal resources available to them to support their work. The success of scientists during the war generated the widespread belief that scientific research was the key to progress, national welfare, and security and should be continued after the war with government support. Following the war there were debates about the form support for science should take: the more democratic view advanced by Kilgore, or the more elitist approach advanced by Bush. Kilgore argued that science should be directed to meet social and economic goals. Bush called for support of science on scientists' own terms. Bush's ideas prevailed. However, in some ways the debate between Kilgore and Bush has never fully been resolved as tensions between science and democracy still persist today.

What emerged from the postwar debate on the organization of science was the social contract, negotiated between the federal government and the scientific community. Under the social contract, special privileges and freedoms were conferred on scientists in the expectation that they would deliver great benefits to society as a whole. The social contract emphasized basic research carried out primarily in universities as well as freedom and autonomy for scientists. Under the social contract, the federal government became the principal patron of university research following World War II.

Academic science grew enormously under the social contract. In 1960, federal expenditures for academic R&D were less than half a billion dollars. By 1995, they had risen to $13 billion (in current dollars). Between 1973 and 1993, the number of Ph.D.-level researchers at academic institutions approximately doubled.

Ocean science flourished under the social contract also. However, its growth and maintenance can be distinguished from the general science case in a number of ways. Ocean researchers are more dependent than other scientists on federal funds. In 1993, the federal government supported 72% of R&D expenditures for academic ocean scientists in comparison to 60.3% of expenditures for all science and engineering at academic institutions. During the period that the number of Ph.D. scientists and engineers at academic institutions doubled, the number of Ph.D.-level oceanographers at academic institutions tripled. Finally, ocean researchers are more dependent on the Department of Defense for support than other scientists. For the 1993-1995 period, DOD financed 38% of oceanographic research in comparison to less than 10% of all science and engineering.

Slow growth in federal funding for academic oceanography, characteristic of the 1980s and 1990s, has not kept pace with the proposal pressure generated by the large increase in the number of academic oceanographers. As a result, success rates for proposals have dropped. At NSF, the success rate in ocean sciences fell from 40% in 1983 to 29% in 1994. As competition for funds continues to increase, negative consequences may become apparent that the oceanographic community will need to address. For example, scientists may be inclined toward safer, less risky projects to better their chances of funding; young investigators may be denied support in favor of more experienced proposal writers; and talented students may be discouraged from pursuing academic careers.

The social contract for science is currently in a fragile state and is undergoing a rethinking such as it has not experienced since its inception. The two parties that forged the contract, the federal government and the scientific community have grown and changed enormously since the contract was first implemented. Many times in the last 50 years commentators have predicted the imminent dissolution of the social contract between the scientific community and the government. For example, the early 1970s were a critical period for the survival of the social contract. Yet the relationship between the government and the scientific community did not deteriorate to the extent anticipated at that time. Today, many of the same negative signals that existed in the early 1970s are again evident. What sets the current period apart however, is that the Cold War has ended and national security is no longer a driving force for the federal support of U.S. science. It is now being argued that pressing national needs, deferred to meet the security challenges imposed by the Cold War, need to be addressed. Furthermore, without the protection of national security to keep science aloof from politics, science is now on a more equal footing with other societal concerns vying for federal dollars.

The National Science Board survey data indicate that the public perception of science has not changed appreciably in the last two decades. Science and science leaders are comparatively well regarded by the American public. However, survey data also point out that most Americans do not have a deep understanding of science. Thus, the public's esteem for science is based more on faith than knowledge.

Survey data do show that Americans have a significant concern about the oceans. In 1996, the Mellman Group, Inc. found that 85% of those surveyed believe that the government needs to do more to protect the oceans because the oceans are thought to be in trouble environmentally. The oceans' problems are believed to stem from a variety of sources, however, oil spills and chemical runoff are the problems perceived to be the most serious. The public's concern presents an opportunity for the oceanographic community to rally popular support for oceanographic causes. Although it must be acknowledged that the public's concerns about the health of the oceans would likely lead to applied rather than basic research opportunities.

Although there is public support for science, the rationales behind that support have shifted from national security to economic security and health care. However, economic security and health care rationales are likely to protect science's independence much less than national security. Furthermore, with the end of the Cold War, it may finally be time to confront the tensions between science and democracy which have persisted since the social contract was first negotiated and draft a new compact between the federal government and science.

It was suggested in this paper that the new social contract will assume a more democratic form for the support of science. A model was developed by describing the elements of the federal support system for science and contrasting characteristics of a democratic scientific system with those of the social contract. The democratic science model has been characterized by: an emphasis on relevance, the broad participation of society, resource allocation mechanisms other than peer review, disperse support to broaden economic benefits, short time horizons, the training of fewer Ph.D.s, the encouragement of a diversity of career paths, and the participation by underrepresented groups in the work force.

The model was then tested using the case of ocean science. The case of ocean science is particularly relevant because oceanographers are more heavily dependent on federal funds than are other scientists. Thus, oceanographers should be particularly attentive to changes in the federal system of support for science.

It was suggested that the democratic science model would favor support of large science programs over little science. Large science programs it was asserted, provide neat packages, substantial publicity value for politicians, and are usually targeted to address relevant society concerns. Often goals appear more tangible for large science programs than they do for little science projects. It was found that large ocean science programs now account for approximately 40% of the NSF OSRS budget. However, more importantly, as the large ocean science programs at NSF have grown, the amount of research money available in the core programs has, on the average, decreased. When inflation is taken into account, the decrease in core program support has been substantial. Large science programs have thus changed the character of research in oceanography. If growth continues in large science programs without corresponding increases in core funding it could change fundamentally the way oceanographers do science in the future. The ocean science community needs to be aware that there are quality versus coordination trade-offs inherent in large science programs. For example, less highly ranked proposals were in some cases funded by NSF because they constituted a critical part of a larger program. This can lead to two sets of criteria being applied in funding decisions: one for core programs and possibly a less stringent one for large science programs. The ocean science community needs to consider what kind of message this example sends to young investigators. Furthermore, it appears likely that large science programs will be critical to the maintenance of support for oceanographers in the near future. If scientists join large science programs to better their chances of future support how will scientific excellence, creativity and freedom be impacted?

In today's political climate, the rhetoric for the support of ocean science is changing. Societal goals and economic considerations have been included in new legislation establishing the National Oceanographic Partnership Program. CORE, formed in 1994 to expand oceanographic academic community participation in science policy making, was instrumental in the passage of this legislation. Lobbying has been promoted by the Oceanography Society to make elected officials aware of the important contributions oceanography makes to society. Clearly, the ocean science community is pursuing a variety of avenues at many different levels to establish relevance for support in the post-Cold War era.

The ATOC experiment was cited as an example of a program where broad public participation has affected the conduct of oceanographic research. Increased bureaucratic requirements and broader public participation in decision making can weaken scientific autonomy and fundamentally change how science is conducted. Ocean scientists must be aware of the trend toward expanded bureaucratic control and be prepared for the complexities it introduces into the experimental process. For example, ocean scientists may increasingly need to budget time and program resources to comply with requirements such as Environmental Impact Statements.

Political resource allocation is currently being used in ocean science funding decisions. An earmark was included in the fiscal year 1997 budget for a national coastal data center. The use of earmarks has been condemned by the NAS and the AAAS because it corrupts the merit-based process of research support that has been one of the strengths of American science and engineering. It represents a direct attack on the autonomous decision making mechanisms developed by the scientific community. Furthermore, it may actually reduce the average quality of tax-supported science by diverting funds from higher quality projects. It has been argued by defenders of earmarking that funds for facilities have been hard to raise. However, in today's fiscal climate of tight budgets, it cannot be ignored that earmarked funds may come at the expense of regular peer-reviewed programs. What happens to the peer review system if other institutions follow suit in seeking academic earmarks for facilities? The ocean science community should develop a response to the use of earmarks to ensure a balanced program of support for all members of the community.

It was indicated that some decentralization of the oceanographic field has occurred, but the time frame over which this dispersion has taken place is unknown. The JOI institutions remain a critical nucleus of oceanographic activity. Federal funding for the JOI schools has remained relatively constant at a level of between 40 and 45% from the primary supporters of basic ocean research, NSF and ONR.

Another characteristic of the democratic science model was short time horizons. Fortunately for oceanographers, shorter time horizons have not been evident in the past few years. In fact, the mean award duration at NSF has actually increased over the past decade. This means that ocean scientists can spend more time conducting research, rather than writing proposals.

The number of new Ph.D.s being produced by ocean science graduate programs will decline in the near future due to significant decreases in class sizes in recent years. Since 1992, the number of new students enrolled in ocean science graduate programs decreased 32% for all schools and 59% for the JOI schools. These decreases can be attributed to lack of support for students. Interest in ocean sciences has not declined, but rather grown dramatically as shown by the increase in the number of applications to ocean science graduate programs. However, given the decreased acceptances to graduate programs, good students will turn to other fields.

It was shown that attitudes toward diverse ocean science career paths have begun to change. The model whereby the measure of success is whether or not an individual enters academia upon graduation is being reconsidered. This reconsideration is to some extent being forced on the community by the decrease in the number of available academic positions for new Ph.D.s. In turn, Ph.D. employment at universities has decreased in the last few years. Dialogue has begun, but more efforts need to be made to promote alternative careers and to examine graduate curricula so that students are better prepared for diverse careers.

The ratio of women to men accepted to ocean science graduate programs has changed considerably in recent years. In 1995, more women than men were accepted to oceanographic programs. Thus, in the near future it is anticipated that women will comprise a larger percentage of the oceanographic work force. At this time, ocean science does not appear to be discouraging foreign students from its programs. The percentage of non-U.S. students in oceanography was slightly higher than the U.S. science average in 1993.

If a scorecard were tallied it would appear that all of the characteristics of the democratic science model described in this paper, with the exception of short time horizons, are evident today. Although some of the changes in the context in which ocean science is conducted are subtle, there are indications that ocean scientists have less freedom and autonomy today than they had shortly after World War II. It has been asserted that the dawning of democratic science is a result of the end of the Cold War. However, it is likely that the changes that have occurred in oceanography would have occurred without the end of the Cold War. The federal deficit and shrinking discretionary program budgets could not have been ignored forever. However, it is suggested that the end of the Cold War hastened the inevitable.

Academic oceanography really knows no other model than the social contract. There was very little academic oceanography in the United States prior to World War II. It is possible that some of the trends documented in this paper are simply the result of the maturation of the field. However, enough issues have been raised here that future study is warranted. The ocean science community needs to continue to respond to changes now occurring within the U.S. research enterprise.

CHAPTER 6. RECOMMENDATIONS

The findings of this research suggest that changes are evident in the system of support for ocean science. With such heavy dependence on federal funding, the ocean science community needs to be prepared for shifts in the paradigm for federal support. Recommendations have therefore been formulated to address two themes central to the support for science: (1) why the federal government supports science and (2) how the government supports science.

6.1 Why

Since World War II, support for science has been based on an implicit contractual agreement between the government and the scientific community. The public provides the funds which the government disburses in accordance with the social contract in the expectation of receiving benefits. Scientists must keep in mind that it is a social contract, science is not apart from, but a part of society. Furthermore, scientists must understand the contractual nature of the relationship and keep their end of the bargain, which is to provide benefits to society.

If scientists want to maintain the social contract they cannot present a case for support that is based on the frustration and discomfort of individual worthy scientists. They must present a case rooted in the welfare of the nation. Ocean scientists need to link their research with society's most pressing problems. Today, as national security yields to international economic competitiveness and domestic well being on the list of national priorities, continuing support for science will depend upon the scientific community's willingness and capacity to contribute to the resolution of economic and domestic problems. Therefore scientists must make the case that basic research in ocean sciences stimulates national economic growth and contributes to the long-term welfare of the nation. Moreover, it is not enough for the scientific community to simply claim that their research is "useful". As Briscoe and Evans assert "The products of the research need to bear fruit."[163] The relevance of research to the public interest must be demonstrated in concrete projects. Briscoe and Evans suggest that the fundamental problem for the ocean science community is the application of research results.[164] They encourage academic researchers to spend some time working with the applications community, including policy makers. Furthermore, they advocate more integration of the people who do research with those who hope to use it.

Basic ocean research is a long term investment, benefits may not be evident until very far in the future. Therefore, educating the public about why it should make the long term commitment is key to public support. Hamburg states that universities have tended to take for granted a

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[163] M. Briscoe and D. Evans, "The Application of Marine Sciences in the Coming Decades," Oceanography, 6(3), 1993, p. 140.

[164] *Ibid.*

special understanding on the part of the public, which may have been presumptuous.[165] Moreover, Beagle believes that scientists over the last decades have lost track of the one principle vital to their existence: if the scientific community wants the American people to make the long-term investment in basic research, then scientists must make the long-term investment in educating the people to take part in a more scientifically literate society. Remember, esteem for science is based more on faith than on knowledge. Scientists need to turn that faith into knowledge, knowledge which will provide a stronger foundation from which to draw support.

Scientists must take the time to explain to the public and elected officials what they do, why they do it, and how it contributes to understanding the natural world. Public education may be difficult for scientists whose talents lie in the laboratory rather than in communicating with the public. Morin asserts that scientists are single-minded in pursuit of their research goals and have little time or energy left over for other activities and interests, at least during their training and their scientifically productive years.[166] As a result, he belives they tend to view public activities with disdain and to be often naive, sometimes arrogant and generally ineffective when they do engage in them. However, there are individuals who can

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[165] D.A. Hamburg, "Conclusion: Constructive Responses to the Changing Social Context of University-Government Relations." in T*he Fragile Contract: University Science and the Federal Government*, ed. by D.H. Guston and K. Keniston, (Cambridge: MIT Press, 1993). p. 229.

[166] Morin, p. 136.

bridge the gap between scientists and the public. The ocean science community should embrace such individuals to bring the messages of ocean science to the public.

The complement to public education must be the acceptance of the public's reasonable concerns, demands, and fears, in other words, educating scientists to play the public's game. As Schmitt says "It's not just a matter of educating the public and the politicans about us [scientists]. It is also a matter of educating ourselves about them [the public] and their needs."[167] Based on the results of its 1996 survey, the Mellman group suggests that instead of trying to re-educate the public, the ocean community should focus its attention on those problems that citizens already believe to be the most serious.

6.2 How

Today, basic ocean research is only one small part of a very complex scientific research enterprise. The economic realities confronting the U.S. over the next decades mean that scientists can expect constraints on funding to persist. In the near future, there likely will not be enough federal funds to satisfy every scientist in the United States. It is therefore important for scientists to understand how research is supported in this country. Furthermore, given the inevitable fact that ocean science

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167 R.W. Schmitt, "Public Support of Science: Searching for Harmony," *Physics Today*, 1, 1994, p. 31.

competes with other good purposes for the favorable opinion of the public and the financial support of a democratic government and given the end of the Cold War, the future relationship of science and government depends heavily on the scientific community's capacity to articulate a plausible rationale for the public support of science.

Until now, much of the justification of science has come from the top of the science community. But policymakers are nearly unanimous in their assessment that how the science community weathers the current fiscal crisis depends on how well individual researchers state the case for science in their communities and their congressional districts.[168]

Many of the most important influences on the research enterprise, for example political judgements and economic policies, are governed by persons outside of the research community. A segment of the ocean science community needs to become more sophisticated, informed, and influential in the national dialogue concerning the research enterprise. Ocean scientists can no longer ignore the political process and trust that someone in Washington will eventually realize how important their work is to the future of the nation. There are too many groups with what may well appear to be more immediate needs than those represented by the long-term investments required for ocean science. Scientists need to

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168 Carlowicz, p. 83.

recognize the terms of the debate, the criteria applied in decisions, and the perceptions of policymakers and the general public. It is suggested that the ocean science community would benefit greatly if it could identify and support those individuals who are willing to undertake efforts to bridge the gap between science and the democratic political system.

Ocean scientists must further understand that in an environment of fiscal constraint not every project can be funded and priorities therefore need to be set. Ocean scientists, through their professional societies and other forums, need to agree on and articulate research priorities. Otherwise, politicians will do it for them.

Lastly, the ocean research community needs to develop responses to the usage of political methods of resource allocation such as earmarking if it wants to maintain the integrity of the peer review system.

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