in the support of nondefense applied research or civilian development.

Internal Government Coordination

Consistent with President Truman's charge in establishing PSRB, *Science and Public Policy* documented in detail the Federal Government's rapidly expanding science and technology programs, noting that they were dispersed across many agencies with little or no coordination among them, except by means of the annual budget process managed by BoB. As one means to improve this situation, it recommended that an interagency committee should be established "to secure maximum interchange of information with respect to the content of research and development programs" and that the Federal Government's role with respect to the national science and technology enterprise should be monitored continually to obtain "an over-all picture of the allocations of research and development functions among the Federal agencies" (Steelman 1947, vol. I, 61).

The report went on to emphasize that science policy issues might often require attention at the highest levels of government. Accordingly, it asserted that "There must be a single point close to the President at which the most significant problems created in the research and development program of the Nation as a whole can be brought into top policy discussions" (Steelman 1947, vol. I, 61).

International Dimensions

The U.S. scientific community was eager to reestablish international communication and information exchange that had been disrupted by World War II. Types of Federal assistance suggested by *Science—The Endless Frontier* and *Science and Public Policy* included funding travel to international scientific meetings, encouraging visits to the United States by outstanding foreign scientists, supporting translations of foreign journals, and awarding international fellowships. S*cience and Public Policy* predicted that "the future is certain to confront us with competition from other national economies of a sort we have not hitherto had to meet" (Steelman 1947, vol. I, 4). Despite this, it went on to argue that it was in the national interest to lend "every possible aid to the re-establishment of productive conditions of scientific research and development in all those countries [of Europe and Asia] willing to enter whole-heartedly into cooperation with us" (Steelman 1947, vol. I, 5). The report suggested that such aid might include assistance in the reconstruction of research facilities in Europe as a component of the Marshall Plan, which had been proposed two months before its release.[30] It also suggested several more modest measures, including international fellowships for U.S. science and engineering students and more experienced investigators to work abroad, and a program for shorter term visits by senior U.S. researchers to allow them to reestablish international connections interrupted by World War II. Reciprocally, it recommended that U.S. universities should be encouraged to admit qualified foreign science and engineering students, particularly into their graduate programs (Steelman 1947, vol. I, 38–40).

Looking into the future and beyond the principal prewar scientific powers, the Steelman report noted that:

> Currently great progress is being made in India in the construction of new scientific research laboratories and in the training of hundreds of first-rate research workers.[31] In the same way Chinese scientific development may be expected to go forward rapidly, and great progress is being made in our neighbor American Republics (Steelman 1947, vol. I, 41).

In short, *Science and Public Policy* took the view that U.S. science policy should be based on a long-term view, particularly with regard to its international dimensions, and that what it tacitly assumed would be short-term problems in other countries should not be allowed to obscure the rising importance of science on a global level.

Monitoring the Condition of the Science and Engineering Enterprise

"A Program for the National Science Foundation"

Science—The Endless Frontier and *Science and Public Policy* had both envisioned a science policy implemented in a genuine peacetime context, albeit with due regard for national security needs. As it happened, the final elements of the U.S. Government's science and technology organization were put in place during the early stages of the Cold War. NSF was created barely six weeks before the start of the Korean War on June 25, 1950, and the first protopresidential Science Advisory Committee, established on April 19, 1951, was created as a response to the Korean crisis on the recommendation of William T. Golden.

As background for the report on science and national security that the White House commissioned in September 1950, Golden interviewed a wide range of scientists, military experts, and politicians, including Bush, Steelman, and three prominent scientists whom President Truman had nominated as members of the first NSB on November 2, 1950: Detlev W. Bronk, a biologist who was president of The Johns Hopkins University and of the National Academy of Sciences (NAS); James B. Conant, a chemist and president of Harvard University; and Lee A. DuBridge, a physicist and president of the California Institute of Technology.

While the main purpose of Golden's interviews was to determine whether in view of the Korean crisis an organization similar to OSRD should be created, he frequently inquired as well about the role that the newly created NSF should play among other agencies of the Federal Government. Golden summarized his conclusions in a February 13, 1951, memo-

[30]Secretary of State George C. Marshall announced the intention of the United States to provide funds for the reconstruction of Europe's infrastructure in an address at the Harvard University commencement on June 7, 1947.

[31]The first volume of the Steelman report was released less than two weeks after India achieved its independence from Great Britain on August 15, 1947.

randum entitled "Program for the National Science Foundation" (Blanpied 1995, 67–72).

Near the beginning of his memorandum, Golden noted that, as a result of the Korean emergency, "Federal funds for research and development of all kinds within the Department of Defense alone, which originally approximated $500 million for FY 1950, are expected to be in the neighborhood of $1,250,000,000 for FY 1952."

It would be tempting, he conceded, for the newly created NSF (which, at the time Golden wrote his memorandum still did not have a director[32]) to attempt to capitalize on this situation. However, he went on, "it may be worth repeating that in accordance with the spirit of the Act [of May 10, 1950] the National Science Foundation should confine its activities to furthering basic scientific studies and that it should not dilute its effectiveness by supporting studies of directly military or other applied character. To do so would seriously impair the long-term mission of the National Science Foundation without materially contributing to the war effort."

Consistent with this long-term view and the high probability that NSF's financial resources would very likely be constrained at least as long as the Korean emergency continued, Golden suggested that a high priority should be assigned to human resources development in the form of a fellowship program. "In view of the disruption of the educational process inherent in the mobilization effort it would be unwise not to undertake some such fellowship program in order to insure the continuing production of scientific leaders over the longer term … The cost of such a fellowship program is very small in relation to its potential value and to the total cost of Government's scientific research program."

More broadly, and with the long-term mission of NSF still in view, Golden recommended that steps should be taken to assess the status of the Nation's science and technology system as a first step in determining the agency's future directions. In essence, he suggested that the Foundation, under the guidance of the Board, should prepare to engage in serious priority-setting based on sound data. To this end, Golden recommended that "the Foundation, promptly after the appointment of a Director, might proceed to the following principal undertakings":

> 1. Prepare a comprehensive review detailing the significant areas of basic science which are now being studied within the United States, showing these separately for research supported by universities, by industry and by the Government. To the extent practicable the pattern should also indicate work in process in friendly foreign countries.
>
> 2. Prepare a comparable survey detailing the existing support of graduate and undergraduate education in the sciences by the many public and private agencies so engaged.
>
> 3. Study the scientific manpower resources of the United States: a) as specifically called for in the Act, by taking over, completing, and keeping current the detailed National Scientific Register[33]; and b) by preparing quantitative analytical studies of available and prospective scientific and technical manpower.
>
> 4. Review basic research activities of other Government agencies and in cooperation with them develop proposals for transferring appropriate portions of these programs to the National Science Foundation. In this connection, and to provide background for its work, the Board might wish to invite other Government agencies engaged in or supporting basic research activities to make descriptive presentations of their programs to the Board.

Golden concluded his February 13 memorandum by observing that "preparations of studies of the aforementioned character are primarily tasks for the staff under the Director but the members of the 24-man Board … are particularly well qualified to plan and determine their undertakings and to give guidance to the staff in the areas of their specialties."

The director of BoB transmitted Golden's memorandum to James B. Conant, chairman of the NSB, on February 15, 1951. The minutes of the Board's fourth meeting, held on March 8–9, 1951, stated that Golden's memorandum had been received, but that no specific action was taken on it. This is not surprising, since the Board had to deal with a particularly full agenda for that meeting. Its principal business was to finalize and approve the Foundation's budget request to Congress for FY 1952. Also, on the first day of the meeting, the Board was informed of President Truman's intention to nominate Alan T. Waterman, chief scientist at ONR, as the NSF's first director (England 1983, 126–7). The nominee joined the Board on the second day of its meeting. The Senate consented to Waterman's nomination later that month, and on April 6, 1951, he was sworn in as NSF director by Supreme Court Associate Justice William O. Douglas.

Congressional and Presidential Directives

Despite the fact that the NSB took no direct action on Golden's memorandum at its March 8–9, 1951, meeting, his suggestion that the policy-for-science of the U.S. Government and the programs of NSF should be based on sound quantitative information was widely shared. In addition to reproducing BoB data on R&D expenditures by Federal agency in its FY 1951 Annual Report, the agency began to publish its *Federal Funds for Research and Development* series during that same fiscal year. Data in the first editions in this series were limited to Federal funds for R&D in nonprofit institutions. However, the coverage expanded to include Federal R&D support in all categories of performer and was also reported by character of work, by field of science, and by agency.

Congress was particularly concerned about the adequacy of human resources for science and technology. The National

[32]President Truman announced his intention to nominate Alan T. Waterman as NSF's first director on March 8, 1951.

[33]The National Scientific Register was established in the Office of Education within the Federal Security Agency in June 1950 following a determination by the National Security Resources Board that a registry of available scientific personnel would be vital to national security. It was transferred to NSF on January 1, 1953.

Science Foundation Act of 1950 explicitly directed the agency "to maintain a register of scientific and technical personnel and in other ways provide a central clearinghouse for information covering all scientific and technical personnel in the United States, including its Territories and possessions."[34]

To carry out this mandate, NSF assumed responsibility for the National Scientific Register from the U.S. Office of Education on January 1, 1953,[35] expanding its coverage significantly in partnership with several science and engineering societies. NSF's third annual report, covering the period from July 1, 1952, to June 30, 1953, included the first survey results on human resources for science and engineering carried out in response to this congressional directive. The agency also issued brief, periodic bulletins with human resources data in specific fields of science and of application.

Evidently the quality and utility of these early quantitative studies were quickly recognized, since an Executive Order issued by President Eisenhower on March 4, 1954, required, among other matters, that:

> The Foundation shall continue to make comprehensive studies and recommendations regarding the Nation's scientific research effort and its resources for scientific activities, including facilities and scientific personnel, and its foreseeable scientific needs, with particular attention to the extent of the Federal Government's activities and the resulting effects upon trained scientific personnel. In making such studies, the Foundation shall make full use of existing sources of information and research facilities within the Federal Government.[36]

One reason why President Eisenhower may have singled out NSF as the most appropriate agency to conduct such studies was the unique partnership among the industrial, academic, and Federal Government sectors reflected in the congressionally mandated composition of the NSB, "so selected as to provide representation of the views of scientific leaders in all areas of the Nation."[37] Congress also recognized the Board's ability to speak with authority on matters pertaining to the vitality of the U.S. science and engineering enterprise. In 1968, the House Committee on Science and Technology, chaired by Emilio Q. Daddario (D-CT), held a series of oversight hearings resulting in the first major set of amendments to the National Science Foundation Act of 1950. Among other things, these amendments provided for a presidentially appointed deputy director, authorized NSF to support applied research, and explicitly authorized support for research in the social sciences. The Daddario amendments also required that:

> The [National Science] Board shall render an annual report to the President, for submission on or before the 31st day of January of each year to the Congress, on the status and health of science and its various disciplines. Such report shall include an assessment of such matters as national scientific resources and trained manpower, progress in selected areas of basic scientific research, and an indication of those aspects of such progress which might be applied to the needs of American society. The report may include such recommendations as the Board may deem timely and appropriate.[38]

Finally, Congress officially concurred with, and made more explicit, the Executive Order issued by President Eisenhower in 1954 by authorizing and directing NSF:

> (6) to provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and engineering resources and to provide a source of information for policy formulation by other agencies of the Federal Government.
>
> (7) to initiate and maintain a program for the determination of the total amount of money for scientific and engineering research, including money allocated for the construction of the facilities wherein such research is conducted, received by each educational institution and appropriate nonprofit organization in the United States, by grant, contract, or other arrangement from agencies of the Federal Government, and to report annually thereon to the President and the Congress.[39]

Science Indicators – 1972, et seq.

Roger W. Heyns, a psychologist who served as a member of the NSB from 1967 to 1976 and who became president of the American Council on Education in 1972, suggested that, for its mandated 1973 annual submission to the President and Congress, the Board might consider preparing a report analogous to periodic reports that assessed various economic and social trends in terms of quantitative data series known as social indicators. Preparation of such a report could draw on the proven capabilities of NSF staff in gathering and analyzing quantitative data on U.S.—and international—science and engineering enterprise. The NSB accepted Heyns' suggestion, naming its fifth report to Congress, *Science Indicators – 1972* (NSB 1973). The positive reception accorded to this first *Indicators* volume encouraged the Board to continue to issue these reports on a biennial basis.[40]

In May 19, 1976, testimony before the House of Representatives' Subcommittee on Domestic and International Scientific Planning, Heyns highlighted some of the main purposes and functions of the *Indicators* reports:

- to detect and monitor significant developments and trends in the scientific enterprise, including international comparisons;

[34]Public Law 81-507, Section 3(a).

[35]See footnote 33.

[36]Executive Order 10521, "Concerning Government Scientific Research," Section 2. Reissued and amended on March 13, 1959.

[37]Public Law 81-507, Section 4(a).

[38]National Science Foundation–Function–Administration, Public Law 90-407, enacted July 18, 1968.

[39]Public Law 90-407, Section 3(a)(6) and (7).

[40]According to H. Guyford Stever, who was NSF director from 1972 to 1976, one of the first significant policy impacts of *Science Indicators – 1976* occurred as a result of a meeting that he and representatives of NSB had with then-Vice President Gerald R. Ford in the spring of 1974. Vice President Ford was particularly interested in the charts showing that other countries were increasing their R&D/GDP investments whereas the comparable ratio for the United States was decreasing. Soon after becoming President in August 1974, Ford set about increasing Federal R&D investments.

- to evaluate their implications for the present and future health of science;
- to provide continuing and comprehensive appraisal of U.S. science;
- to establish a new mechanism for guiding the Nation's science policy;
- to encourage quantification of the common dimensions of science policy, leading to improvements in research and development policysetting within Federal agencies and other organizations; and
- to stimulate social scientists' interest in the methodology of science indicators as well as their interest in this important area of public policy (NSB 1993b, xi).

Heyns clearly regarded the periodic preparation of the *Indicators* reports in terms of partnerships involving producers, users, and science policy scholars. The Board has called on all these groups over the years as it seeks to expand and refine these reports in order to reflect both the principal issues enduring in and changing science policy and the best scholarly thinking on quantification of these issues.[41]

In 1982, Congress officially recognized the unique significance of the *Indicators* reports by requiring that, instead of more broadly defined annual reports on the status and health of science required by the 1968 amendment to the National Science Foundation Act, "The Board shall render to the President, for submission to the Congress no later than January 15 of each even numbered year, a report on indicators of the state of science and engineering in the United States." [42]

This same legislation also encouraged submission of other reports on important science- and engineering-related issues, stating that "The Board shall render to the President for submission to the Congress reports on specific, individual policy matters related to science and engineering and education in science and engineering, as the Board, the President or the Congress determines the need for such reports."

Beginning with the 1987 edition, and consistent both with this legislation and the changing character of the U.S. research enterprise, the titles of these mandated biennial reports became *Science and Engineering Indicators*.

Presidential Statements

U.S. presidents from Franklin D. Roosevelt through William J. Clinton have demonstrated their recognition of the importance of science and engineering in a number of ways: through, for example, annual budget submissions to Congress, organizational initiatives designed to improve the effectiveness of the Federal Government's research and policy-making systems, and programmatic initiatives using science and engineering to advance critical items on their broad policy agenda. (See sidebar, "Major Presidential Science Policy Initiatives.") However, few presidents have given public addresses focused primarily on their science policies. The first notable exception was a speech delivered by President Truman in September 1948 during the first time of transition. Almost exactly 50 years later, in February 1998 during the current time of transition, President Clinton also delivered a public science policy address.[43] A comparison between these two speeches indicates both the endurance of several key science policy themes over the past half-century and the significant changes in emphasis that have occurred during that time.

Harry S Truman, 1948

President Truman delivered his address at the opening session of the Centennial Meeting of AAAS in Washington, D.C. (Truman 1948). A report of his speech was featured the next day on a front-page article in *The New York Times*. Truman used the occasion to propose a national science policy whose five principal elements were drawn directly from the report Steelman published a year earlier.

First, the President called for a doubling of total national R&D expenditures over the next 10 years so that, by 1958, those expenditures would exceed $2 billion and would be equal to 1 percent of GDP, or what he referred to as national income. The occasion of President Truman's AAAS address marked the first instance in which a leading political figure proposed that U.S. national R&D investments should be gauged in terms of GDP. As it happened, by 1958, national R&D investments had far exceeded the challenge that President Truman had laid down 10 years earlier. According to official estimates, in 1948, national R&D expenditures were slightly less than 0.5 percent of GDP; by 1958, that ratio was estimated to have been 2.36 percent. Changes in the Department of Defense's accounting system during the 1948–58 period make it difficult to compare R&D expenditures over that period.[44] But it is reasonable to assume that the R&D/GDP ratio, calculated according to the prevailing accounting practices of 1948, would have been closer to 2 than to 1 percent by 1958.

When President Truman spoke to AAAS, however, he could not have foreseen two of the principal reasons for the spectacular increases in national R&D expenditures that were to occur during the next decade: first, a rapid growth in defense R&D following the invasion of South Korea in June 1950; second, substantial increases for basic research and space-related R&D following the launching of Sputnik I by the Soviet Union in

[41]Papers presented at a symposium organized to critique the first, 1972 report were published in Elkana et al. (1978).

[42]Congressional Reports Act, Public Law 97-375, Section 214, enacted December 21, 1982.

[43]President Dwight D. Eisenhower announced the appointment of a full-time science advisor in a national radio address on November 7, 1957. President John F. Kennedy made a major science policy address at the Centennial celebration of NAS on October 23, 1963 (NAS 1963). President James E. Carter spoke at NAS on April 23, 1979, on the occasion of its annual meeting (*Weekly Compilation of Presidential Documents* 1979).

[44]Beginning in FY 1953, the Department of Defense began to include salaries and related expenses of personnel engaged in R&D in its estimates of R&D expenditures, resulting in an increase of approximately $1 billion in its estimated R&D expenditures between FY 1952 and FY 1953 (NSF 1968, 221, note c).