PUBLICATION

Science Literacy: Essential for Decision Making

Joann P. DiGennaro

January 2005

Program on Information Resources Policy

Center for Information Policy Research

Harvard University

The Program on Information Resources Policy is jointly sponsored by Harvard University and the Center for Information Policy Research.

Joann P. DiGennaro founded the Center for Excellence in Education with the late Admiral H.G. Rickover and has served as its President since 1983. CEE sponsors the Research Science Institute and the USA Biology Olympiad for academically talented students to nurture them to careers of excellence and leadership in science and technology, and to further international cooperation among future leaders of the global community. To date, Ms. DiGennaro has negotiated science and educational agreements between the Center and 49 nations, and she advocates education for the gifted in speaking engagements in many countries. An attorney by training, she is the author of Scholarships and Fellowships for Math and Science Students. Joann DiGennaro serves on numerous Boards, including the US Army War College and the Sts. Cyril and Methodious Foundation in Sofia, Bulgaria. She is active in US philanthropy and has implemented educational and business projects in China and Bulgaria. She formerly served on the Board of Visitors of George Mason University and has consulted for UNESCO in several southern nations of Africa.

E-mail: pirp@deas.harvard.edu URL: http://www.pirp.harvard.edu
ISBN 1-879716-92-5 **P-05-1**

January 2005

PROGRAM ON INFORMATION RESOURCES POLICY

Harvard University **Center for Information Policy Research**

Affiliates

AT&T Corp.
Australian Telecommunications Users Group
BellSouth Corp.
The Boeing Company
Booz Allen Hamilton
Center for Excellence in Education
Commission of the European Communities
Critical Path
CyraCom International
Ellacoya Networks, Inc.
Hanaro Telecom Corp. (Korea)
Hearst Newspapers
Hitachi Research Institute (Japan)
IBM Corp.
Korea Telecom
Lee Enterprises, Inc.
Lexis–Nexis
John and Mary R. Markle Foundation
MITRE Corp.
Motorola, Inc.
National Security Research, Inc.
NEC Corp. (Japan)
NEST–Boston
Nippon Telegraph & Telephone Corp (Japan)
PDS Consulting
PetaData Holdings, Inc.
Samara Associates
Skadden, Arps, Slate, Meagher & Flom LLP
Strategy Assistance Services
TOR LLC
TransMedia Exchange
United States Government:
- Department of Commerce
  - National Telecommunications and Information Administration
- Department of Defense
  - National Defense University
- Department of Health and Human Services
  - National Library of Medicine
- Department of the Treasury
  - Office of the Comptroller of the Currency
- Federal Communications Commission
- National Security Agency
- United States Postal Service

Verizon

ACKNOWLEDGEMENTS

It is has been said that few thoughts are original. It also has been stated that solutions to difficult problems need to be broken into simplest components and synthesized and massaged with information already out there. Such have been my observations and thoughts in completing this document: *Science Literacy: Essential for Decision Making*.

Professor Anthony G. Oettinger, Chairman, Program on Information Resources Policy, Harvard University, provided me the opportunity to work under his seasoned and meticulous tutelage these past few years to complete this document with an interdisciplinary focus about science for policy and policy for science. What seemed like a slam-dunk became an auspicious and laborious undertaking. From the corporate world to the academic world, from law school to over twenty years of administrating a nonprofit educational organization, I was not as prepared as I thought I was for the rigors of looking at issues from venues of all requisite stakeholders. Professor Oettinger was patient in guiding my political orientation to that of a chronicler of scientific policy analysis. I am a better person for having had the honor to work with this distinguished scholar, a leader in US governmental policy.

As President of the Center for Excellence in Education, that I co-founded with the late Admiral H.B. Rickover, I owe a great deal of gratitude to the Board of Trustees and to the Center's Chairman, Mel Chaskin, who approved my acceptance of Research Affiliate at Harvard in the Department of Program Information Resources Policy. I particularly thank Admiral Bob Inman, the Center's former Chairman of the Board and my mentor, for encouraging me to undertake this project. To Michael Jordan, Chairman and CEO of EDS, and to Gordon Binder, former Chairman of Amgen, I am indebted for their conversations and guidance. To Nick Gouletas, Chairman of American Invsco, I tip my hat for saying, "Go for it. You have things to say that need to be heard."

This work is my own. For any mistakes, I am totally responsible. As to differences of opinion about the content, I welcome more dialogue to better understand decision-making and to assist in the formulation of better US policy.

Contents

Tables

Executive Summary

This study explores the relationship between scientific knowledge and government decision-making from the perspective of the author's two decades of experience as an educator, as a teacher, professor, and president of an educational nonprofit organization, from the analytical skills and willingness to question assumptions honed by her education and experience as a lawyer, and from her service in government.

Public Perception and Public Policy

The process of acquiring and using knowledge is both individual and collective. Factual information is integrated into a person's belief system, which colors his or her perception of the information and determines what, if any, action results from the information. How factual information and opinions are received by the individual is affected by the character of modern communications and mass media. The effect of communications and mass media on the polity is an aggregate of the individual processes of integration of information and the resulting actions. The over-simplification of information and errors in reporting found in mass media are impediments to understanding of scientific information by the public.

Science and Public Policy

"Science" includes both the process of seeking knowledge and the knowledge gained from that process. The level of scientific knowledge in this country is generally low. In varying degrees, this lack of knowledge is shared by the public, the media, and government officials, most of whom are generalists or involved in work not directly related to science. Many policy decisions are affected by the lack of scientific knowledge, and greater knowledge would improve the results of those decisions. The impact of low scientific knowledge among decision makers, the media, and the general public is explored in three areas: (1) the continuing controversy about silicone breast implants, (2) nuclear power and Three Mile Island, and (3) the funding of scientific research.

Silicone Breast Implants

The interaction of a lack of scientific knowledge, fear, and the decision-making processes of the judicial branch of government (and to a lesser extent the executive and legislative branches), led to litigation and protective regulation concerning the use of silicone breast implants. Hindsight has shown that this reaction was unsupported by proper scientific evidence. Yet, despite scientific findings of no demonstrable harm by both a court-appointed panel of experts and its own advisory panel of experts, the FDA continues its ban. The episode highlights problems related to the use of scientific evidence in the judicial process, and the urge to regulate

to prevent the possibility of danger even absent properly conducted studies showing that the danger exists. The persistence of such decisions, which often do not allow the weight of scientific evidence to prevail, demonstrates how science education needs to be strengthened for policy decisions.

Three Mile Island and Risk

The nuclear power industry and the incident at Three Mile Island test the limits of scientific knowledge in policy making. Policy is made in a political context which includes a large emotional component in public opinion. At what point does public fear outweigh scientific risk assessment in deciding policy? While the odds of an accident are extremely small, the public focus is more on the gruesome and fatal impact on any victim of such a rare accident. The TMI situation, where safety features in the design actually prevented a meltdown, was worsened by a lack of knowledge of the low risk of a disaster on the part of decision-makers, the media and the public. The long-term effect of the public,s reaction to TMI, based on a lack of knowledge of the safety features in reactor design and of the excellent safety record of power reactors in the United States, was to apply the *coup de grace* to an already ailing industry, at great cost both to the environment and to meeting demand for electric power.

Research Funding

Government funding for scientific research, especially basic research, has become increasingly political. Lack of scientific knowledge in the public lessens support for research from which the public perceives no immediate benefit, which can have adverse long term effects on scientific development. The lack of scientific knowledge of decision-makers who are responsible for the budget process and lobbying by interested parties tend to skew the allocation of funds for research, and even the total amount of funding compared to other industrialized nations. The struggle for funding allocations and the role of public opinion and interest groups can be seen, for example, in health and medical research by the growth of funding for research in “alternative” medicine.

Perspectives

Popular beliefs often are at odds with scientific development, and popular beliefs are often formed in ignorance of science and scientific research methods. Lack of scientific knowledge on the part of media reporters and editors contributes to the public’s lack of information or misinformation. Politicians are sensitive to public opinion and to the media, and are reluctant to authorize spending on scientific projects which they and the public do not perceive as of immediate benefit. Scientists, temperamentally unaccustomed to the hurly-burly of the political process, eschew participation in the process at their own peril and at the peril of future basic research. The gulf between scientific knowledge and popular belief contributes to confrontational political action and continuing controversy which undermines rational policy making.

Scientific Literacy and Science Education

The lack of scientific knowledge is not only shown in the making of policy decisions, but also appears in the context of international competitiveness. American students are ranked in the middle on mathematical and scientific knowledge when compared with students in other countries. The domestic and international deficit in scientific knowledge needs to be reduced with improved science and math education at all levels. While seminars for decision-makers and media personnel, or improved graduate programs and college-level courses would help, many citizens do not have a college education, much less a graduate degree. To the extent that their opinions sway politicians, every effort must be made to have those opinions rest upon knowledge of science. Understanding of the scientific method, analysis and facts needs therefore to begin early in the learning process and to be built upon as that process continues. Increasing scientific literacy of the public would reduce the influence of emotion in decision making, and thus improve the quality of policy decisions. Issues which are now highly controversial would be less so where the public is sufficiently educated about the issues and the related scientific evidence, as well as having the analytical skills to sort them out rationally.

Toward the Future

Because the need to upgrade science education for all citizens is most critical at the earliest levels of education, the study has identified specific concerns at the elementary and secondary levels which will have the greatest impact on overall scientific knowledge of the public, the media and decision makers. To improve scientific literacy and science education in the United States, development of national standards for grades K through 12 need to be considered, along with an increase in “advanced” or “enriched” science and math classes, and a special effort to teach science to students not expected to attend college. Special consideration needs to be given to making extra efforts to teach science to students who are socially and economically disadvantaged. Recruiting and retaining teachers who are thoroughly knowledgeable in the science or math subject to be taught, irrespective of whether that person has a degree in education, encouragement of magnet science and math schools and charter schools, and making college courses available to qualified students, regardless of age or grade level, also deserve serious consideration.

Chapter One

Introduction

Freedom, a free mind and science will lead them [the people] into such a jungle and bring them face to face with such marvels and insoluble mysteries that some of them, the recalcitrant and the fierce, will destroy themselves, others, the recalcitrant but weak, will destroy one another, and the rest, weak and unhappy, will come crawling to our feet and cry aloud: "Yes, you were right, you alone possessed his mystery, and we will come back to you—save us from ourselves!"

Feodor Dostoevsky[1]

In every system of governance, decisions on public policy are based on a combination of information and values. "Policy" implies consistency, even rationality. Many factors influence decisions on policy and, because such influences are dynamic, they are difficult to identify or measure. One influence is values: values affect information and information affects values, whether for the individual or for society.

If the values underlying government decisionmaking are not based on knowledge, the resultant decisions may be misguided, perhaps dangerous. This is especially true where facts are involved, where measurements can be made and results duplicated and proved. Public perceptions of science have often influenced decisions on policy. Where science and policy meet, gaps in knowledge need to be identified so that the knowledge and information needed to make a decision that will affect the public can be sought and provided.

This report examines the nature and effects of the gap between decisions made by government and the scientific knowledge that ought to, but sometimes does not, undergird these decisions. The report begins with questions: What influences the public perception of science? How do such perceptions influence policy decisions either depending upon science or affecting science? Science for policy, which is driven by the scientific establishment, is different from policy which is influenced by other stakeholders—including the public, government, academe, the media, and corporate leaders—which are largely outside the specialized domains of scientists. To illustrate the ways in which different stakeholders perceive issues related to science, three areas are reviewed here: silicon breast implants and nuclear power relate to applications of science to public policy decisions, and research funding relates to policy regarding science.

In this author's view, the public and its decisionmakers (notwithstanding *Daubert v. Dow Pharmaceuticals, Inc.*[2]) have little by little abrogated their responsibility for making reasoned

---

[1]Feodor Dostoevsky, *The Brothers Karamazov,* David Magarshack, trans., 1958; repr 1964, Baltimore, Penguin Books Inc., p. 303, spoken by The Grand Inquisitor.

judgments based on careful evaluation of evidence. Sometimes conclusions are made by innuendo, quick news clips, emotion, or numbers without meaning. The scientific community, too, shares the blame. As the discussion in **Chapter Four** of the breast implant cases here suggests, in the absence of a credible spokesperson in the scientific community, concern for the abuse of scientific method was never raised during those proceedings. Conflicting expert scientific witnesses in a legal dispute involving issues of science may often leave the public in a quandary about the sufficiency and substantiality of evidence. And scientific evidence itself cannot address matters of feelings, such as fear.

The difficulties inherent in adjudication might be reduced by the work of professional groups to establish guidelines for examining the credentials of expert witnesses. As in the breast implant cases, many in the legal community have proposed that judges should exercise judicial authority to convene expert panels of specialists to collate and evaluate scientific evidence for intricate, specialized cases.

At the heart of this report is a plea for better and more comprehensive science education, particularly at the elementary and secondary levels. That is still where most people in the United States obtain their knowledge of science, even though the hope is that more knowledge may be acquired in college or university. Journalists who report stories involving scientific issues and the editors who cut and paste those stories need better scientific education. Judges, who are usually generalists, are called on to render decisions in cases that involve complex scientific information. Juries composed of people who may never have attended college, even, possibly, may not have completed high school, are called on to render verdicts based on an understanding of scientific evidence.

The need for a scientifically literate public and for elevating debate on the role of science in national decisionmaking is critical. It would seem a truism that policy for science cannot be well formulated unless those in a position to influence policy understand science, but a truism may not take account of reality. The intention in this report is to encourage informed thinking about science and public policy and science education among decisionmakers and other stakeholders, whose visions differ and even often compete.

Chapter Two

Public Perception and Public Policy

As long as there are human beings facts don't exist in a void," said the writer. "Once a fact emerges into consciousness it is already an interpretation.

Stanislaw Lem[1]

2.1 The Theoretical Context

Information is not knowledge until it has been received and retained by one or more persons.[2] Whether a communicated fact causes a belief of or action by the person receiving the communication depends on whether and to what degree the person who receives the information understands it. Information can be understood only by individuals—that is, one person cannot understand something for another. Information needs to be processed by, and is subject to the limits of, each person.

2.1.1 Individual Cognitive Processing

The process by which knowledge is acquired is dynamic. What one "knows" is derived from individual experience and from information that has been communicated to and received by one. What one learns depends, initially, on the quality and quantity of the information communicated. Learning depends also on one's ability to absorb and retain information, and, beyond this, on one's ability to analyze the information. Processing information involves both intellectual ability and filters—the biases and values accrued over the course of a lifetime—which affect how the information is received and processed. The filters are inevitable limitations on acquiring and processing information and the results produced through them are inevitably distorted.

2.1.2 Public Cognition

The acquisition of knowledge is far more complicated than for individuals when it becomes a public acquisition, that is, knowledge as a public perception. In this case, rather than for one to try to understand the level of knowledge and the thought processes of one person, the effort must

---

[1] *Sledztwo* (The Investigation), Adele Milch, trans., New York, Seabury Press, 1974, p. 162.

[2] Often regarded as the application of knowledge in a manner society considers beneficial, the concept of wisdom is laden with value. Its worth depends on the opinion of others. Whether an action is judged "wise" will be pronounced by both the actor and by others. The judgment is necessarily retrospective, rendered only after the effect of an action is visible. A decision or action is the application of knowledge, hence, its worth depends on the degree of knowledge and on an understanding of the decisionmaker and of others to whom the decisionmaker is accountable.

be multiplied by hundreds of millions in order to assess level of knowledge and the thought processes of hundreds of millions of people interacting with one another. Some people receive communicated information on a particular subject; some receive different (often conflicting) information on the same subject. A piece of information may be transmitted to millions on the evening news or in a conversation between two people. And some, of course, will understand what they receive better than others will. The "marketplace of ideas" is volatile; the speed with which information is communicated and of the recycling of opinion affect how consensus is developed. The greater the frequency with which information is communicated and received, the greater its effect.[3]

2.2 Mass Media as Filters

The media affect public perception of life in general and perception of issues of public policy in particular. Most of the information the public receives it obtains through the media—usually, from news rendered in generalities, oversimplified and sensationalized.

The financial success of mass media depends on their ability to attract large audiences for which advertisers will pay the media to reach. The quest for audience or circulation leads to an emphasis on sensationalism, on worst possible outcomes, particularly in assessing risks to individuals, groups, or society.[4] To give just one example of this tendency, the potentially disastrous results anticipated from the impact of a large meteor crashing to earth receives extensive coverage, while the overwhelming odds against the event receives the status of a footnote, if any mention at all.

Reporters must achieve a "marriage of the sales mentality to the electronic image."[5] The broadcast media (TV and radio) allow audiences little time to take in nuances of risk. Newspaper journalists may have more lead time before deadlines than broadcasters, but all reporters are pressed in this way. "Getting news" usually takes precedence over discussing information that may enlighten, inform, even, in some instances, stay true to the facts.[6] David R. Gergen, a White

---

[3]Frequency and effect offer a loose analogy, because there is no standard by which to measure the turnover of information. There are, however, examples of limited measurements, such as media ratings used to allocate advertising dollars. See Harvey Brooks, "Can Science Survive in the Modern Age?" *Science* **174** (October 1971), 21: "As society becomes more complex and interconnected, the 'systems' effects of each decision spread more and more widely."

[4]Nearly every decision, consciously or unconsciously taken, involves the assessment of risk in weighing possible outcomes of a contemplated action. A simple decision—whether to leave home and drive to work—requires an assessment of whether the consequences of not going to work outweigh the risk of an auto accident (the risk of death or physical or financial injury) while driving to work.

[5] Jeffrey W. Kirsch, "On a Strategy for Using the Electronic Media To Improve the Public's Understanding of Science and Technology," *Science, Technology and Human Values*, vol. 4, no. 27 (Cambridge: Harvard University and MIT, Program on Science, Technology, and Public Policy) Spring 1979, p. 52.

[6]Warren Breed, "Social Control in the Newsroom: A Functional Analysis," *Social Forces* 33, no. 1 (1955): 326-335; reprinted in Wilbur Scramm (ed.), *Mass Communications: A Book of Readings* (2nd Ed.), Urbana: U. of Illinois Press (1960), pp. 178-94, at pp. 187-88.

House adviser to Presidents Nixon, Ford, Reagan, and Clinton and director of communications for President Reagan, lamented that "quality reporting is fighting a rear-guard action." In Gergen's view, the mass media, having "experienced an erosion of audience," respond with "food fights and titillating news,"[7] and he foresees that the economics of the industry will drive it to further trivialities. Robert E. Rubin, former Secretary of the Treasury (1995-99), has decried the use of personal attacks in public dialogue and the superficial coverage of issues in politics at the end of the twentieth century and the opening of the twenty-first. "If you give a serious speech about trade, you don't get coverage…."[8]

The media attempt to reach as broad an audience as possible, and, to do so, they deal with issues by focusing on challenge and conflict among those affected by its outcome. To attract viewers, television relies on visually exciting presentations, but these limit verbal expression. Except for special TV programming or feature sections of a newspaper, news usually is filtered information and rarely filtered to make it educational. The mode of transmission of information, broadcast or print, changes the character of the pressure from these factors, but in both media information needs to timely—which is to say, fast—even if the events reported are not yet clear.

The mass media summarize and simplify information, mainly for two reasons. First, the time or space devoted to news and features are limited. For this reason, information must be tailored to that time or space. Second, information is simplified and filtered on the basis of what the medium decides the public will understand. Thus, news coverage will reflect what the medium perceives as the public's level of knowledge and sophistication.

The accuracy of reporting which is affected by limits on time and space, simplification and filtering, and the need to attract and maintain an audience is also constrained by three other factors: the reporter's and the editor's knowledge, their diligence, and their integrity. A reporter who does not understand what is being reported is liable to offer misstated "facts" or a misleading impression of events through incorrect emphasis, flawed wording, or misquotation and misrepresentation. A reporter who lacks diligence or is unwilling to ensure the accuracy of a report will present errors in a story. A reporter who lacks understanding and diligence will mislead. Similarly, an editor who does not understand will not be able to correct a reporter's copy or know what to include, what to exclude, or what to emphasize.

Errors in reporting are paradoxically magnified when the media compress and simplify information. Were information not compressed, however, the absence of compression would not guarantee either a significant reduction in errors nor their elimination. A higher baud rate does not equal an increase in the public's ability to comprehend and absorb information. New means of delivery, such as the Internet and CD-ROMs (compact disks–read-only memory), offer vast

---

[7]David Gergen, Francis Greenwood Peabody Lecture, Harvard University, April 10, 1999.

[8]Albert R. Hunt, "Politics and People, Reflections of a Heavyweight," *Wall Street Journal*, July 1, 1999, A-23.

quantities of information, but, as in the “old” computer saying, that can mean vast quantities of “garbage in, garbage out.” Finding information on the Internet depends on what is available and on the skill involved in the search. The quality of available information and its accuracy, not to mention bias, vary and are difficult to assess. A search necessarily begins with a particular searcher and that searcher’s skills, but it also depends on the methods of various search engines (Lycos™, Google™, LookSmart™, Jeeves™) and the skill of a Web site designer in maximizing the site’s visibility to the search engines. Information on the Internet often lacks such traditional multilevel filters as reporters, editors, and analysts, and as a rumor mill the ‘Net’ operates at light speed. Chat rooms and “blogs” are often long on opinion from the writer, and short on fact and reason. A researcher’s “critical thinking” is therefore very important to how information is sifted and, ultimately, accepted or rejected.

Chapter Three

Science and Public Policy

Public policy by its nature involves communication and perception, but the gap between fact and public perception and its effect on public decisionmaking can be observed in science. Science presents verifiable empirical information that can be compared objectively to a public perception.

This report focuses on the sciences and on policy for science, not simply because of the ease of discerning a gulf between fact and public perception, but mainly because scientific knowledge is extremely important to national security and to the United States' economic competitiveness.

Webster's dictionary defines "science" as the "observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena," as a "methodological activity, discipline, or study."[1] The definition includes both the process of seeking knowledge and the knowledge gained from that process.[2] This paper is primarily concerned with the knowledge gained from that process.

The *Science and Engineering Indicators* report for 2000 of the National Science Foundation (NSF) drew a distinction between "science literacy," which the report called the possession of technical knowledge, and "scientific literacy," which "involves not simply knowing the facts, but also…the ability to think logically, draw conclusions, and make decisions based on careful scrutiny and analysis of those facts."[3] The NSF report defined "pseudoscience," or "junk science," as "claims presented so that they appear scientific even though they lack supporting evidence and plausibility."[4]

Scientific knowledge, or the lack thereof, is evident in the public arena. The general public's level of knowledge and its opinions influence government decisionmaking, which is to say, the formulation and implementation of policy, including policy for science. The level of knowledge of public officials also is a determinant of policy. The knowledge possessed and communicated by the mass media affects the knowledge of both public officials and the public. The knowledge of all these people, where it does not the result from personal observation, is based on their

---

[1] *Webster's II, New Riverside University Dictionary* (Boston: Houghton Mifflin Co., 1984).

[2] The Latin roots of science are *scientia*, *scientiae*, "knowing, knowledge intelligence, science," including "of a particular branch of knowledge, knowledge, skill expertness, art"; and *scio, sciere*, "to know, understand, perceive, have knowledge of, be skilled in." Charlton T. Lewis, *An Elementary Latin Dictionary* (Oxford: Oxford University Press, 1891, 1966).

[3] National Science Board, *Science and Engineering Indicators 2000* (Arlington, VA: National Science Foundation, 2000 (NSB-00-1)), Chapter Eight, "Science and Technology: Public Attitudes and Public Understanding," p. 8-31.

[4] Ibid., p. 8-31 and note 37.

education in science. Public policy affects scientific knowledge. Policy decisions are made on how much tax money will be budgeted for scientific research, on the uses of public funds for the teaching of science, from elementary schools through to universities. Beyond funding, governing authorities also determine policy for curriculum planning, student testing, and academic requirements.

The interaction of scientific knowledge, public policy, and decisionmaking occurs at all levels of government and in many forms. Judges as well as juries of citizens are called upon to evaluate scientific evidence, and their decisions will be affected by the knowledge of lawyers and witnesses and their ability to communicate scientific information to both judge and jury. Local and state governments make daily choices that use scientific information which will affect the safety, the health, and the environment in their communities. The federal government is even more dependent on science in reaching decisions. The quality of government—local, state, or federal—decisions and policies depends on the knowledge of the decisionmaker and on a willingness to apply that knowledge. Science is essential to certain policy decisions, but, as discussed in **Chapters Four** and **Five**, decisions can be made without regard to scientific findings, with selective use of scientific findings, and, in some cases, using scientific information that has been tailored to influence policy.

Political science is the study of the processes, principles, and structures of government an of political institutions, as well as the study of politics.[5] A polity, broadly defined, is a form of governance, its institutions, interrelationships, and philosophy; a democratic polity allows for compromise within a labyrinth of views and values. Science, by definition, cannot compromise, even when the disposition of human and financial resources may require practical tradeoffs in the study of science. What is called the scientific method requires a cautious approach to the interpretation of (scientific) evidence and excludes any interpretation for the purpose of political expedience. The politicization of science has given a new turn to the term “political” science, one that may be dangerous to the future of scientific research and the development of new technology, as well as for reasoned debate on public policy. The next few chapters show how science issues were involved in and handled in public policy decisions in the cases of silicone breast implants and nuclear power for civilian use and in the funding of scientific research, offering examples of the failure to contain controversies within the bounds of fact or, it may seem, reason. These instances also indicate a lowering of the public understanding of science, of scientific fact and reasoning, thereby illustrating the importance of science education.

---

[5] *Webster's II.*

Chapter Four

Silicone Breast Implants: The Courts and Scientific Evidence

4.1 What Happened

Silicone breast implants were developed in the early 1960s, and the first reported surgical use of them took place in 1962. In 1976, when the U.S. Food and Drug Administration (FDA) first regulated new medical devices, it grandfathered silicone breast implants.[1] In response to concerns that silicone implants caused cancer, in 1982 the FDA proposed to classify the implants in such a way that manufacturers would need to prove their safety in order to continue to sell them.[2]

4.2 Impact: The Press, Litigation, and Regulation

A wave of litigation then engulfed the industry, beginning with Maria Stern's suit against Dow Corning, one of the manufacturers of silicone breast implants.[3] The resultant verdict in 1984,which gave $1.7 million in compensatory and punitive damages, was based on expert testimony that theorized that the autoimmune disease Stern had developed was caused by the implants. The court barred public exposure of much of the evidence used in the trial. In June of 1988, the FDA adopted the classification of the implants proposed in 1982 and gave manufacturers until June of 1991 to prove affirmatively that the devices were safe and effective.[4]

Press coverage of the breast implant cases consisted of "news" and "evidence" about implants causing connective tissue disease. Six years after Stern's suit was filed, the first major broadcast news report on the dangers of silicone implants was aired on the December 10, 1990 broadcast of the CBS News program, "Face to Face with Connie Chung." During the program, Chung assigned culpability to Dow Corning for its product and blamed the FDA for permitting its marketing. A congressional hearing on this subject was held eight days after the TV report.[5]

---

[1] 41 Federal Register 37458, July 23, 1976. To "grandfather" or to insert a "grandfather clause" is to exempt from a new law or regulation a condition, use, or practice existing at the time of enactment or promulgation.

[2] 47 Federal Register 2820, Jan. 19, 1982.

[3] *Stern v. Dow Corning*, U.S. District Court for Northern California, San Francisco, Calif. No. C-83-2348-MHP.

[4] 53 Federal Register 23874, June 24, 1988.

[5] Hearings, House of Representatives, Committee on Government Operations, Subcommittee on Human Resources and Intergovernmental Relations, Dec. 18, 1990, "Is the FDA Protecting Patients from the Dangers of Silicone Breast Implants?" 101st Cong., 2d sess.

According to a study completed in June of 1999, by 1997 between 1.5 and 1.8 million women had received implants.[6] Although juries had found that implants caused connective tissue disease and Dow Corning and other manufacturers had agreed to settle a class-action suit, no scientific evidence for implants causing connective tissue disease supported an FDA prohibition of their use.[7] Instead, epidemiological research cited in the study concluded that the scientific evidence did not demonstrate a clear link between implants and connective tissue disease or suggestive symptoms, although it did not rule out the possibility, however remote, of a link. The question that arises is what the role of policymakers should have been. Press coverage of the legal cases helped form public opinion that implants presented a serious health risk, with the result that the public demanded government protection from this perceived danger. The FDA responded to fear, but without giving much weight to the absence of properly tested scientific findings to support a conclusion that the implants actually posed such a risk.

4.3 Comment

Public perception of the information that the legal community and the media presented as evidence exemplified the tendency of both the public and government to assess blame when scientific analysis of the issue might have dictated otherwise. The media hyped confusion about the evidence, the public expected a remedy even though no causal link—though legally ruled on[8]—was scientifically established. The FDA then responded to public opinion, and its ruling on implants resulted in thousands of lawsuits being filed on behalf of women with breast implants which claimed injury.[9] In April of 1994, the major manufacturers of silicone implants agreed on a settlement of $4.25 billion, with one billion of that amount set aside specifically for lawyers.[10]

---

[6]A study by a thirteen-member panel appointed by the Institute of Medicine, National Academy of Science, at the request of Congress, was reported in Milo Geyelin and Laurie McGinty, "Panel Concludes There Is No Connection Between Implants and Major Diseases," *The Wall Street Journal*, June 22, 1999, B-15.

[7]Although insufficient evidence existed to conclude that silicone implants caused connective tissue disease or immune system dysfunction, the FDA put the burden on manufacturers to prove a negative, that the implants did not cause health problems, that they were safe. When the FDA received inconclusive reports, it banned implants on the basis of the failure to prove that burden clearly. See "FDA May Not Ignore a Risk Because Evidence Identifying It Is Not Definitive," 56 Fed. Reg. at 14624, April 10, 1991.

[8]A judicially determined "fact" or "truth" may not be valid as scientific proof. The law is satisfied with decisions of judges and jurors, and, for the purposes of legal proceedings and newspaper reports, such findings are considered conclusive. Were a jury to award damages on a finding that the moon is made of green cheese, for the purposes of the law, the moon would be considered to consist of green cheese. The ruling could become binding and not subject to further challenge, in spite of scientific evidence to the contrary.

[9]The coordinating federal judge, Samuel C. Pointer of the Northern District of Alabama, in his announcement on Feb. 25, 2000, of his impending retirement, stated that "More than 27,000 breast-implant lawsuits were transferred to this court during the past 7+ years, and I expect that, when my retirement becomes effective, there will be fewer than 70 cases still pending in this court." [On-line]. URL: http://www.fjc.gov/BREIMLIT/mdl926.htm (Accessed Sept. 4, 2001.)

[10]*Lindsey v. Dow Corning Corp*., No. CV 92-P-10000-S, No. Civ. A 94-P-11558-S (N.D. Ala., Sept 1, 1994).

This controversy indicated a clear discrepancy between scientific evidence and legal evidence. Epidemiologists and researchers at the Mayo Clinic saw the legal settlement and criticism by the plaintiffs' lawyers that their study was biased because it had been paid for by Dow Corning as a slap at both scientific evidence and their research. Their study, published shortly after the announcement of the settlement, showed no link between the breast implants and disease. In the summer of 1998, the European Committee on Quality Assurance and Medical Devices in Plastic Surgery also reported that evidence was "conclusive" that implants did not cause autoimmune or connective tissue diseases and that "there is no scientific evidence that such things as silicone allergy, silicone intoxication, atypical disease, or a "'new silicone disease exist.'"[11] Later the same year, an Independent Review Group established by Britain's Minister for Health came to a similar conclusion: it found "no histopathological or conclusive immunological evidence and "no epistemological evidence" of disease caused by the implants.[12] Congress also ordered a review of all relevant research, including more than three thousand publications. In June of 1999, the chairman of the specially appointed committee of the Institute of Medicine concluded, "We could find no definitive evidence linking breast implants to cancer, immunological diseases, neurological problems, or other systemic diseases."[13]

4.4 The Courts and Expert Testimony: A Dilemma

Courts represent a decisionmaking forum in which scientific knowledge is lacking. Both judges and the ordinary citizens who make up juries are asked to evaluate complex scientific evidence and make decisions, often forced to choose between competing experts' views framed in highly specialized language. This situation is not new. In 1902, Judge Learned Hand wrote of the problems inherent in expert testimony:

> [H]ow can the jury judge between two statements each founded upon an experience confessedly foreign in kind to their own? It is because [jurors] are incompetent for such a task that the expert is necessary at all…. One thing is certain, [the jury] will do no better with the so-called testimony of experts than without, except where it is unanimous. If the jury must decide between such, they are as badly off as if they had none to help.[14]

---

[11]Doug Bandow, "Many Torts Later, the Case Against Implants Collapses," *The Wall Street Journal*, Nov. 30, 1998, A23.

[12]Silicone Gel Breast Implants: Report of the Independent Review Group, 1998, p. 6.

[13]Stuart Bondurant, University of North Carolina School of Medicine, quoted in Milo Geyelin and Laurie McGinty, "Panel Concludes There Is No Connection Between Implants and Major Diseases," *The Wall Street Journal*, June 22, 1999, B15. The thirteen-member panel was appointed by the Institute of Medicine, National Academy of Sciences, at the request of Congress.

[14]*Historical and Practical Considerations Regarding Expert Testimony*, 15 Harv. L. Rev. 40, 54, 56 (1902).

Because the number of silicon breast implant cases reached into the thousands and involved complex claims, special litigation rules governing such cases in federal courts were invoked, and one judge was appointed to oversee the conduct of all such cases in the federal courts.[15] This appointee, Chief Judge Samuel Pointer of the Northern District of Alabama, appointed a scientific panel of four independent medical experts to supplement the evidence offered by each side of the case.[16] According to John M. Kobayashi, the special counsel designated to the panel by Judge Pointer, "This is the first-ever independent science panel in which the scope of its report is to be available to all out-standing cases throughout the nation."[17]

The panel reported that "The main conclusion that can be drawn from existing studies is that women with silicone breast implants do not display a silicone-induced systematic abnormality in the types or functions of cells of the immune system."[18] These findings provided the first real scientific evidence in the litigation and revealed that earlier conclusions had been made with inadequate information. Reports by experts selected by the court, rather than by litigants, may be valuable in resolving difficult scientific issues in the courtroom. As of May 2003, the Dow Corning Corp., the leading manufacturer of silicone breast implants, remained in bankruptcy, and the battle continued.[19]

The appointment of expert panels in the breast implant cases was made possible by a landmark decision concerning the admission of scientific evidence in federal courts. In *Daubert v. Dow Pharmaceuticals, Inc.*,[20] the Supreme Court abandoned the "general acceptance" standard

---

[15]In re *Silicone Gel Breast Implants Products Liability Litigation*, 793 F. Supp. 1098 (1992). The action does not apply to lawsuits filed in state courts. Litigation involving common facts in more than one federal district is governed by 28 U.S. Code section 1407. The order appointing Judge Pointer can be found at 793 F. Supp. 1098 (1992).

[16]In re *Silicone Gel Breast Implants Products Liability Litigation* (MDL-926), No. CV 92-P-1000-S (N.D. Ala., Oct. 31, 1996), Order No. 31E. The report of the Rule 706 National Science Panel was submitted to the court on 30 Nov. 1998. Though not the only study ordered, this one became the work on which all courts implementing federal court rules relied concerning scientific evidence. Previous studies had been ordered by judges in the federal courts of the Southern and Eastern Districts of New York (*In re Breast Implant Cases* No. 92 CV 7821, SDNY & EDNY, 23 Oct. 23, 1996) and the District of Oregon (*Hall v. Baxter Healthcare Corp.,* Civ. No. 92-182-JO, Dec. 18, 1996). See Eliot Marshall, "New York Courts Seek 'Neutral' Experts," *Science* 272, April 12, 1996, p. 189.

[17]Thomas M. Burton, "Legal Beat: Implant Makers Get a Boost from Report," *The Wall Street Journal*, Dec. 2, 1998, p. B-1.

[18]Summary of the Report of the National Panel, Silicone Breast Implants in Relation to Connective Tissue Diseases and Immunologic Dysfunction, [On-line]. URL: http://www.fjc.gov/BREIMLIT/SCIENCE/summary.htm (Accessed Sept. 4, 2001.)

[19]In April 1999, the plaintiffs filed a motion to disband the panel and to disregard its findings on the basis of the alleged bias of the Canadian scientist, Dr. Peter Tugwell, of the University of Ottawa, who, they said, had had a series of undisclosed financial and professional relationships with defendant Bristol-Myers-Squibb. Judge Pointer denied the motion on April 20, 1999. *Canadian Medical Association Journal*, Vol. 160, p. 1688, June 29, 1999. Information on the status of both the bankruptcy and the litigation is available [On-line]. URL: http://www.implantclaims.com/ (Accessed May 1, 2003.) and URL: http://www.fjc.gov .

[20]509 U.S. 579 (1993). The *Daubert* case arose in the context of scientific evidence. The general principles in that case were extended to all expert testimony in *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999).

for the admission of expert testimony. The Court held that the adoption of the Federal Rules of Evidence superseded the ancient decision in *Frye v. United States*,[21] that expert opinion based on a scientific technique was inadmissible unless the technique was "generally accepted" as reliable in the relevant scientific community. Although *Daubert* may be regarded as having opened the door to bizarre theories not yet accepted by the scientific community, the Court said that Rule 702 of the Federal Rules of Evidence placed appropriate limits on the admissibility of "purportedly scientific evidence" by giving the judge the responsibility of ensuring that an expert's testimony rests on a "reliable foundation" and is relevant to the issues in the case. It said that the use of the word "scientific" in the rule "implies a grounding in science's methods and procedures, and the word "knowledge" connotes a body of known facts or of ideas inferred from such facts or accepted as true on good grounds.

In making the preliminary assessment under *Daubert*, the presiding judge would examine the following the theory or technique in question to determine at a minimum:

- whether it could be (or has been) tested;
- whether it has been subjected to peer review and publication;
- what was its known or potential error rate;
- whether there were standards controlling its operation and, if so, how these were maintained; and
- whether it has attracted wide acceptance within a relevant scientific community.

The actions of Judge Pointer and other judges in the breast implant cases in appointing expert panels to advise the court on the conflicting expert testimony presented to them represent an innovation that may assist in careful decisionmaking. They also reflect the judges' comprehension of their own shortcomings in understanding the experts. Because judges are continually pressed to act as scientific gatekeepers in intricate lawsuits, their appointment of expert panels makes clear that they themselves are generalists, without the knowledge to make such judgments unassisted and must obtain help to ensure that the evidence demonstrates a relationship between cause and harm, judgment and damages.

The Federal Rules of Evidence require that evidence assist the jury (Federal Rule 702). Contrary and complicated evidence by experts may prove difficult for the triers of fact to resolve. In cases that pose evidentiary decisions, such as in the breast implant cases, juries are often asked to choose between two contrary but plausible explanations of fact. Many legal authorities believe that the *Daubert* standard will assist judges to determine admissibility by limiting dubious,

---

[21] 293 Fed. 1013 (D.C. Cir. 1923)(use of polygraph).

nonscientific, “junk science” evidence, such as was admitted in a number of the breast implant cases, and which appear to have influenced decisionmaking at the regulatory policy level.

Chapter Five

Three Mile Island and Risk: Science and Public Perceptions

On March 28, 1979, an accident occurred at the nuclear energy facility at Three Mile Island (TMI), ten miles from the city of Harrisburg, Pennsylvania, that proved more terrifying in its implications than its actuality. The technology at TMI provided sufficient safeguards so that, despite many errors and malfunctions, no meltdown occurred, nor did any injuries or deaths, yet the event has become legend.

What happened at TMI highlighted the differences between a scientific assessment of risk based on statistical analysis and probability theory and a public unwillingness to accept such an assessment in the determination of public policy. At the time of TMI, public opinion regarded statistical analysis as something akin to Russian Roulette: everyone focuses on the possibility that the hammer will strike the one loaded round for a fatal result, even though the odds (6:1) actually favor hitting an empty cylinder. Public opinion was molded in part by the media's emphasis on a worst-case scenario and by the suspicion, based on little understanding, that the industry was covering up serious risks of the accident. Complicating the public's uneducated and fearful response to events was the nuclear power industry's ineffectiveness in communicating how, when an accident has occurred, a nuclear power facility's safety systems work to prevent a disaster. This ineffectiveness had further impact when the public was unable to differentiate between the unsafe design of Chernobyl, where a meltdown did occur, and the safety systems in the U.S., which prevented a meltdown at TMI.

5.1 What Happened

The failure of controls of a major reactor at the nuclear power facility at TMI caused a partial loss of coolant and threatened a possible meltdown of the reactor's core. Failure of a cooling system can overheat the core and cause a core meltdown, in which case the reactor's fuel can burn through the bottom of the plant into the earth. Interaction with groundwater can create steam that can explode and spew radioactivity into the air above and surrounding the nuclear power facility. Manufacturers use emergency core cooling systems to prevent such occurrences, and at TMI these systems worked: the reactor shut down before meltdown, and no interaction with groundwater occurred.

At the time of the accident, experts in the field of nuclear power did not fully understand that the issue of risk went to the heart of the public values and social choice. Risk, both as a technical and as a social concept, encompasses uncertainties and complexities that need to be assessed. For stakeholders, scientific uncertainty can yield disparities in the interpretation of risk; for policymakers, decisions need to be made even in unresolved disputes. Thus, policymaking may be weighted not only by unresolved risk, such as scientific risk, but also by social values, which reflect attitudes about the unknown. Risk analysis is difficult, because the technical problems involved in an issue may be pitted against the politics involved in the issue. The public's fear may be regarded as irrational by scientists, yet to the public that fear will be felt as reasonable. Perhaps more than any other factor, fear of the catastrophic potential of nuclear power carries the greatest weight with the public. The smallest mishap in the nuclear energy industry conjures the effects of nuclear weapons—mushroom clouds of exploding atomic or hydrogen bombs bringing immediate death and then the slower agony of radiation sickness. "Despite technical studies that assert that the probability of a severe reactor accident is low, people's perceptions of the risks involved are largely unresponsive to the claims of technical risk assessments."[1]

Science often may not have the last word on reason—and almost never on policy. In government, the views of the people may and generally do count more than scientific reasoning. Communication of both scientific information and risk evaluation was a major problem in the TMI crisis. Few would dispute that communication between the media and engineers at the nuclear power facility suffered from a lack of common understanding or a common language. From the press's viewpoint, "Covering TMI was like suffering from color blindness at a watercolor exhibition."[2]

5.2 Impact of TMI

Atomic energy was envisioned by William L. Laurence as a "veritable Prometheus bringing to man a new form of Olympic fire,"[3] which he claimed in 1959 would deliver "wealth and leisure and spiritual satisfaction in such abundance as to eliminate forever any reason for one nation to covet the wealth of another."[4] Public opinion generally favored civilian manufacture and use of nuclear energy through the 1970s,[5] although by the middle of that decade, it began to erode.

---

[1]Phillip A. Greenberg, "Safety, Accidents, and Public Acceptance," in *Governing the Atom: The Politics of Risk*, edited by John Byrne and Steven M. Hoffman (New Brunswick, N.J.: Transaction Publishers (1996), p. 155.

[2]Anna Marie Cunningham, "Not Just Another Day in the Newsroom: The Accident at TMI," in *Scientists and Journalists: Reporting Science as News*, edited by Sharon M. Friedman, Sharon Dunwoody, and Carol L. Rogers (New York: The Free Press, 1986), 208.

[3] Laurence, William L., "The Atom Gives Up," *Saturday Evening Post*, September 7, 1940, pp. 12-13. Laurence (1888-1977) was a science writer and editor at the *New York Times*, who won two Pulitzer Prizes (1937 and 1946), and who was chosen as the official historian of the Manhattan Project.

[4] Laurence, William L., *Men and Atoms* (New York: Simon and Schuster, 1959), p. 240.

[5] Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power*, 1945–1975 (Cambridge and New York: Cambridge University Press, 1991), 236-38.

Joop van der Pligt, in *Nuclear Energy and the Public*,[6] studied the history of public attitudes toward nuclear energy, concluding that TMI "had a significant impact on public attitudes towards the construction of additional nuclear power plants."[7] His analysis of opinion polling from 1974 through 1981 on the acceptability or unacceptability of building more nuclear power plants found "no significant trend towards either increasing or decreasing levels of acceptability" before TMI; and after TMI, a "significant increase of opposition" and a decrease in support.[8]

Prior to the 1970s, little public attention was directed toward the nuclear power industry, with the few public opinion surveys taken concerning the subject indicating a general acceptance of the optimism expressed by Laurence. Criticisms of the nuclear industry, particularly with respect to safety and potential environmental impact, began to take a higher profile in the early 1970s.

Well before the accidents at TMI and Chernobyl, some groups began questioning the safety of nuclear power facilities. The Union of Concerned Scientists (UCS),[9] founded in 1969, early on asked questions about emergency cooling systems at Atomic Energy Commission (AEC) licensing hearings. From leaked information and at secret meetings with technical staff of the AEC, the UCS learned of potential problems in these systems and that internal debate about the systems was building at the AEC.[10] The UCS publicized such issues of nuclear safety at public forums, opposed licensing of nuclear energy facilities, and encouraged scientific debate outside the AEC on the safe use of nuclear energy. What began as a scientific investigation into technical difficulties grew into a political confrontation as the UCS alleged that the AEC had suppressed dissent within its laboratories and among its regulatory staff. The result was widely publicized hearings in 1976 by the Joint Committee on Atomic Energy.[11] This political confrontation caused a slowdown in the licensing of new facilities. What had started as internal dissent at the AEC, and then become a public dispute among scientists, soon attracted political activists.

---

[6] Oxford, U.K., and Cambridge, MA: Blackwell Publishers (1992).

[7] Ibid., at 2.

[8] Ibid., at 4. Polls after TMI showed that 95% of the public knew of the TMI accident, 80% were "disturbed" by it, and 50% to 70% believed that there would be a future similar accident.

[9]The Union of Concerned Scientists "is an independent nonprofit alliance of 50,000 concerned citizens and scientists across the country…founded in 1969 by faculty members and students at the Massachusetts Institute of Technology who were concerned about the misuse of science and technology in society [and] called for the redirection of scientific research to pressing environmental and social problems." URL: http://www.ucsusa.org/index.html

[10] John L. Cambell, *Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy* (Ithaca, NY: Cornell University Press, 1988), pp. 54-63.

[11]U.S. Congress, Joint Committee on Atomic Energy, "Investigation of Charges Related to Nuclear Safety," 94th Cong., 2d sess., 1976.

In May of 1973 Ralph Nader's Public Citizen, through its Critical Mass Energy Project, sued the AEC to shut down two-thirds of the nation's reactors. The suit added to the pressure on members of Congress not to advocate legislation favoring uses of nuclear energy. Nader's group helped organize other groups on local, state, and national levels, and rallies and strategy sessions were focused "not so much on the technical aspects of nuclear power as…previously…but on the political strategies required to slow or halt the [atomic] sector's growth."[12] Between 1972 and 1973, *The New York Times* published twenty-seven articles on the issue of the safety of nuclear reactors.[13] In 1974, the death of Karen Silkwood raised suspicions of foul play and a cover-up of safety violations by a nuclear plant operator.[14] In 1975, twenty members of the House of Representatives introduced a bill calling for a five-year suspension of licensing for all nuclear plants, and twenty-eight state legislatures had antinuclear bills pending.[15]

At the same time as the issue of nuclear safety was experiencing this higher profile, the industry itself was weakened financially. The extremely high initial capital costs associated with constructing nuclear generating facilities, the long time needed to build them, and the means by which funding was obtained, all contributed to an industry which could not withstand additional burdens. John L. Campbell points out[16] that private utilities sought to build large-capacity generating facilities to meet expected demand for electric power. Utilities could obtain funding for construction by issuing stock, issuing bonds, or tapping retained earnings. Earnings were regulated by utility commissions, which allowed rates to be charged which earned the utility a percentage of the value of capital plant in use. Consumers naturally opposed utility requests for higher rates, and nuclear power opponents came to see rate proceedings as a way to keep funds from nuclear projects. Utilities turned to the bond market just as interest rates were rising and had to offer high interest to attract investors. By 1974, interest payments were 25% of the total cost of constructing nuclear facilities.

With utilities vulnerable financially, and the only practical way to obtain funding being a return on the rate base, the accident at TMI and its impact on public opinion amounted to a coup de grace. State utility commissions, sensitive to public opinion, declined to allow partially completed facilities into the rate base and companies were forced to cancel plans for nuclear

---

[12]Campbell, *Collapse of an Industry*, 64.

[13]Ibid., 63.

[14]Karen Silkwood, who worked at a nuclear energy facility in Oklahoma, died in a single car crash while supposedly on her way to meet with a reporter and a union official to deliver evidence of serious safety violations at the facility. The police report of the crash concluded that Silkwood had fallen asleep while driving, but a private investigator hired by the union said that Silkwood's car had been hit from behind. No documents were found at the scene of the crash or in Silkwood's belongings. For a discussion of the use of Silkwood's death by activists, see Jerome Price, *The Antinuclear Movement* (Boston: Twayne Pub., 1990), 95-99.

[15]Ibid., 65.

[16]John L. Campbell, *Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy* (Ithaca: Cornell University Press, 1988), pp. 94-104.

generating facilities, building instead, smaller coal or oil burning plants.[17] The intervention of anti-nuclear activists in the plant licensing process also increased the costs of construction in terms of the cost of the proceeding and in terms of the resulting delay in construction, as well as additional costs for new safety requirements.[18]

In the wake of TMI, strong negative perceptions of civilian manufacture and uses of nuclear energy caused the U.S. nuclear power industry to become nearly moribund. The decline in orders for nuclear reactors between 1974 and 1979 became a total absence.[19] A number of orders for nuclear plants were cancelled, including some that were already under construction, and the cost of abandoning these plants totaled nearly $10 billion.[20] According to the U.S. Office of Technology Assessment (OTA), the cost per kilowatt of generating capacity was $430 in 1971, and was projected to increase fourfold to $1,880 for plants to be finished in 1987.[21] Of seven nuclear power plants nearing completion in 1983, the OTA reported that their cost would be between 550 and 900 percent of the cost of building comparable plants in the early 1970s.[22] The result was a return to the use of fossil fuels to generate power, with all the attendant environmental consequences.

After TMI, for the first time, polling data showed that more people opposed than favored construction of nuclear power plants. The erosion of trust that accelerated with the accident at TMI in 1979 became an avalanche in 1986, after the accident on April 26 at the nuclear power station in Chernobyl, which devastated the Ukraine.[23] The nuclear power industry failed in 1979 to explain clearly to the public how its safety design prevented the feared meltdown, and in 1986 failed to make clear the contrast in designs which led to a meltdown in the Ukraine but none at TMI. Since the 1980s, public opinion polls have shown broad opposition to the construction of

---

[17] The declining financial condition of the industry fueled suspicions that it was cutting corners on safety to maintain profits. As the suspicions were transformed into political activism, the result was more financial pressure on the utilities, accelerating the financial problems.

[18] See Bupp, Irvin C., Jean-Claude Derian, Marie-Paule Donsimoni, and Robert Treitel, "The Economics of Nuclear Power," *Technology Review*, vol. 77, no. 4 (1975), p. 14-25.

[19] Campbell, p. 97; Michael Hatch, "Nuclear Power and Postindustrial Policies in the West," *Energy and Environmental Policy,* vol. 7, p 238 (1996).

[20]Campbell, p. 4, citing Itteilag, Richard L. and James Pavle, "Nuclear Plants' Anticipated Costs and Their Impact on Future Electric Rates," *Public Utilities Fortnightly,* vol. 115(6), p. 36 (1985). In the United States in 1994, 109 nuclear reactors in 41 states generated roughly 20 percent of all the electricity used.

[21]*Nuclear Power in an Age of* Uncertainty (Washington, D.C.: U. S. Congress, Office of Technology Assessment, OTA-E-216, February 1984), pp. 58-60.

[22]Ibid.

[23]Freundeberg, William R., and Eugene A. Rosa, "Are the Masses Critical?" in William Freundenberg and Eugene Rosa (eds.), *Public Reaction to Nuclear Power* (Boulder, CO: Westview Press, 1984); *Nuclear Power in an Age of* Uncertainty (Washington, D.C.: U. S. Congress, Office of Technology Assessment, OTA-E-216, February 1984), pp. OTA Report, pp. 211-234; Joop van der Pligt, *Nuclear Energy and the Public* (Oxford, Eng., and Cambridge, Mass.: Blackwell, 1992).

additional nuclear power reactors in the United States,[24] and since 1988 the margin of opposition has remained roughly 2 to 1.[25] By the 1990s, the nuclear power industry and its safety precautions were in such disrepute that the most popular cartoon character on national television became Homer Simpson, a bumbling control operator at a nuclear plant who was shown blithely stuffing his face as the dials headed into the red.

Recent shortages of electric power (most notably the California power crisis in 2000) may have renewed interest in civilian use of nuclear energy. In 2000 and 2001, owners of 40 percent of the nuclear energy plants in the United States announced plans to apply for renewal of their operating licenses, and the resistance to these was reported to be less than might have been anticipated. The energy crisis may have changed attitudes. On the basis of sales of generating plants, the value of a plant was reported to have increased from about $100 per megawatt to nearly $800 in the past two years, although as of early 2001 no company had put forward plans to build a new nuclear energy facility.[26]

5.3 Analysis

Political and economic considerations contributed to the demise of the nuclear energy industry, but mismanagement of information at TMI and then by Nuclear Regulatory Commission (NRC) were major contributors. Prior to the accident at TMI in 1979, public criticism of the safety of nuclear energy had begun to undermine public confidence in the technology (see section **5.2**). The accident at TMI was seized on by opponents of nuclear energy, media coverage of it was so inaccurate, and corporate leadership within the industry demonstrated such weakness in their botched response, both in the media and through public relations management, that the incident proved a near-fatal blow to the industry in the United States.

Although the technology that closed down the reactor at TMI worked as it was supposed to in the situation, the complicated scientific and technological issues involved in the production of nuclear power nevertheless were trumped in the public eye by public policy issues regarding energy sources and the risks to public health and safety. After the disaster at Chernobyl in 1986, the industry was unable to explain clearly and simply in what ways design and safety procedures at Chernobyl were inferior to those in use in the United States and how defects that had led to the disaster in Ukraine were not present in the United States.

---

[24]OTA Report (1984), 211-212.

[25]Phillip A. Greenberg, "Energy Policy Studies," in *Governing the Atom*, 128. Opposition continued, but the public's view of nuclear power in general was less negative: "In 1999, 48 percent of Americans believed the benefits of nuclear power outweighed the harms, while 37 percent held the opposite view and 15 percent that the benefits and harms were equal." NSF, *Science and Engineering Indicators—2000*, op. cit., "Science and Technology: Public Attitudes and Public Understanding," p 8-19.

[26]Peter Behr, "Nuclear Power May Be Making a Comeback," *The Washington Post*, April 23, 2001, A1.

In 1979, the President's Commission on the Accident at Three Mile Island directed the preparation of a staff report analyzing the flow of information to the public concerning the TMI accident. The task force analyzed the coverage of forty-three news sources and the handling of information by Metropolitan Edison and the Nuclear Regulatory Commission, and concluded:

"The public information operations mounted by the utility and the NRC were so inadequate that it is impossible to find any evidence of a conspiracy or a coordinated effort to mislead the public on the facts of the accident — though the confusion may have had the same net effect. While the public was indeed misled at certain points, this was in large part a function of the exhaustion of the participants, an absence of individuals who could explain technical information in lay terms, and genuine confusion among the decision-makers. ..."[27]

The utility was faulted for being unprepared to present information to the public in an effective way: "Small staff size, lack of understanding of nuclear technology, and inexperience, particularly in dealing with the national media, made the utility public information specialists ineffectual during the accident."[28] According to another investigator, "Fundamental communication problems proved particularly damaging to the company because the inadequate flow of information was often mistaken by journalists for intentional cover-up."[29]

On May 1, 1979, *Washington Post* columnist Richard Cohen wrote of the nuclear energy industry generally:

> They lied, they lied, they lied.… They told us it was safe. What a lie. They told us it was clean. Did you ever hear such a lie? ...As a nation we are like people who have been told the check is in the mail. This is the one where we grow up and get the bad news and learn that never again are we going to listen and believe the garbage we have been getting from the utility companies.[30]

---

[27] President's Commission on the Accident at Three Mile Island, *Report of the Public's Right to Information Task Force* (Washington, D.C.: GPO, 1979), p. 47.

[28] Sharon M. Friedman, "A Case of Benign Neglect: Coverage of Three Mile Island Before the Accident," in Sharon M. Friedman, Sharon Dunwoody and Carol L. Rogers (eds.), *Scientists and Journalists* (New York: The Free Press, 1986), p. 184. Friedman was also a member of the Public's Right to Information Task Force.

[29] Anna Marie Cunningham, "Not Just Another Day in the Newsroom: The Accident at TMI," in *Scientists and Journalists*, 205. Cunningham was a member of the Public's Right to Information Task Force.

[30] *Science in the Streets*, Report of the Twentieth Century Fund Task Force on the Communication of Scientific Risk (New York: Priority Press, 1984), pp. 36-37 (quoting from The Washington Spectator, May 1, 1979).

Another influence on public perception was the behavior of NRC officials, who, like antinuclear groups, "provided the news/media with some of the most frightening information during the accident."[31]

The President's Commission found with respect to the media coverage:

> The reporters who covered the accident had widely divergent skills and backgrounds. Many had no scientific background. Because too few technical briefers were supplied by NRC and the utility, and because many reporters were unfamiliar with the technology and the limits of scientific knowledge, they had difficulty understanding fully the information that was given to them. In turn, the news media had difficulty presenting this information to the public in a form that would be understandable.
>
> a. This difficulty was particularly acute in the reporting of information on radiation releases.
>
> b. They also experienced difficulty interpreting language expressing the probability of such events as a meltdown or a hydrogen explosion; this was made even more difficult when the sources of information were themselves uncertain about the probabilities.[32]

Why were the media so inaccurate? Why was the public so easily swayed against nuclear energy? Without scientific knowledge—that is, without a foundation for critical thinking about scientific data—fear seeped in. Ignorance—of facts and actual risks demonstrated by the industry and public officials, the media, and the general public—grew into rumor and fear. As of early 2002, however, perceptions of the nuclear energy and of its safe use remain unresolved. Nuclear energy remains a viable source of energy even with the difficulties inherent in its production and use. But how will decisions about the mix of sources of energy and its use be made? What will provide the basis for those decisions? Controversies on scientific issues pose a dilemma: How will the public interest best be served, particularly in deliberations that require a scientific assessment of risk?[33] How can the public best be educated on scientific subjects in order to reduce the impact of emotion on decisions on such issues?

---

[31] Anna Marie Cunningham, "Not Just Another Day in the Newsroom: The Accident at TMI," in *Scientists and Journalists*, 209.

[32] *Report of the President's Commission on The Accident at Three Mile Island, The Need for Change: The Legacy of TMI*, Washington, D.C., GPO (1979), p. 57.

[33] Another issue of risk assessment is the wide use of chlorine compounds, which have potentially harmful effects that have alarmed both the public and government policymakers: "Industry turns out at least 10,000 chlorine compounds and no regulatory body is capable of studying and regulating them one by one." Christopher Anderson, "Cholera Epidemic Traced to Risk Miscalculation," *Nature* **354** (Nov. 28, 1991), 255. The Environmental Protection Agency has wrestled with how to balance the risk of cancer from chlorination with the microbial risk of no disinfection at all. Most epidemiologists agree that a relatively small risk of cancer is preferable to the possibility of an epidemic.

5.4 Courts and the Law

A growing awareness among political activists of the well-established legal principle of "nuisance" has diminished prospects for construction of new, privately owned nuclear facilities, or any unpopular facility. Precedent defines the term broadly.

If a cooling tower casts a shadow on a neighbor's property, thereby reducing its value, the tower could be considered a nuisance. If the value of the property were reduced owing to the neighbor's fear of accident or contamination, the facility could be considered a nuisance and would not be permitted. If the present owner of the land were to suffer anxiety as the result of the construction of a facility, or if such anxiety were to develop after construction was completed, the facility could be banned or ordered to close.

A classic case of this type is *Everett v. Paschall.*[34] Everett owned and occupied a lot in a residential neighborhood in Seattle, Washington, that was separated by an alley from Paschall's property. Paschall used a cottage on his property to maintain a small, private sanitarium for tuberculosis patients. On the basis of testimony, the trial court refused an injunction against Paschall's use of the property after finding that beyond three feet there was no danger of infection or contagion; that TB germs are destroyed within minutes by exposure to daylight; that the cottage was kept disinfected; that every effort was made to prevent any danger to the public; and that there was no danger to persons living in the immediate vicinity. The court also found that facilities such as this one filled a serious need and that Paschall's use therefore provided a public benefit.

The decision was reversed by Supreme Court of Washington, which declared the use of the cottage as a sanitarium to be a nuisance per se. The court rejected "the principle underlying the lower court's decree—that is, that the danger being only in the apprehension of it, a fear unfounded and unsustained by science, a demon of the imagination—the courts will take no account of it.…"[35] The court ruled instead in favor of fear:

> if the dread of the disease and fear induced by the proximity of the sanitarium, in fact, disturb the comfortable enjoyment of the property of the appellants, we question our right to say that the fear is unfounded or unreasonable, when it is shared by the whole public to such an extent that property values are diminished. The question is, not whether the fear is founded in science, but whether it exists; not whether it is imaginary, but whether it is real, in that it affects the movements and conduct of men.

[34] 61 Wash. 47, 111 P. 879 (1910). Subsequent passages quoted here were all taken from this source.

[35] Ibid. at p. 880.

> Such fears are actual, and must be recognized by the courts as [are] other emotions of the human mind.[36]

The court also held that "[c]omfortable enjoyment means mental quiet as well as physical comfort." Because Everett would be annoyed or distressed in mind, the court found that a nuisance existed and ordered the sanitarium closed.[37]

That decision and others like it create the ultimate NIMBY—"not in my backyard"—weapon. Anyone may use the existence of "not entirely unreasonable" fear to prevent beneficial actions or to discriminate against certain groups on the basis of an alleged (or real) fear. This approach could be used to bar people with the acquired immunodeficiency syndrome (AIDS) from a neighborhood, or mental health patients, felons, nuclear energy facilities (of any type), and waste disposal sites, power lines, the storage, manufacture, or use of chemicals, and a host of other unpopular groups or activities limited only by the imaginations of opponents.

When an opponent can bring an expert "friendly" to the cause to provide a theory in support of the fear, the courts lean toward deeming the fear reasonable. "If there is a difference of opinion among those skilled in the profession, can this court say that the fear expressed by a layman for his safety and that of his family is unfounded or imaginary?"[38]

According to the judgment in *Everett*, "Popular belief...cannot, in this day, be shaken or dispelled by mere scientific asseveration or conjecture."[39] Progress is thus held hostage by ignorance. Modern Luddites can control policymaking when the courts and politicians are unwilling to make decisions contrary to either unfounded fears or superstition.[40]

The court in *Everett* noted the view of "a M. Sicard, a professor of the Faculty of Medicine" in France, that fear is "the result of temperament, training, and thought" that "can be partially

---

[36] Ibid. at p. 880.

[37] Ibid. at pp. 880-81. In doing so, the court relied on a number of decisions involving similar circumstances. *Baltimore v. Fairfield Imp. Co*., 87 Md. 352, 39 Atl. 1081 (injunction against allowing a leper to live in a neighborhood); *Cherry v. Williams*, 147 N.C. 452, 61 S.E. 267 (TB hospital closed); *Stotler v. Rochelle*, 109 P. 788 (Kans.)(barred the opening of a cancer hospital); *Deaconess Home & Hospital v. Bontjes*, 207 Ill. 553, 69 N.E. 748 (hospital closed).

[38] *Park v. Stolzheise*, 167 P.2d 412 (Wash. 1946).

[39] *Everett v. Paschall*, 111 Pac. 879, 880.

[40] This brief discussion is not intended as a definitive statement of nuisance law. The *Everett* rationale has been applied in states other than Washington, but not everywhere. Some states apply different standards to government owned facilities and those owned by private enterprise, regulated utilities or not. Nuisance is a matter of state law and thus, a wide variety of outcomes may be expected. In Washington, it should be noted, *Everett* has been discussed and found inapplicable to different facts, but it has never been explicitly overruled.

eradicated by reasoning and education," but never wholly eliminated.[41] Only education can reduce fears born of ignorance—a truism that holds true.

[41] *Everett v. Paschall*, 111 Pac. 879, 880. The court referred to opinions in the Paris *Revue* as appearing in *Current Literature* **49**, 3 (September 1910), 290.

Chapter Six

Research Funding: Trends, Controversies, Public Perception

Decisionmakers' need for scientific knowledge can be shown in trends of the federal government in funding scientific research. In 1945, President Franklin D. Roosevelt requested Vannevar Bush (1890–1974), then the director of the Office of Scientific Research and Development, to write a report that would encourage government support for scientific research and, at the same time, be a primer on the use of joint efforts for academic institutions and corporations on the importance of science and technology for the national interest. The result was *Science, The Endless Frontier*,[1] in which Bush established workable priorities for how government can promote scientific progress in the United States. The report spoke also to government's role in providing monies (in the form of scholarships) to potential future leaders in science and technology, in order to maintain the United States' competitiveness. "[O]ne of the peculiarities of basic science," Bush noted in the report, "is the variety of paths which leads to productive advance. Many of the most important discoveries have come as a result of experiments undertaken with very different purposes in mind."[2]

6.1 Basic or Applied?

"Pure research" has been described as research without specific ends, but such a broad definition can be misleading. The term "basic research" has been reserved for research that involves a quest for some fundamental understanding of natural phenomena. Its goal is to increase the general knowledge and understanding of nature and its laws. Basic research provides the means to answering a large number of important practical problems, but not a specific solution to any one of them. This is not to suggest that applications of science often cannot be foreseen—potential applications are often seen in general, rather than specific, terms.

The distinction between applied and basic research has increasingly blurred. In many instances industrial scientists tackle specific problems from broad fundamental viewpoints. According to Harvey Brooks,

> that the basic/applied distinction is increasingly unrealistic in failing to recognize the extent to which even some of the deepest and most fundamental research questions originate from problems that were first identified in a practical context but which subsequently opened up whole new vistas of fundamental intellectual inquiry best pursued in the style and

---

[1] U.S. Office of Scientific Research and Development. *Science, The Endless Frontier.* A report to the President by Vannevar Bush, director of the Office of Scientific Research and Development, July 1945 (Washington, D.C.: U.S. Gov't. Printing Office, 1945).

[2] Ibid., 13.

> logical sequencing of curiosity-driven exploration usually associated with the term basic research.[3]

Donald E. Stokes, in *Pasteur's Quadrant*, argued that Bush too narrowly expressed the motives for basic research and the actual sources of technological innovation, that a definition such as Bush's of the relationship of scientific discovery to technological improvement itself increases the difficulty of policymaking for science.[4] According to Harvey Brooks:

> The original categorization of basic research as a distinct activity arose in the U.S. historical context from fear, often well justified by experience, that a sort of Gresham's law would operate in circumstances when basic and applied research were in political competition for resources -- a fear that short-term goals, easily articulated in popular terms, would drive out long-term efforts at deeper conceptual understanding that were harder to articulate intelligibly to a relatively uneducated public.[5]

Concern has been expressed that universities may be diverted from what they do well—namely, the institutionalization and codification of the generic knowledge underlying industrial practice—in order to undertake more commercially oriented activities that require market judgment and which also may be done well away from the business environment.[6]

This danger may be overblown. For centuries individuals have demonstrated that science and technology are intricately intertwined. According to Charles Coulson Gillispie, "[K]nowledge finds its purpose in action and action its reason in knowledge."[7] Brooks has attempted to lay to rest the perception that basic and applied research are poles apart: "T]he terms basic and applied are…not opposites. Work directed toward applied goals can be highly fundamental in character in that it has an important impact on the conceptual structure or outlook

---

[3]Harvey Brooks, "Some Reflections on the Past, Present, and Future of U.S. Science and Technology Policy," The Merton C. Flemings Lecture, presented March 23, 1995. Harvey Brooks is Benjamin Pierce Professor of Technology and Public Policy, Emeritus, Kennedy School of Government, and Gordon McKay Professor of Applied Physics, Emeritus, Division of Engineering and Applied Sciences, Harvard University. His research has been in the fields of solid state physics, nuclear engineering, underwater acoustics and science and public policy. See URL: http://ksgnotes1.harvard.edu/BCSIA/BCSIA.nsf/www_people/BrooksHarvey

[4]Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, D.C.: The Brookings Institution, 1997), 3. Stokes calls Vannevar Bush's concept of "basic research" as research performed without thought of practical ends an "aphorism" rather than a definition.

[5] Brooks, "Some Reflections on the Past, Present and Future of U.S. Science and Technology Policy."

[6]Harvey Brooks, "Research Universities and the Social Contract for Science," *Empowering Technology*, Lewis M. Branscomb, ed. (Cambridge, MIT Press, 1995).

[7]Charles Coulson Gillispie, quoted in *Pasteur's Quadrant*, 32. Gillispie was Editor in Chief of the *Dictionary of Scientific Biography* (New York: Charles Scribners Sons, 1975).

of a field. Moreover, the fact that research is of such a nature that it can be applied does not mean that it is not also basic."[8]

Prior to World War II, the U.S. government held basic research as its prime responsibility for funding at its laboratories and at universities, while applied or development or technology-based projects were viewed as a corporate expense. In the early years of the twentieth century, the United States had profited in national defense from technological expertise at industrial research facilities such as Westinghouse and General Electric, but complacency of both government and of the United States' allies at the beginning of the War led to an initial blindness to the needs of applied research for "preparedness." Government research facilities, academic institutions, and corporations were then perceived as independent and autonomous entities where the cross-fertilization of basic and applied science was less than might prudently have been expected.

Policymakers learned the danger of limiting research and the sources of important pharmaceuticals during World War I, when the United States could not manufacture Salvarsan, a drug used to treat syphilis, because the U.S. patents were held by a German company. In wartime, the German company could not supply the U.S. market nor could the United States obtain a license to manufacture the drug. The stalemate continued until the United States entered the war, on April 6, 1917, and in October of 1917 could apply provisions of the Trading with the Enemy Act.[9] The dangers of limited research were reflected again in 1957, when the Soviet Union launched the Sputnik satellite, and the Soviet's well-orchestrated propaganda campaign and public relations blitz encouraged in the United States the public perception of the dangers of a lagging scientific base.

6.2 Trends in Federal Funding

In 1997, according to the NSF, the United States spent roughly $211 billion on R&D, or about 2.6 percent of the country's total gross domestic product (GDP). Of that $211 billion, industry provided about 63 percent.[10] **Table 6-1**[11] shows post-World War II trends in overall R & D expenditures (1953-1998). By comparison, since 1970, Japan and Germany have spent

---

[8]Harvey Brooks, "Applied Science and Technological Progress," *Science* **156** (June 30, 1967), 1706-12; *Applied Science and Technology Progress: A Report to the Committee on Science and Astronautics, U.S. House of Representatives, by the National Academy of Sciences* (Washington, D.C.: U.S. Gov't Printing Office, 1967) (full report).

[9]Patricia S. Ward, "The American Reception of Salvarsan," *Journal of the History of Medicine* (January 1981), 60-61, text and note 37.

[10]NSF, *Science and Engineering Indicators—2000*, Appendix Tables 2-1 and 2-3.

[11] National Science Board, *Science & Engineering Indicators – 2000*. Arlington, VA: National Science Foundation, 2000 (NSB-00-1), Table 2-3.

considerably more on non-defense R&D spending as a percentage of the gross domestic product (GDP) than the United States: in 1990, Japan spent almost 50 percent more and Germany roughly 30 percent more.[12]

In 1991, euphoria in the West at the collapse of the Soviet Union and, with it, the end of the cold war encouraged the view in the United States that military preparedness and significant funding for military R&D were largely no longer needed. The Department of Defense accounted for 61.2% of the federal R & D budget in 1989, while in 1999 its share was only 46.8%.[13] What the public appears not to have understood was that a large part of military-related budgets supported academic research. Deep cuts in military spending therefore reduced funding to academic laboratories with no other agency, except NIH, filling the gap. Total R&D expenditures by the federal government, in constant 1992 dollars, decreased $4.7 billion between 1989 and 1999.[14]

In 1935, of the $50 million universities in the United States spent on research, the federal government provided about $12 million.[15] Proportionally, the federal government's share grew from 66.7% in 1953, to a high of 77.3% in 1965, and then shrank to a low of 61.5% in 1991. Since 1991, the percentage has averaged just under 63%.[16] Since the mid-1970s, the National Institutes of Health (NIH), have accounted for 45 percent of funding of all university and academic research.[17]

---

[12]NSF, *SEI-2000*, p. 2-46 and App. Table. 2-64.

[13] NSF, *SEI-2000*, App. Table 2-25.

[14] NSF, *SEI-2000*, App. Table 2-26.

[15]National Resources Committee, *Research—A National Resource*, Vol. 2 [of how many total?] (Washington, D.C.: U.S. Gov't Printing Office, 1938), 178.

[16] National Science Board, *Science & Engineering Indicators – 2000*. Arlington, VA: National Science Foundation, 2000 (NSB-00-1)(hereafter NSF, *SEI-2000*) Appendix Table 2-8, U.S. basic research expenditures, by performing sector and source of funds: 1953-1998.

[17]Rosenberg and Nelson, 94.

U.S. R&D expenditures, by performing sector and source of funds: 1953–98

(Millions of current dollars)

Performing sector:	Total U.S.	Federal Govt.	Industry			Industry FFRDCs	Universities & colleges						U&C FFRDCs	Other nonprofit institutions				Nonprofit FFRDCs
Funding sector:	Total U.S.	Federal Govt.	Total	Federal Govt.[a]	Industry[b]	Federal Govt.[a]	Total	Federal Govt.	Nonfed. Govt.	Industry	U&C	Federal Nonprofit	Federal Govt.[c]	Total	Federal Govt.[a]	Industry	Non-profit	Federal Govt.[a]
Calendar year[d]																		
1953	5,160	1,015	3,630	1,430	2,200		273	149	40	21	37	27	131	112	58	26	28	
1954	5,621	963	4,070	1,750	2,320		301	165	45	24	40	29	161	127	65	31	31	
1955	6,281	973	4,517	2,057	2,460	123	342	191	50	27	42	32	187	131	64	35	32	9
1956	8,500	1,130	6,272	2,995	3,277	333	391	221	57	32	46	36	217	146	71	37	38	11
1957	9,908	1,297	7,324	3,928	3,396	407	433	242	64	37	51	40	267	167	79	37	51	14
1958	10,915	1,507	8,066	4,436	3,630	323	491	280	72	39	56	45	316	195	95	38	62	18
1959	12,490	1,681	9,200	5,217	3,983	418	586	356	81	40	61	50	349	234	125	42	67	22
1960	13,711	1,801	10,032	5,604	4,428	477	705	453	90	40	67	55	385	264	148	48	68	48
1961	14,564	1,987	10,353	5,685	4,668	555	834	557	101	40	75	62	440	304	169	49	86	92
1962	15,636	2,188	11,037	6,008	5,029	426	993	687	112	41	84	70	500	363	200	54	109	130
1963	17,519	2,558	12,216	6,856	5,360	414	1,178	839	125	41	96	78	580	408	234	55	119	165
1964	19,103	2,965	13,049	7,257	5,792	463	1,375	995	138	41	114	88	629	417	250	55	112	205
1965	20,252	3,156	13,812	7,367	6,445	373	1,595	1,167	150	42	136	101	630	472	286	62	124	215
1966	22,072	3,308	15,193	7,977	7,216	355	1,818	1,335	160	45	165	114	652	537	329	70	138	210
1967	23,346	3,444	15,966	7,946	8,020	419	2,035	1,491	168	52	200	126	696	561	342	74	145	225
1968	24,666	3,497	17,014	8,145	8,869	415	2,187	1,586	185	58	221	139	722	596	364	81	151	235
1969	25,996	3,790	17,844	7,987	9,857	464	2,280	1,624	208	61	233	155	731	642	388	93	161	245
1970	26,271	4,154	17,594	7,306	10,288	473	2,418	1,686	237	66	259	171	727	677	410	95	172	230
1971	26,952	4,409	17,829	7,175	10,654	491	2,565	1,760	262	72	290	182	735	709	427	98	184	215
1972	28,740	4,676	19,004	7,469	11,535	548	2,757	1,890	282	79	312	195	785	771	472	101	198	200
1973	30,952	4,837	20,704	7,600	13,104	545	2,953	2,009	302	90	343	211	841	882	566	105	211	190
1974	33,365	5,132	22,239	7,572	14,667	648	3,216	2,160	320	104	393	239	926	995	639	115	241	210
1975	35,686	5,561	23,460	7,878	15,582	727	3,570	2,400	348	118	432	272	1,067	1,076	675	125	276	225
1976	39,458	5,890	26,107	8,671	17,436	890	3,899	2,619	369	131	480	300	1,266	1,162	711	135	316	245
1977	43,456	6,211	28,863	9,523	19,340	962	4,346	2,893	394	155	569	337	1,551	1,248	740	150	358	275
1978	48,822	6,962	32,222	10,107	22,115	1,082	4,996	3,329	443	182	679	364	1,826	1,402	830	165	407	333
1979	55,521	7,471	37,062	11,354	25,708	1,164	5,715	3,848	482	215	785	386	2,091	1,629	985	180	464	390
1980	63,332	7,831	43,228	12,752	30,476	1,277	6,455	4,335	519	264	920	419	2,366	1,700	1,000	200	500	475
1981	72,307	8,605	50,425	14,997	35,428	1,385	7,085	4,670	581	314	1,058	463	2,483	1,788	1,038	225	525	538
1982	80,837	9,501	57,166	17,061	40,105	1,484	7,603	4,879	621	363	1,207	534	2,608	1,950	1,175	250	525	525
1983	90,030	10,830	63,683	19,095	44,588	1,585	8,251	5,210	658	432	1,357	595	2,944	2,138	1,313	275	550	600
1984	102,308	11,916	73,061	21,657	51,404	1,739	9,154	5,748	721	518	1,514	654	3,337	2,478	1,550	323	605	625
1985	114,747	13,093	82,376	25,333	57,043	1,863	10,308	6,388	834	630	1,743	713	3,709	2,736	1,700	376	660	663
1986	120,297	13,504	85,932	26,000	59,932	1,891	11,540	7,028	969	745	2,019	780	4,051	2,842	1,700	420	722	538
1987	126,255	13,588	90,160	28,757	61,403	1,995	12,807	7,768	1,065	831	2,262	882	4,369	2,834	1,569	449	816	501
1988	133,903	14,342	94,893	28,221	66,672	2,122	14,219	8,592	1,165	934	2,527	1,003	4,631	3,187	1,762	496	928	510
1989	141,909	15,231	99,860	26,359	73,501	2,195	15,631	9,314	1,274	1,062	2,852	1,131	4,781	3,664	2,062	556	1,046	547

U.S. R&D expenditures, by performing sector and source of funds: 1953–98

(Millions of current dollars)

Performing sector:	Total U.S.	Federal Govt.	Industry			Industry FFRDCs	Universities & colleges						U&C FFRDCs	Other nonprofit institutions				Nonprofit FFRDCs
Funding sector:	Total U.S.	Federal Govt.	Total	Federal Govt.[a]	Industry[b]	Federal Govt.[a]	Total	Federal Govt.	Nonfed. Govt.	Industry	U&C	Federal Nonprofit	Federal Govt.[c]	Total	Federal Govt.[a]	Industry	Non-profit	Federal Govt.[a]
Calendar year[d]																		
1990	152,039	15,671	107,404	25,802	81,602	2,323	16,935	9,935	1,399	1,167	3,186	1,249	4,955	4,115	2,345	614	1,156	636
1991	160,863	15,249	114,675	24,095	90,580	2,277	18,201	10,662	1,482	1,243	3,457	1,358	5,163	4,603	2,679	668	1,256	696
1992	165,211	15,853	116,757	22,369	94,388	2,353	19,383	11,523	1,524	1,321	3,568	1,448	5,271	4,847	2,806	703	1,339	748
1993	165,442	16,532	115,435	20,844	94,591	1,965	20,499	12,311	1,550	1,388	3,719	1,533	5,283	4,978	2,839	721	1,418	749
1994	168,854	16,432	117,392	20,261	97,131	2,202	21,626	13,009	1,611	1,448	3,960	1,598	5,317	5,125	2,900	747	1,478	759
1995	183,232	17,133	129,830	21,178	108,652	2,273	22,647	13,604	1,741	1,539	4,139	1,624	5,372	5,165	2,848	814	1,502	812
1996	196,540	16,627	142,371	21,356	121,015	2,297	23,720	14,180	1,839	1,655	4,375	1,672	5,410	5,343	2,906	891	1,546	771
1997	211,268	16,814	155,409	21,798	133,611	2,130	25,001	14,849	1,940	1,773	4,686	1,754	5,466	5,628	3,036	969	1,623	820
1998 .. prelim.	227,173	17,189	168,922	22,216	146,706	2,373	26,343	15,558	2,070	1,896	4,979	1,840	5,517	6,006	3,254	1,051	1,702	823

FFRDCs = Federally Funded Research and Development Centers; U&C = universities and colleges

NOTES: Data are based on annual reports by performers except for the nonprofit sector; R&D expenditures by nonprofit sector performers have been estimated since 1973 on the basis of a survey conducted in that year. The next updates of these data, covering the years 1953–2000, along with technical notes explaining methodological issues of measurement, will be provided in National Science Foundation, Division of Science Resources Studies (NSF/SRS), *National Patterns of R&D Resources: 2000* (Arlington, VA: forthcoming). Data are preliminary for 1998.

[a]For 1953–54, expenditures of industry FFRDCs were not separated out from total Federal support to the industrial sector. Thus, the figure for Federal support to industry includes support to FFRDCs for those two years. The same is true for expenditures of nonprofit FFRDCs, which are included in Federal support for nonprofit institutions in 1953–54.

[b]Industry sources of industry R&D expenditures include all non-Federal sources of industry R&D expenditures.

[c]Includes R&D expenditures of FFRDCs administered by academic institutions, nearly all of which are federally funded.

[d]Expenditure levels for academic and Federal Government performers are also in reference to calendar years, unlike the levels typically provided in statistical reports on these institutions alone, which are in reference to fiscal years. These calendar–year expenditure levels are approximations based on fiscal year data.

SOURCE: National Science Foundation, Division of Science Resources Studies (NSF/SRS), *National Patterns of R&D Resources* (Arlington, VA: biennial series).

See page 1-33; figures 2-2, 2-11, and 2-12; text table 2-1; and figures 6-1 and 6-2 in Volume I.

6.3 Controversies

But even at the NIH, which saw its percentage of the federal research budget increase , increases ear-marked for particular areas of research were a cause of contention. In one instance, the forces of traditional medicine have been battling with researchers in “alternative” medicine for the spoils of war that are dollars and status. As leaders of the traditional camp see fewer NIH funds marked for basic research in teaching hospitals while increasing amounts go toward funding what they see as questionable medical research, they often have invoked the terms junk science and pseudoscience (see **Chapter Three** and section **4.4**) to describe these rivals.

NIH’s Office of Alternative Medicine (OAM) was elevated to the status of institute in October 1998, and renamed the National Center for Complementary and Alternative Medicine (NCCAM).[18] In 1998, the OAM’s budget was $20 million; in 2000, the Center’s budget was $68.7 million; and for 2003, $113.4 million.[19] OAM had been part of the Office of the NIH Director. Like other institutes at NIH, the Center’s grants are reviewed by scientists of its own choosing, not by scientists in other NIH Institutes and Centers, as was the case in the past. NCCAM’s advisory council also reflects a shift in power from representatives of traditional medicine.

The legislation also called for creation of a presidential commission to make recommendations to Congress on issues involving alternative medicine. The *New England Journal of Medicine*, not surprisingly, sniffed that many alternative remedies reflect “a reversion to irrational approaches to medical practice.”[20] The success of organizations supporting alternative medicine in gaining passage of the legislation over the objection of Dr. Harold Varmus, then Director of NIH, was attributed to the effort of Sen. Tom Harkin (D-IA).[21]

Were the traditionalists merely entrenched interests protecting their own turf at the expense of ignoring innovative alternatives; defending orthodoxy against new knowledge? Or were they the defenders of real science against an onslaught of wackos? Either way, the jockeying demonstrates that politics and public opinion have become significant influences in the decisionmaking process. Where NIH funds less than 30 percent of research grant applications,[22]

---

[18] Omnibus Consolidated and Emergency Supplemental Appropriations Act, P.L. 105-277.

[19] National Center for Complementary and Alternative Medicine, “NCCAM Funding: Appropriations History,” http://nccam.nci.nih.gov/about/appropriations (accessed May 1, 2003).

[20] *Chronicle of Higher Education*, Nov. 6, 1998, A51.

[21] Senator Thomas Harkin (Dem.-Iowa), *Chronicle of Higher Education*, Nov. 6, 1998, A51. An early director of OAM, Joseph Jacobs, resigned and blamed Harkin’s interference. Eliot Marshall, “The Politics of Alternative Medicine,” *Science*, Vol. 265, 30 Sep 1994, p. 2000-02.

[22] Cary P. Gross, Gerard F. Anderson and Neil R. Powe, “The Relation between Funding by the National Institutes

the traditional medicine forces had lost their absolute control over the allocation of research funds.

Public perception and political influences affect not only how are funds allocated to nontraditional science and medicine, but also how funds are allocated within traditional medicine. An article in The New England Journal of Medicine reported that, overall, the NIH's priorities for financing research on 29 major diseases was closely correlated with the relative numbers of deaths and disability an illness causes. Those diseases were found to cause 62 percent of deaths and disability. Two illness that had become politically sensitive, AIDS and breast cancer, received 10 times and 7 times, respectively, more research financing than to any other disease with a comparable burden of death and disability.[23] According to Dr. Varmus, in setting priorities, the amounts that the NIH determined for financing research were not calculated solely by the "burden index" but also in accord with prospects for making advances on specific diseases.[24]

6.4 Public Perception

According to Vannevar Bush, "There is a perverse law governing research: Under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure."[25] But in the words of Albert Einstein, "Science will stagnate if it is made to serve practical goals."[26]

Fundamental and applied research, although they share some similarities, are different. The difference between funding and supporting research about quarks and funding and supporting research to develop sugar-free ice-cream is clear to the public. In the past century, the public seems to have perceived science in a positive light, given the social benefits of scientific innovation, and has rarely questioned federal funding priorities for R&D. Without stakeholders to step up to address science issues responsibly, public support for funding their work weakens. When an uneducated lay public sees and hears only the confusion and controversy of experts, public opinion will not favor the scientific community.

---

of Health and the Burden of Disease," *The New England Journal of Medicine*, Vol. 340, No. 24, June 17, 1999, pp. 1881-87.

[23] Ibid.

[24] Harold Varmus, "Evaluating the Burden of Disease and Spending the Research Dollars of the National Institutes of Health," *New England Journal of Medicine*, Vol. 340, No. 24, June 17, 1999, pp. 1913-15.

[25] U.S. Office of Scientific Research and Development. *Science, The Endless Frontier.* A report to the President by Vannevar Bush, director of the Office of Scientific Research and Development, July 1945 (Washington, D.C.: U.S. Gov't. Printing Office, 1945), p.

[26] Albert Einstein, *Einstein on Peace*, edited by Otto Nathan and Heinz Norden (New York: Simon and Schuster, 1960), p. 402. The authors translated Einstein's words from a German manuscript of his response to questions posed by Jacob Landau of the Overseas News Agency, Jan. 20, 1947.

Scientists do science, policymakers make policy, including for science. What is the process by which science policy is established? By whom is the policy made and with what inputs? Science policy issues are mixed determinations of the conduct of scientific research and the tools for making the policy which affects the conduct of scientific research. Between “mostly scientific” and “mostly political” lies the realm of conflict for decisionmaking. Substantive R&D decisions were until the 1970s somewhat removed from the day-to-day quibbling of the political forum.

The Food and Drug Administration Modernization Act of 1997 provides an example of well-crafted science policy. Two federal acts, the Food, Drug, and Cosmetic Act and the Public Health Service Act, had neither of them been revised since 1938, and the “modernization” was a collaboration of the biotechnology industry and pharmaceutical research and manufacturers with Congress and government regulators. The enactment of this legislation offers a lesson in patience, respect, and understanding among the interested parties. Throughout laborious negotiations and amidst the fluid politics of the 1990s, those working toward revision had to deal with a discrepancy between the FDA’s fiscal resources and its responsibility to meet an increasing workload while holding to the goal of international harmonization. The agency needed to reconcile the lengthy process of approving a drug for a particular use, intended to protect the public, with the delay in making a potentially life-saving drug available for prescription, a process which took far less time in other developed countries.

In 1992, by agreement of the FDA and the biotechnology and pharmaceutical researchers and manufacturing industries, led by Gordon Binder, CEO of Amgen, Inc., a new procedure was implemented when Congress enacted the Prescription Drug User Fee Act (PDUFA), whereby industry would pay a fee equal to approximately one-third of the cost of drug review and the FDA was committed to aggressive performance goals. The act had a five-year “sunset provision.” Under this law, industry paid $327 million in user fees during fiscal years 1993 through 1997, and these fees enabled the FDA to make major improvements to its drug review process and to hire six hundred new reviewers.[27] It was an instance of those with knowledge educating decisionmakers with positive results.[28]

Like issues in other areas affected by political decisionmaking, science issues are decided in the context of the law, but, unlike other issues, they are also decided in political balancing acts wherein scientific evidence is but a single variable in the determination of policy.

---

[27]Prepared statement of Gordon M. Binder, Chairman and CEO of Amgen, on behalf of the Biotechnology Industry Organization and the Pharmaceutical Research and Manufacturers of America, U.S. Senate, Committee on Labor and Human Resources, Hearings, "Proposals to Reform the Performance, Efficiency, and Use of Resources of the Food and Drug Administration." S. Hrg. 105-23, April 11, 1997, 184.

[28]Binder's leadership and his ability to communicate about both the science and the politics involved were crucial to the outcome.

Chapter Seven

Perspectives

You live life looking forward, you understand life looking backward.

Soren Kierkegaard[1]

7.1 Science and Popular Beliefs

There has always been tension between science and both the governors and the governed. Scientific discoveries sometimes seem to threaten economic, social, or political interests. More often, as in many spheres, the powerful seek to protect their power against what is perceived as a threat by what they do not understand. Fear can also motivate the public, something not lost on politicians seeking popular support. History is littered with the wreckage of censorship, ostracism, imprisonment, and executions intended to stem the tide of science.

In ancient Athens, scientific speculation became identical with the crime of "impiety." About 440 B.C., according to Plutarch, a law was introduced to impeach or exile the impious, "those who denied the gods or taught about celestial phenomena."[2] In 411 B.C., Protagoras was brought to trial for this crime and charged by Eupolis, an author of comedies, with being an "imposter about the phenomena of the heavens" and his books were burned in the marketplace.[3] In 399 B.C., Socrates was condemned to death for "meddling in the affairs of the heavens."[4]

The story is told of Thales of Miletus, that while stargazing he fell into a well. An Egyptian teased him: "Is it because you found nothing on earth to look at, that you think you ought to confine your gaze to the sky?"[5] That thought persists today — that because of their strange curiosities scientists are removed from reality.

In sixth and seventh centuries B.C. in Greece and for many centuries later in western Europe, the study of science was seen as undermining religion. The study of science and

---

[1] Alastair Hannay, ed. and tr., *Soren Kierkegaard Papers and Journals: A Selection*, London and New York, Penguin Books (1996), p. 161. "It is quite true what philosophy says: that life must be understood backwards. But then one forgets the other principle: that it must be lived forwards."

[2] Mario Untersteiner, *The Sophists* (Oxford, Basil Blackwell, 1954)

[3] Mario Untersteiner, *The Sophists* (Oxford, Basil Blackwell, 1954).

[4] Richard Olson, *Science Deified and Science Defied*: *The Historical Significance of Science in Western Culture, from the Bronze Age to the Beginnings of the Modern Era, ca. 3500 B.C. to A.D. 1640*, vol. 1 (Berkeley: University of California Press, 1982), 80.

[5] Tertullian, *Ad Nationes* (Book ii, Chapt. 4), in *Ante-Nicene Fathers*, edited by Alexander Roberts and James Donaldson, vol. 2 of 10 (Buffalo: Christian Lit. Pub. Co., 1885-96), vol. 3 (1887), pp. 132-33.

philosophy was considered arrogant and unnecessary— and later as blasphemy. The early philosopher and cleric, Arnobious,[6] asked:

> What is it to you...to examine, to investigate who made man, what origins souls have, who conceived the causes of evils, whether the sun is larger than the earth, or measures a foot across, whether the moon shines by the light of another or by its own beam? ...There is no gain in knowing these things nor any loss in not knowing them. Leave these things to God and allow him to know what, wherefore, and whence something is.[7]

Questioning the validity of scientific thinking (even of science) persists in the present. The general understanding of science remains poor, a poverty that affects making intelligent decisions about scientific issues. Most people hear "Bacon" and think first of something that goes with scrambled eggs, hear Newton and think "fig." In 1999, a poll by the NSF found that 40 percent of the respondents were very interested in science and technology, but only 17 percent described themselves as well-informed about it while about 30 percent described themselves as poorly informed.[8] These figures are not surprising in light of reports of abysmal achievements in basic math and science among U.S. students at all levels of education.

According to Carl Sagan (1934–1996):

> I have a foreboding of an America in my children's or my grandchildren's time—when the United States is a service and information economy; when nearly all the key manufacturing industries have slipped away to other countries; when awesome technological powers are in the hands of a very few, and no one representing the public interest can even grasp the issues; when the people have lost the ability to set their own agendas or knowledgeably question those in authority; when, clutching our crystals and nervously consulting our horoscopes, our critical faculties in decline, unable to distinguish between what feels good and what's true, we slide, almost without noticing, back into superstition and darkness.[9]

---

[6] Arnobius was a distinguished rhetorician at Sicca in Proconsular Africa and Christian convert during the reign of Diocletian (284-305).

[7] Arnobius of Sicca, *The Case Against the Pagans*, trans. George E. McCracken, vol. 1 of (Westminster, Md.: The Newman Press, 1949), 11; 61.

[8] NSF, *SEI – 2000*, Ch. 8, "Science and Technology: Public Attitudes and Public Understanding," p. 8-7. [On-line]. URL: www.nsf.gov/sbe/srs/seind00/c8/c8s1.htm (accessed 10 Mar 2003) Respondents to the poll were read the following statement by the interviewer: "There are a lot of issues in the news, and it is hard to keep up with every area. I'm going to read you a short list of issues, and for each one—as I read it—I would like you to tell me if you are very interested, moderately interested, or not at all interested." Table 8-3, notes. Respondents were also read the following statement: "Now I'd like to go through this list with you again, and for each issue I'd like you to tell me if you are very well informed, moderately well informed, or poorly informed." (Don't know responses excluded.) Table 8-4, notes.

[9] Carl Sagan, *The Demon-Haunted World* (New York: Random House, 1996), 25.

Attitudes toward science and the worth of scientific research affect federal funding of such research, particularly when it involves health or safety or the national defense. An old story goes that a Congressman once thundered, “This begins a new era in the history of civilization. Never before has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world. The menace to our people...would call for prompt legislative action, even if the military and economic implications were not so overwhelming.” When? The 1800s—and the power in question was the internal combustion engine.[10]

In 1857, the Senate debated funding another technology. Opponents thought that in the hands of enemies the project “could be made [a] powerful and dangerous…engine of war” and suggested also that the government should not fund a project likely to fail. According to a proponent:

> This is by no means the first time that an important experimental enterprise has been scouted as a wild and visionary scheme, involving a useless waste of time and money. This case belongs not to the thousand schemes and humbugs of the hour, resting on no principles of science or of common sense, but which contravene both. It belongs to no class of supposed new discoveries, nor does it propose the development of any new principle hitherto untried and unknown. It only proposes to extend and enlarge the operation of a well known principle of natural science, and which has been thoroughly tested. But all new and untried enterprises, whether practicable or impracticable, must pass the ordeal of public and private criticism. Fulton’s experiment encountered jeers and ridicule, when he placed the first steamboat upon the waters of the Hudson. The first idea publicly announced of the possibility of running carriages or cars over land by steam power, at the rate of thirty or forty miles an hour, was jeered at as the fancy of some hare-brained lunatic.... The experiments and labors of these men have overcome and outlived all opposition and all skepticism, and their names stand enrolled among the benefactors of their country....[11]

This controversy concerned not the space race and its military implications or strategic implications of the Internet but whether to fund the laying of the first transatlantic telegraph cable.

---

[10]Dixie Lee Ray and Lou Guzzo, *Trashing the Planet: How Science Can Help Us Deal with Acid Rain, Depletion of the Ozone, and Nuclear Waste (Among Other Things)* (New York: Harper Perennial, 1992), 22, quoted in Fumento, *Science Under Siege*, 355.

[11]*Congressional Globe*, 34th Cong, 2d sess. Sen. John Bell (1797-1869) (Whig - Tenn.) opposing the bill in remarks on Jan. 22, 1857, at p. 826. Sen. Solomon Foot (1802-1866) (Rep. – Vt.) responding in favor on Feb. 25, 1857, at p. 869. The extensive debate on this measure in both the House and Senate raised nearly every issue that policymakers in the twenty-first century still face.

7.2 Science and the Media

Scientists may well be correct in criticizing the media for its dearth of science or technical knowledge. The relationship between scientists and journalists has been described as that of xenophobes or evangelists. In 1980, William Burrows, a science journalist, wrote:

> Scientists assume that virtually everything they do is far less easily understood by lay people than other sorts of endeavors. Scientists think that whatever they tell a reporter is bound to come out wrong. Most ordinary reporters...consider scientists to be unemotional, uncommunicative, unintelligible creatures who are apt to use differential equations and logarithms against them the way Yankee pitchers use inside fast balls and breaking curves.[12]

A survey of members of the National Association of Science Writers conducted five years before the accident at TMI, indicated that only 11 percent had any special preparation to write about science.[13] No survey has been conducted of newspaper editors to discover their expertise or technical qualification. "For the inexperienced reporter," according to David M. Rubin, "the easiest question [at TMI] was 'what if?' The result was an over emphasis on worst-case scenarios."[14] When journalists lack technical information and must therefore depend on their sources, they are hostage to those sources. For risk assessment, a journalist needs to be able to sort out conflicting information, but, in matters relating to science, without knowledge of science, a journalist left to juggle stakeholders' interests—and values—may skew a story toward either critics or advocates about an issue, without understanding what truly is at stake. Although a journalist equipped with scientific training may succumb to many of the same forces, the probability of a knowledgeable journalist passing on biased information is lessened the more knowledge that reporter brings to a story. Reporting on technological risks is, by the nature if the subject, difficult, even controversial, and every stakeholder involved will seek to influence a story through the dissemination of information favorable to their own positions. Sources of information can be expected to frame risks in their own terms, and therein lie the politics of communication that make accuracy very difficult to obtain and achieve by media..

Who and what source(s) should a journalist believe in order to report responsibly on issues that require public analysis and informed decisionmaking? The American Association for the Advancement of Science (AAAS), the National Association of Science Writers, and the Media Resource Service (MRS) of the Scientists' Institute for Public Information (SIPI) all have been

---

[12] William Burroughs, "Science Meets the Press: Bad Chemistry," *The Sciences* (April 1980), 14.

[13] Sharon Friedman, *Changes in Science Writing Since 1965 and Their Relation to Shaping Public Attitudes Towards Science* (College Park: Pennsylvania State University Press, 1974)

[14] David M. Rubin, "What the President's Commission Learned About the Media," in *The Three Mile Island Accident: Lessons and Implications* , ed. Thomas Moss and David Sills (New York: New York Academy of Sciences, 1981, pp. 95-106.

trying to educate journalists about issues of science and technology. According to Leon E. Trachtman, professor of communications at Purdue University:

> The avalanche of popular articles dealing with possible risks associated with the use or nonuse of various foods, drugs, chemicals, and energy systems may well be calculated not to help in the making of wise choices, but rather to prevent the making of any choices at all.[15]

Thus the media are capable of becoming a political tool by being manipulated to encourage a particular outcome of a policy debate. For that reason, if no other, journalists need educated knowledge of math and science in order to be able to resist manipulation and to be able instead to apply both their knowledge and their critical thinking to issues involving science and technology.

7.3 Science Policy and *Realpolitik*

The increase of political input into science policy and the decrease in general public understanding of science, in combination, increase the risk that science policy decisions will become more and more expressions of an intellectual alienation from science whereby politics increasingly sees answers in science as irrelevant to providing answers to human problems. As scientific facts are increasingly viewed as less important in deciding policy than the politics of the issue, public support for science research is likely to suffer. Yet scientists remain aloof from the political fray.

The late George E. Brown, Jr., ranking minority member of the House of Representatives Committee on Science, Space and Technology, warned of the dangers of silence by scientists: "Unless scientists become more involved in shaping federal policy, their work many no longer receive adequate support."[16] The public is the ultimate stakeholder of science and technology, and until the last decade of the twentieth century, supported scientific pursuits, almost unquestioningly. Yet the U.S. the public expects policymakers to seek justifications for increasing (or decreasing) funding projects. High-energy research offers an example of inadequate scientific persuasion for what seemed esoteric and capital-intensive research. The demise of federal support for the Superconducting Super-collider (SSC) in 1993 may have signaled public disenchantment with funding for research megaprojects perceived as possessing little or no practical value. Many members of Congress supported cutting off funding to the project because of their concern about the federal budget deficit, not because they opposed the

---

[15] Leon Trachtman, quoted in *Science in the Streets*, 70; from Trachtman, "The Public Understanding of Science Effort: A Critique," *Science, Technology and Human Values* (Summer 1981), 13.

[16] George E. Brown, Jr., "Defining Values for Research and Technology," *Chronicle of Higher Education* (July 10, 1998), B4; adapted from a speech by Brown presented to the Colloquium on Science and Technology Policy of the American Association for the Advancement of Science, 1998. George E. Brown, Jr., (1920-1999) served as a member of the House (D-CA) from 1963-71 and 1973-99. He was chairman of the Committee on Science, Space and Technology in the 102nd and 103rd Congresses, and ranking member thereafter until his death.

project itself. But who outside a physics laboratory could explain the national need for congressional appropriation of over $11 billion for the SSC, with even more funding needed in the future? Those with a stake in the project were unable to explain clearly and persuasively its potential benefits to the public. Capital intensive projects, particularly esoteric ones such as the SSC and the manned space program, will increasingly require cogent public justification by scientists.

Proponents of such massive appropriations of funds might have taken some lessons from the relentless championing of the development of a nuclear reactor by Admiral H. G. Rickover. Rickover built a successful nuclear-powered submarine program by focusing the attention of government, industry, and the U.S. public on the practical engineering aspects of nuclear reactors, using his excellent relationship with the media. The first generation of electricity using civilian nuclear energy was a direct outgrowth of the naval nuclear power program that he developed and led.

Spending on scientific research that the public finds hard to understand has increasingly been viewed as removed from public needs. The public perception of the possible effects of radiation from nuclear energy, from substances everywhere that allegedly cause cancer, from medical technology that seems to run amok has affected policymakers' responses to science policy issues. The public is left to react to increasingly complex and seemingly incomprehensible scientific facts by listening and being guided or misguided by the media, special interest groups, and politicians who often know little more about science issues than the public.

Public hearings aired for political expediency have multiplied. According to Alan S. Binder:

> Political debate has too much 'spin' and too little straight talk. The system is too argumentative and tied up in partisan and procedural knots. More important, government appears excessively beholden to those with political clout, often at the expense of public interest.[17]

Michael Fumento has called such debate an "*argumentum ad populum*" and offered this example: a group of kindergartners studying a frog are trying to determine its sex. "I wonder if it's a boy frog or a girl frog," says one student. "I know how we can tell!" pipes up another. "All right, how?" asks the teacher, resigned to the worst. Beams the child: "We can vote."[18]

---

[17]Alan S. Binder, "Is Government Too Political?" *Foreign Affairs* (November-December 1997), p. 115. Binder is a professor of economics at Princeton University and a former vice-chairman of the Federal Reserve.

[18]Peter Huber likened courtroom proceedings in the Audi sudden-acceleration cases to "how the kindergarten student determines the sex of a frog," in *Galileo's Revenge: Junk Science in the Courtroom* (New York: Basic Books, 1991), 65; quoted in Michael Fumento, *Science Under Siege: Balancing Technology and the Environment* (New York: William Morrow, 1993), 283.

Good science is based on the idea of objective knowledge and on empirical testing and peer review. Julian Peto, a cancer epidemiologist remarked, “If the Pope had been right and Galileo wrong, we could hardly view their debate in the same light.”[19] In a nutshell, that is the dilemma for policymakers. Science policy is a hybrid: because *policy* is a social construct with political underpinnings, politicians, the public, and regulatory agencies make choices about the application of conflicting scientific data. The *scientific* issues involved in policy need to be viewed free from politics and decided by on the basis of testing and peer review.

Many engaged in science and science policy are concerned that bureaucratic processes slow research and increase its cost. The U.S. public, however, appears to rely on the federal government for assessments of importance and for public accountability. The issue is not simply complete autonomy for research that promises social benefits, but, rather, the ability to evaluate and identify spending priorities that would enhance the contribution of science to society without interfering with the integrity of the research. According to Harvey Brooks, “Scientists cannot have it both ways: ask to be subsidized by the public because of the ultimate practical value of their work, while arguing that science does not change power relations and, by itself, has no distributional effects.”[20]

It is apparent that public debate concerning the degree of scientific autonomy with respect to government policy will not go away. Science no longer is perceived as a technical enclave detached from society. The social impact of scientific advances and their potential risks will increasingly involve policy makers in what might previously have been thought to be purely scientific issues. While public oversight of the expenditure of public funds is normal, it is the degree of oversight that is likely to cause researchers to worry about government encroachment on free inquiry. Where funding decisions are used to limit scientific inquiry, such as in the recent controversies concerning stem cell research, the scientific community may perceive a threat to its independence. As the Supreme Court of Washington stated in 1910 in *Everett v. Paschall*, “The theories and dogmas of scientific men, though provable by scientific reference, cannot be held to be controlling unless shared by the people generally.”[21] In 1998, a government committee that evaluated public input in NIH decisionmaking found that Congress was favorable to decentralized priority-setting at NIH.[22]

---

[19]Sheila Jasanoff, *Risk Management and Political Culture* (New York: Russell Sage Foundation, 1986), p. 70 and n. 153. Sheila Jasanoff is Pforzheimer Professor of Science and Technology Studies at Harvard University.

[20]Harvey Brooks, “Research Universities and the Social Contract for Science,” in *Empowering Technology*, edited by Lewis M. Branscomb (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1995), 209.

[21]*Everett v. Paschall*, 61 Wash. 47, 52, 111 P. 879, 881 (1910). This decision has never been overruled.

[22]Institute of Medicine, Health Sciences Section, Health Sciences Policy Program, Committee on the NIH Research Priority-Setting Process, *Scientific Opportunities and Public Needs, Improving Priority Setting and Public Input at the National Institutes of Health* (Washington, D.C.: National Academy Press, 1998), [On-line]. URL: http://www.nap.edu/browse.html and http://www.nap.edu/catalog/6225.html (accessed 10 Mar 2003)

According to Sheila Jasanoff, some policy analysts would have “science policy” as an intermediate step between technical assessment and “pure” policymaking. They believe that “’Science policy’ …should be subject to the general institutional and legal controls that ensure legitimacy in U.S. policymaking. In particular, when purely technical debates may safely be left to experts, science policy decisions should be exposed to democratic and judicial as well as scientific checks.”[23] The distinction decisionmakers need to make is between questions that are to be considered scientific and those that are social policy.

[23]Jasanoff, op. cit., p. 72.

Chapter Eight

Scientific Literacy and Science Education

Science literacy, and the ability to understand and interpret data and information,[1] are critical to the practice of responsible science, to decisionmaking for science policy and to a nation's ability to compete globally. The case studies above reveal that decisionmakers, opinion molders, and the public all need, but lack, scientific knowledge. In the United States from 1979 through 1999, according to *Science and Engineering Indicators 2000*, 88 percent of the population surveyed has consistently said they were either very or moderately interested in new scientific discoveries. However, that interest does not appear to correlate positively to understanding those discoveries.[2] The difference suggests that Americans lack the education in science and math needed to translate interest into comprehension.

8.1 Where We Are: The Deficit

Student achievement in science and math increased somewhat between 1977 and 1996 in the U.S., according to the National Assessment of Educational Progress (NEAP).[3] However, international TIMSS comparisons show that U.S. students do less well than students in other nations.[4] In 1995, forty-one countries participated in TIMSS, and twenty-six of them again participated in 1999, along with twelve others.[5] The tests measured science and mathematics achievement in students at eighth grade level. As the results show, U.S. students scores ranked in the middle (see Table 8-1). In 1995, in mathematics U.S students ranked 28th among students from forty-two participating countries; in 1999, they were 19th among students from thirty-eight countries. The average score of U.S. students only rose from 500 to 502. The average score of U.S. students in science dropped, from 534 in 1995 to 515 in 1999.

---

[1] NSF, *SEI-2000*, p. 8-31. ("[I]t is useful to draw a distinction between *science* literary and *scientific* literacy. The former refers to the possession of technical knowledge. …Scientific literacy, on the other hand, involves not simply knowing the facts, but also requires the ability to think logically, draw conclusions, and make decisions based on careful scrutiny and analysis of those facts….")

[2] NSF, *SEI—2000*, Appendix Table 8-1: "Level of public interest in selected policy issues: 1979-99 (selected years)"

[3] NSF, *SEI-2000*, pp. 5-12 through 5-14.

[4] Third International Mathematics and Science Study (TIMSS). TIMSS is conducted by The International Study Center, Lynch School of Education, Boston College, in cooperation with the National Center for Educational Statistics of the Department of Education, the National Science Foundation, the World Bank, and the participating countries. Testing is to be conducted every four years, the first two such tests being in 1995 and 1999. See www.timss.org (accessed 10 Mar 2003)

[5] Sixteen countries participating in 1995 did not participate in 1999. Among them were Austria, Belgium (Walloon), Denmark, France, Germany, Ireland, Norway and Sweden, whose students had scored higher than U.S. students.

Table 8-1

National Rankings in Standardized Tests

Rank	Mathematics		Science	
1	Singapore	604	Taiwan	569
2	South Korea	587	Singapore	568
3	Taiwan	585	Hungary	552
4	Hong Kong	582	Japan	550
5	Japan	579	South Korea	549
6	Belgium (Fl)	558	Netherlands	545
7	Netherlands	540	Australia	540
8	Slovak Republic	534	Czech Republic	539
9	Hungary	532	England	538
10	Canada	531	Finland	535
11	Slovenia	530	Slovak Republic	535
12	Russia	526	Canada	533
13	Australia	525	Slovenia	533
14	Finland	520	Canada	533
15	Czech Republic	520	Hong Kong	530
16	Malaysia	519	Russia	529
17	Bulgaria	511	Bulgaria	518
18	Latvia	505	United States	515
19	United States	502	New Zealand	510
20	England	496	Latvia	503
21	New Zealand	491	Italy	493
22	Lithuania	482	Malaysia	492
23	Italy	479	Lithuania	488
24	Cyprus	476	Thailand	482
25	Romania	472	Romania	472
26	Moldova	469	Israel	468
27	Thailand	467	Cyprus	460
28	Israel	466	Moldova	459
29	Tunisia	448	Macedonia	458
30	Macedonia	447	Jordan	450
31	Turkey	429	Iran	448
32	Jordan	428	Indonesia	435
33	Iran	422	Turkey	433
34	Indonesia	403	Tunisia	430
35	Chile	392	Chile	420
36	Philippines	345	Philippines	345
37	Morocco	337	Morocco	323
38	South Africa	275	South Africa	243

Source: *TIMSS International Mathematics Report* (Chestnut Hill, MA: Boston College, 2000), p. 32; and *TIMSS International Science Report* (Chestnut Hill, MA: Boston College, 2000, p. 32. www.timss.org

Science and Engineering Indicators – 2000 reports that "[t]he percentages of [college] students who need remedial work in mathematics and science have remained high over the past 20 years."[6] In 1997, 22 percent of first-year colleges students needed remedial work in math, and 10 percent in science.[7]

These surveys indicate that a deficit in scientific knowledge exists in the U.S. which could have serious consequences. The next step is to identify its causes and to seek ways to reduce it.

8.2 Educational Needs

Conferences, fellowships, seminars, and other such specialized programs can be used to enhance and increase the scientific knowledge of certain professionals, such as judges and journalists, but the heart of the problem can be attacked only through an effort to improve students' science and scientific knowledge at the earliest levels of education.

If a rising tide can be said to lift all boats, then increasing the minimum of scientific knowledge for all students should help improve informed public input into policy decisions. This must be done in a manner that neither restricts nor inhibits, but encourages, the achievement of excellence by those with ability and desire to excel. Auto mechanics, house painters, carpenters, and machinists as well as scientists, engineers, and lawyers all can be called to vote and to serve on juries. Policy in a democratic society needs to take into account everyone's hopes and fears, and it can be improved through increasing the knowledge of all citizens and, as a beginning, of every student in its educational institutions.

Education policy in the United States, particularly for science education, needs improvement, but not with the political posturing that often supplants reasoned discussion. Reasoned judgments and decisions derive from knowledge and from experience, both in the context of personal and societal values. Given that strong convictions grounded in acrimony can undermine human values, if stridency and obstinacy cannot be avoided, they can be softened.

As illustrated in Table 8-2, increasing the amount of money spent per secondary-school pupil does not necessarily translate into higher achievement in math or science. The academic excellence in South Korea or the Czech Republic shown in their 1995 TIMSS ranking, was achieved while spending less than one third of what is spent per pupil in the U.S. The solid performance of Bulgarian students cannot be attributed to wealth or spending. Money, along with other variables, may be important to student achievement, but the calling for increased spending alone to improve math and science is not the answer.

---

[6] NSF, *SEI-2000*, p. 4-13.

[7] Ibid.

Table 8-2

TIMSS Expenditure per Pupil

Country	TIMSS Rank 1999		Per Pupil Expenditure 1993 ($)
	Math	Science	
United States	19	18	6,500
England	20	9	4,500
Japan	5	4	4,200
South Korea	2	5	2,000
Czech Republic	15	8	1,900
Hungary	9	3	1,800

Sources: Rankings from TIMSS (1999); approximate dollar amounts for per pupil expenditures derived from bar graph in "World Education League: Who's Top?" *The Economist*, March 29, 1997, p. 23.

The TIMSS study indicated that in France, the United States, and Britain, where classes usually number about twenty, pupils do significantly worse than those from East Asian countries where class size is almost twice that many. It is intuitive that smaller class size encourages better learning, yet it may not be so.

While the comparison between U.S. student and international students achievement does not fully explain the health of the U.S. educational system, most notable authorities hold that mathematics is universally measurable without significant bias. Its mastery provides the foundation for higher order cognitive skills imperative for scientific and technological advances.

The public is increasingly skeptical of the quality of public elementary and secondary education. However, to say that excellence can be achieved only in math and science magnet high schools, International Baccalaureate Programs, and in private and in charter schools denigrates the democratic principle of what a public school education is all about.

A better approach might be to determine why students cannot meet university/college entrance requirements, or need remedial courses, and then to meet the challenge to assure that every child is adequately provided an opportunity to master those requirements. A university is an institution for higher learning, not lowered learning. Stakeholders should ask hard questions and expect accountability of math and science educational policymakers just as they demand accountability in policy for science and science for policy.

At the secondary level of schooling, the National Science Foundation high school programs based solely on demonstrated academic talent have been weakened or discontinued. Why? A program officer at NSF, who wishes to remain anonymous, stated to the author that "the programs are considered 'elitist' and encourage excellence rather than diversity," as if excellence and diversity were mutually exclusive. Let's think about this issue. Is excellence "elitist" when it means demonstrated and quantifiable achievement as measured by multiple criteria such as test scores, participation and awards in math and science competitions, leadership in science, math related activities, research even while in high school, and superior recommendations, perhaps even with college credits while in secondary school?

One suggested approach for improving math and science learning is to establish national measures for achievement, and then work to bring all students up to agreed achievement levels. Where there is poor testing performance, extra effort to overcome the causes and to bring the student up to the standard would be needed. Due to social and environmental factors, a disproportionate number of individuals in a specific population category may need additional assistance to achieve mastery of some scientific material. There can be no variable standard for science and math proficiency. Either the facts and concepts are known and understood, or they are not. That this is demonstrated by various testing measures does not lead to the conclusion that quantifiable assessment of mastery of a subject is unfair and biased. Rather than diluting assessment tools and curricula, it is better to assure that each K-12 student meets standards of measurable achievement. Imposed parity, quotas, or methods of measurement to make everyone look qualified is a certain path to continued scientific illiteracy and the demise of the citizenry.

American students over the past half century have experienced the pit of education as the pedagogical pendulum alternates between rote memory and free-form "enabling." In order to attain scientific literacy, students need both a solid grounding in basic math and in science facts and concepts, and training that develops critical thinking skills and an understanding of the scientific method.

Chapter Nine

Toward the Future

The following measures, among others, need to be considered to improve scientific literacy and science education in the United States:[1]

1. K-12 national standards in science and math;
2. assessment by states to meet national standards;
3. an increase in "advanced" and "enriched" courses for K-12;
4. a special effort to teach science to students not expected to attend college;
5. a special effort to teach science to students particularly disadvantaged, socially and economically;
6. encouragement of "magnet" science and math schools and "charter" schools;
7. a pooling of resources to allow precocious students to attend college for the third and fourth years of secondary school;
8. no requirement of a teaching degree for a teacher in the math or science subject to be taught whose competence in that subject is demonstrable by objective testing; and
9. testing of teachers by valid and reliable measures to demonstrate competence in core subject areas.

The future of science lies in the cultivation of academic, corporate, and government relationships and in collaborations based on mutual respect and an understanding that nothing less than excellence will be expected. The interdependence of these groups will require new and creative ways to do scientific research and to make science policy if the quality of life expected by the U.S. public is to be improved, and if scientific and technological competitiveness is to be maintained and enhanced. Success in these endeavors requires increased understanding by the general public and decisionmakers of science and math, which in turn requires more effective education in these subjects.

---

[1] These measures are a synthesis derived from the author's eighteen years of experience in education as a teacher, consultant, policy maker, and administrator.

Acronyms

AAAS	American Association for the Advancement of Science
DOD	Department of Defense
FDA	Food and Drug Administration
GDP	gross domestic product
MRS	Media Resource Service (SIPI)
NIH	National Institutes of Health
OAM	Office of Alternative Medicine (NIH)
PDUFA I	Prescription Drug User Fee Act (1992)
R&D	research and development
SIPI	Scientists' Institute for Public Information
SSC	Superconducting Supercollider
TIMSS	Third International Mathematics and Science Study

JPDIGENNARO

JPDIGENNARO

ISBN1879716925

ISBN1879716925