32. M. I. Soueit, *Bull. Narcotics* **19**, 1 (1967).
33. J. C. Ball, C. D. Chambers, M. J. Ball, *J. Criminal Law Criminol. Police Sci.* **59**, 171 (1968).
34. F. G. Wilkins, *Brit. Med. J.* **2**, 496 (1967); J. A. Talbott and J. W. Teague, *J. Amer. Med. Ass.* **210**, 299 (1969).
35. E. Tylden, *Brit. Med. J.* **2**, 502 (1967).
36. J. Kaplan, *Marihuana—The New Prohibition* (World, Cleveland, 1970).
37. L. E. Hollister and J. Kaplan, *J. Clin. Pharmacol.* **9**, 345 (1969).
38. *Home Office Report by the Advisory Committee on Drug Dependence, Cannabis* (Her Majesty's Stationery Office, London, Eng., 1968).
39. E. G. Williams, C. K. Himmelsbach, A. Wikler, B. J. Lloyd, Jr., *Pub. Health Rep.* **61**, 1059 (1946).
40. E. A. Carlini, *Pharmacology* **1**, 135 (1968); D. E. McMillan, L. S. Harris, J. M. Frankenheim, J. S. Kennedy, *Science* **169**, 501 (1970).
41. D. Holtzman, R. A. Lovell, J. H. Jaffe, D. X. Freedman, *Science* **163**, 1464 (1969); L. E. Hollister, F. Moore, S. L. Kanter, E. Noble, *Psychopharmacologia* **17**, 354 (1970).
42. T. Pivik, V. Zarcone, L. E. Hollister, W. Dement, *Psychophysiology* **6**, 261 (1969).
43. L. J. Thompson and R. C. Proctor, *N. Carolina Med. J.* **14**, 523 (1953).
44. G. T. Stockings, *Brit. Med. J.* **1**, 918 (1947); D. A. Pond, *J. Neurol. Neurosurg. Psychiat.* **11**, 271 (1948).
45. L. E. Hollister, *Clin. Pharmacol. Ther.* **12**, 44 (1971).
46. Supported in part by NIH grant MH-03030.

Mission-Oriented R & D

Senator Mansfield's questions sharpen congressional uncertainties about federal R & D patterns.

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Congress has a wonderful knack for asking fundamental questions about public policy. Recent questions about "national science policy"—implying that such a policy is extinct or embryonic, indispensable or impossible—reveal the fact that many congressmen think they have not been getting fundamental answers.

Answers have been based upon a rhetoric that has enlivened and served the R & D (*1*) community since World War II. Basically, it describes a logical framework of national goals and agency missions, not national science. Now the rhetoric seems fatigued. It may still be valid, but it certainly is not persuading Congress to support basic research. Many members of Congress don't believe it at all.

There still exist the same institutional patterns for R & D that once seemed to represent the best interests of government, industry, and universities. Indeed, they seemed to serve the goals and missions of the people. These patterns are now challenged; they are, perhaps, crumbling. They may be worth preserving, but Congress isn't sure they are—neither are some members of the R & D community. If new patterns for R & D in the United States are drawn, will the great public goals be served as well in the future as some think they were in the past? In fact, given the rising and varied demands of the day and the declining enthusiasm for R & D, will some goals be reached at all?

Three factors that bear on the future of mission-oriented R & D are discussed here. The first is one of Congress's most famous recent actions affecting mission-oriented R & D: the "Mansfield Amendment," which attempts to curtail the non-mission-oriented research said to be supported by DOD. The Mansfield Amendment is important not because its direct effects have been great, but because it is the formal expression of deeper congressional concerns, the tip of an apparently large iceberg—and it does have the stamp of the Majority Leader of the Senate.

The second factor is the almost bewildering array of countervailing forces, in Congress and elsewhere, that have shaped the environment in which the Mansfield Amendment was passed and that have undermined the old rhetoric about federal support of R & D. The third consists of recent budgetary trends and some speculations about future trends in federal support for R & D. I have also presented a few of my own judgments on what ought to be done by the federal government and by the R & D community.

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Section 203—Beginnings

Section 203 of Public Law 91-121, the military procurement authorization for 1970, specifies that: "None of the funds authorized to be appropriated by this act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation." On 11 August 1969, Senator J. William Fulbright proposed the provision on the floor of the Senate as part of a broader amendment that cut funds to be authorized for Defense R & D. The amendment was passed on 12 August after desultory debate, without a word being said about Section 203. After the vote, Senator Mike Mansfield, taking the floor to praise Fulbright's amendment, said he had prepared an amendment identical to Section 203. The Mansfield Amendment, therefore, should have been attributed to Fulbright. But the popular name may be best, since Mansfield has relentlessly questioned DOD—as well as other federal agencies, including the White House science staff—about the implications of implementing Section 203. For example, in a letter of 22 September to John S. Foster, Jr., director of Defense Research and Engineering, Mansfield said he was concerned "with the vast expenditures of the Department of Defense for research and development" (*2*). He warned that "we must seriously inquire about the future role of the Defense Department in funding university research."

On 20 November 1969, the day after Section 203 became law, Mansfield wrote to Secretary of Defense Melvin Laird, saying that the "specific intent

[of Section 203] was to reduce the sponsorship by the Department of Defense of non-mission oriented research —research that did not have a direct and apparent relationship to a specific mission of the Department of Defense." The issue of "apparent to whom?" was not raised, nor has it been raised since in public; however, the issue of "judged by whom?" became exceedingly knotty. Mansfield went on to say that it was a "clear policy of Congress to reduce [the] dependency by the scientific community on the Department of Defense." At this point, Mansfield apparently felt that DOD would not respond adequately to his injunctions about Section 203. He told Laird in his letter of 20 November that "the Congress of the United States does not attempt to enact futile gestures." As if that frosty barb weren't enough, he then asked Comptroller General Elmer Staats to evaluate the efforts DOD made to comply with Section 203. Deputy Secretary of Defense David Packard wrote to Mansfield on 1 December and pledged full compliance with the language and spirit of Section 203.

On 4 December, Foster provided lengthy answers to a series of questions posed by Mansfield and outlined DOD's general philosophy in supporting R & D. His four main points were a restatement of the general case for mission-oriented R & D: "(1) Each major department and agency should carry out a research and development program needed to meet its responsibilities, that is, needed to fulfill its missions more effectively. . . . (2) For a research and development effort to be healthy in the long term, it must include some investment in applied research and in relatively basic research . . . . (3) The Defense Department research project offices provide continuous and immediate 'coupling' of research results into developmental and operational activities. . . . (4) University groups represent a unique national resource of excellence in research and development. This is why we [DOD] select academic investigators to carry out some of our work." It is worth noting here that Mansfield has not questioned, challenged, or even commented upon Foster's formulation. Months later, Mansfield implied that he essentially agrees with it.

On 5 December, Mansfield wrote to the heads of nine major federal agencies that support research [such as NSF, HEW, Commerce, AEC, and NASA] and said, rather extravagantly, "Section 203 . . . expresses a fundamental change in Federal funding for research. In essence, it emphasizes the responsibility of the civilian agencies for long term, basic research."

During the next several months, at Packard's and Foster's direction, DOD reviewed every single man-year of effort within its basic and applied research to assure itself—and, ultimately, to try to assure the Congress—that each project filled the requirements of Section 203. It could be argued that DOD should not have attempted to justify individual projects on a man-year level, but should have focused on clusters of research projects that constitute programs, since the latter could more easily be shown to have a meaningful, mission orientation. But Fulbright and Mansfield had made it clear that they wanted a project-by-project review. This was a massive job, to review individually almost 15,000 projects representing a total annual expenditure of about $1.3 billion.

As a result of the review, some projects were either curtailed, placed in a terminating phase, or cut out. The estimated annual funding for 404 terminated projects, that is, the FY 1970 funds that might have been used for the projects judged not to fulfill the conditions of Section 203, was about $10 million. This budget reduction was swamped by the $64 million budget cut imposed by Congress on DOD's planned FY 1970 program. Few of the cut projects have been supported by other agencies during this period of constrained federal R & D, although NSF has been trying to rescue the most important of the jeopardized projects.

Section 203—Motives

Between August 1969 and July 1970, Mansfield changed his emphasis in two significant ways. Section 203 initially seemed to be a budget-cutting gambit aimed at DOD alone, and to be particularly tied to Fulbright's criticism of DOD research in the social sciences and in universities. This was clearly Fulbright's position, and probably Mansfield's as well. Later, however, although Mansfield censured again and again the "undue dependency of American science on military appropriations," he also began to declare much larger implications of Section 203. On 10 July 1970 he said, "[W]e in Congress need to start asking very seriously about the state of public policy for science in this country. What is it? Who is forming it? Who is minding the store?" (*3*). Thus, what began as a straightforward and, in many ways, sensible constraint on the R & D program of DOD has evolved, according to Mansfield, into a fundamental reexamination of national science policy. Without necessarily accepting the electrifying possibility that this one undebated legislative sentence could become the core of a new national policy, it is fair to say that Section 203 has deepened the welter of introspections and sharpened certain inescapable choices regarding federal R & D.

The second way in which Mansfield's view has changed is that he no longer seems so intensely concerned about DOD's support of university scientists. He still asks "whether strong ties should be continued between the Pentagon and our universities" (*4*), but he has become explicitly permissive when academic research can be shown to have a direct bearing on military needs: "[Section 203] does not say the Defense Department shall fund no university research" (*5*). This change of emphasis may seem significant only for DOD's position, but it is of broader import. It probably reflects the impact on Congress of many university scientists, academic administrators, and industrial R & D leaders who discussed Section 203 during late 1969 and 1970 and who urged the Congress not to tinker with the principle that every mission-oriented agency maintain links with basic research.

In outline, Mansfield's argument is thoroughly healthy and reasonable. He is asking, first, for an explicit rationale for DOD's investment in R & D and, second, for a government-wide rationale for the levels, proportions, and departmental conduits of the total federal investment in R & D. Mansfield apparently sees the current federal pattern as a collection of accidents, and the research directors as accident-prone drivers. This collection, he seems to think, has simply accumulated over 25 years. He asks with disarming innocence for a comprehensive national policy for R & D.

What troubles the R & D community is this: Boring into the edifice of what has passed for national science policy may damage a structure which, however complicated and haphazard in its construction, has nevertheless housed brilliant work. To ask for specific forecasts of applications of current research—as the Mansfield Amendment seems to do by demanding specific operational goals for individual basic research projects—

is to discourage basic research by raising questions that may not have serious, responsible answers.

Section 203 Raises Basic Issues

Section 203 seems to violate what most observers, especially foreign ones, have long regarded as a key principle of U.S. technological success: the philosophy of letting every mission-oriented agency support research that is broadly relevant to its long-range mission. This pluralism is not a satisfying policy in the sense of a rigorously consistent master plan. It is not very tidy organizationally. It makes any kind of central "surveillance" difficult, and resource allocation cumbersome. In addition, successful pluralism today requires financial support on a scale that only the United States and the Soviet Union can afford. Perhaps most important, pluralism suits an era of financial expansion better than it does an era of contraction. Yet it has the virtue of being compatible with the environment of freedom, decentralization, and independent competition within which first-class research and rapid development thrive. Moreover, pluralism gives the country, through its government, a broad scientific base for stimulating, understanding, and exploiting innovations to serve national goals.

From an administrative perspective, Section 203 creates a thicket of ambiguities. Research managers find it difficult to set up specific, objective criteria for deciding what projects fill the conditions of Section 203. Conscientious research administrators believe that in the final analysis they must make rather subjective technical judgments on the originality of proposed projects, on the qualifications of proposed investigators, and on the likely results and possible applications. These judgments inevitably are debatable.

The relationships of DOD with the academic community are complicated and probably worsened by Section 203. It seems either to make every researcher supported by DOD a bomb maker or to jeopardize his support, even though the researcher and a DOD research administrator have a common, legitimate interest in advancing a particular field. This has occurred at exactly the troublesome period, maybe even at the turning point, when some people argue that there should be no DOD-university relations at all.

The most serious long-range issue raised by Section 203, as it applies to DOD, may be whether we wish to continue to have independent university scientists knowledgeable enough about defense technologies, and about the strategic issues involved, to seriously debate national security policy. Contemporary debates about missile defenses and arms control, for example, could hardly be as informative in details and as rich in strategic lore without the participation of many scientists who grew up in academic laboratories and were challenged by the problems of defense technology. These scientists then served the government as officials or consultants on both sides of various debates. Without such debates, DOD would be isolated not only from some streams of American opinion, but also from the sometimes technically subtle arguments central to necessarily changing concepts of defense, deterrence, and arms control. To illustrate, if the current strategic arms limitation talks produced a substantial agreement—and there probably is no more urgent goal facing the country—strong reasons will be given for maintaining (or perhaps increasing) the level of defense R & D as insurance against the possibility of a strategically destabilizing technological surprise. This might be wise if there were strong controls over decisions on how far to carry R & D, as well as strong and reliable verification provisions in the arms freeze or reduction. But such a strategic choice about R & D must be debated broadly. Should the country toss away, as a matter of policy, this area of investigation and debate by first-rate academic scientists? I think not, and apparently Mansfield now agrees.

The implications of Section 203 are equally ominous for other federal agencies. For example, there would seem to be no reason why Mansfield's logic wouldn't induce other legislators to add similar amendments to the appropriations for Commerce and HEW. Would the basic research projects of NBS satisfy the criterion of a "direct and apparent relationship" to a specific commercial function or operation? Even if no such criteria are added in the legislative process, federal research administrators cannot help but be influenced by the precedent established for DOD's research. Again, the Section 203 criterion, which is deceptively simple and rational, can be interpreted to require that each man-year of research be justified in terms of its relevance to a particular long-range mission.

Section 203 and the GAO

One final element in the recent history of Section 203 reveals the issues starkly: the review by GAO. On 23 June 1970, Staats reported to Mansfield on GAO's review of DOD's implementation of Section 203. By and large, GAO tried hard: they consulted officials at various levels in DOD, sampled many projects, and were not cranky in their interviews with people who had divergent views about Section 203.

Their first "finding" was that "DOD did not furnish guidance to try to attain uniform application of Section 203 and made minimal tests of the results of the reviews" *(6)*. In some ways, this is correct—it is also misleading. There were two reasons for DOD's action. First, DOD said it was not able to formulate specific guidance because it was not possible to make precise, long-range predictions about the results and ultimate applications of basic research. Many judgments were required, said DOD, to try to comply with what is a rather ambiguous law. Nevertheless, said GAO, because Section 203 is law, uniform guidance and judgments are required; otherwise DOD must stop supporting the research. Thus DOD and GAO have different, although reasonable, points.

DOD's second decision, exposed nicely by GAO, was to decentralize the Section 203 reviews so that decisions on relevance would be made by those closest to the research and its applications. With this organizational approach, top management in DOD naturally made "minimal tests," mostly to keep the in-house reviewers on their toes. One would expect to find, as GAO did, that, with a decentralized approach, "interpretations of the law differed widely, as shown by the numerous reversals by higher echelons of determinations that projects did or did not qualify" *(6)*. DOD seemed to be damned if they did review at the top and damned if they didn't.

In August 1970, after a discussion of DOD's efforts to comply with Section 203 in FY 1970 and of GAO's findings during hearings on appropriations to DOD for FY 1971, Senator Thomas McIntyre (who chairs an R & D subcommittee of the Armed Services Committee) made an admirable attempt to put into perspective the effects of Section 203. Among other things, he said that while "there is no precise, self-applying test" to use for Section 203,

"the overwhelming majority of [DOD] research projects . . . meet the relevancy test" (*7*). He also proposed a 20 percent increase in the NSF budget for next year (FY 1972).

Future Uncertain

The future of Section 203 remains uncertain. In lengthy testimony last summer before Congressman Emilio Daddario's House Subcommittee on Science, Research, and Development, Mansfield said that "Section 203 [does not] intend to cut off the Defense Department from the research that it needs" and that "the role of the Defense Department in sponsoring basic research is intended, however, to be incidental rather than predominant" (*8*). Despite Mansfield's ostensibly balanced arguments, he continues to reinforce the widely cited fallacy that DOD is "dominant" in the federal support to universities and colleges. In fact, DOD's relative role has steadily declined, from 47 percent of the federal obligations in 1955 to 14 percent in 1971, while during this period HEW has grown from 19 to 45 percent and NSF has grown from 5 to 18 percent.

In the House-Senate conference report on DOD authorization for FY 1971, Section 203 did not appear in the same form as it did in FY 1970 (*9*). Instead of the phrase "direct and apparent relationship," the conference used, "in the opinion of the Secretary of Defense, a potential relationship [to a military function or operation]." Obviously, this wording gives DOD much greater flexibility. The conferees unanimously concluded that DOD should be given "greater assurance that basic research may be conducted to provide the broadest body of scientific knowledge to support future military needs" (*10*). Mansfield was "greatly distressed" and said, "[T]he modified language is worse than would be the elimination of the amendment totally . . . the fight is far from ended" (*11*). It seems reasonable to expect that he will pay a great deal of attention to the fate of his amendment and to his belief in the "much-needed focus on a coherent national science policy" (*11*).

Perhaps the debates stimulated by Section 203 have, through some peculiar twists, helped to focus constructive attention on the national needs for R & D. One early result was the excellent hearings held by Daddario's committee, which produced a report diffidently called "Toward a Science Policy for the United States" (*12*).

R & D Rhetoric Fatigued

I have dwelled on the Mansfield Amendment because it exemplifies many of Congress's concerns about R & D. Even broader problems for mission-oriented R & D in the future are embedded, I believe, in attacks on the old rhetoric of R & D. It was the failure of this rhetoric to persuade Mansfield that helped trigger the passage of Section 203. I here give a few highlights of seven related central arguments about the old rhetoric. I try to integrate many of the most pressing questions that federal R & D managers and other scientists are asked in discussing R & D before congressional committees. In practice, of course, each committee is usually more concerned about one or two questions and excludes the rest. Thus this discussion is artificially more unified than "the congressional viewpoint," if such a thing exists. Nonetheless, if the scientific community developed a consensus that was honestly responsive to the main questions posed here, the health of the scientific community would likely be assured.

1) *Sequential view of R & D.* Most scientists who testify before congressional committees naturally attempt to make large, complex R & D programs more understandable to laymen. In this attempt, they tend to reinforce the simplification that (i) basic research regularly uncovers new ideas that (ii) are then fed into the hands of development engineers who (iii) neatly establish the technical and economic feasibility of a new gadget or technology which (iv) can then be introduced smoothly into efficient production, and thus (v) the research-to-production process effortlessly solves some problem or meets some national need. (Obviously, the process is worded differently for, say, health-related R & D, but the general tack is similar.)

Given repeated, implicit statements of this sequential theory of R & D, it is little wonder that Congress finds it a bit hard to understand, for example, why research sometimes takes 20, 30, or more years to pay off. For this reason, if you promise, you must deliver; if you overpromise, watch out. It is also hard for Congress to understand why, given such an apparently controlled R & D system, major technical problems in development crop up from time to time and cost a lot of money to solve. One basic trouble with the sequential view is that it, in effect, throws out probabilistic caution about long-term research. It also leaves out originality, synthesis, bad luck, serendipity—all of the unexpected events throughout R & D. R & D, including basic and applied research, is treated as any other activity capable of being planned (*13*).

But feedback along all stages of R & D is not easily presented or recognized. The importance of new technologies in making some research possible is not widely understood. Worst of all, even with a neat, sequential theory of R & D, any alleged excess or waste at the research stage is often assumed either to be amplified in later stages or to be unnecessarily costly in terms of alternative uses of the same resources.

2) *Science and education.* For many years the natural sciences have been blessed with a great deal of federal support at our universities. In part this was because the old rhetoric, almost a cliché now, held that excellent advanced research is, and must remain, inseparably linked to education, particularly to graduate education. But as campuses grew, many of them became more depersonalized and research activity was blamed in various ways for many university problems. With critiques of the multiversity came new questions about the federal government's role in supporting higher education: Should the government support other areas besides the sciences? Should it take care of the many students not interested in careers in research? Should teachers (senior faculty) be returned to the classroom? (*14*). More recently, there is a new emphasis: how many people should be trained for future R & D and in what fields?

Now, facing more directly the public policies about research and education, Congress is bluntly asking whether research leads to more or fewer educational benefits. And, if there are benefits, are they achieved for a few by sacrificing higher quality education for the many? The old debates about the role of research in universities and about future needs for scientists, which have long been inactive, have been revived.

3) *Duplication.* When a congressman surveys a federal R & D budget of $16

billion and a total national R & D expenditure of $25 billion, he finds it impossible to believe that there is no duplication among the scores of agencies supporting tens of thousands of research projects at hundreds of research centers throughout the country. The old rhetoric claimed the existence among investigators of a stimulating competition that produced a dynamic marketplace of ideas, from which the best ones could be culled. Federal R & D managers also said there was coordinated screening among the government's research agencies to assure that there would be little, if any, unnecessary duplication. Clearly, for many people these arguments are no longer persuasive. Congress says that some belt-tightening will lead to greater efficiency. More than a few scientists, concerned about the apparent mediocrity, if not the redundancy, of much of the research, are tempted to agree.

4) *Measures of quality.* Some representatives and senators have been asking searching questions about what they see as an overelaborate "buddy system" masquerading as a scientific "judicial system." All too few people in Congress understand the enormous, largely unpaid efforts invested by scientists in the panel review system used by most agencies to evaluate proposals for federal support. Worse still, the dedication of most of these reviewers to high quality is just not grasped by a number of influential members and staff of congressional committees. Logrolling, it seems to some congressmen, is being increasingly substituted for what were once rigorous standards of scientific quality and productivity. For these reasons, Congress may make more decisions about what should be done; thus, more detailed congressional reviews are being substituted for those judgments that are thought to be left unmade or to be made on nonscientific grounds.

5) *Measures of need and relevance.* Despite the valiant and often insightful efforts of a few scientist-analysts, Congress sees little progress being made in solving the difficult "apples and oranges" problem of allocating resources to and within various federal R & D areas. Why this amount for health, compared with that amount for defense? And within each national mission, for example health, why this much for heart disease, compared with that much for cancer? Within a discipline, say physics, why so much for solid state, compared with so much for nuclear? The old rhetoric said, "Leave most of this to the scientists to decide." Now Congress wants new, more thoughtful, systematic measures of national R & D needs and the comparative relevance of specific projects to specific needs.

6) *Measures of payoff.* Clearly, measures of need and relevance are cousins to measures of payoff. But even lacking a way to gauge the exact future relevance of a single current project, some people ask the research community either (i) to show systematically the payoffs of all or most of our past investments in R & D, or (ii) to assess comprehensively the range of possible future consequences of present R & D. Too often, retrospective assessments have been anecdotal and have seemed to present only the few best results of past activities. Prospective reviews got bogged down in such complexity that commonsense skepticism undercut the most conscientious endeavors. Hence, say some congressmen, without some certified likely output, without a demonstration of balanced allocations and reasonable returns, why so much input? Moreover, during the last few years many congressmen have called for the even more complicated task of "technological assessment," in which one must show not only the direct results of R & D but also the second- and third-order indirect effects of introducing new technology into the social system.

7) *PPBS.* In the 1960's, it appeared that the old arguments for federal R & D could be revitalized by giving the major agencies an injection of systems analysis. But the failure of the economics-dominated PPBS to cope successfully with R & D—even in that mecca of analysis, the Pentagon—has been regarded, perhaps only semiconsciously, as a proof that the R & D community has been getting away with something. Most of the above problems and concerns about the old rhetoric have come together in the executive branch's own confusion about how to apply PPBS to R & D.

For major development projects, some analytic planning can be, and has been, done successfully. For basic and applied research, the bureaucratic momentum called level-of-effort funding tends to prevail. The idea that PPBS cannot or should not be applied to most R & D can be argued cogently. Harvey Brooks succinctly captured the essence of the R & D planning problem: "Many of the current demands for better scientific planning are probably as naive as the early demands for economic planning. . . . Today our felt need to plan too far exceeds our understanding of how the system of science and technology really operates" (*15*).

Basic Issues

Underlying the above arguments surrounding the old rhetoric are at least three more basic issues.

1) *Pure science.* Among these issues is the mythology of pure science. Many scientists believe that pure science (or research) is the only good science (or research). Thus, social status within the R & D community tends to be based upon the degree to which one does or has done pure science. This tendency isolates scientists from a direct concern with ultimate applications. It also explains why engineers have long been "out" and why genuinely interdisciplinary projects, though urgently needed and not inherently impure, have been professionally risky and have occasionally been a haven for the less creative. Needless to say, these attitudes are not consonant with mission-oriented R & D, and they completely blur valid distinctions among the different kinds of talent and temperament needed for various jobs in research and in development. Obviously, many scientists do not have these attitudes; some are strongly committed to certain ultimate applications that can be met only through lengthy, broad, and somewhat unpredictable research.

There is a growing new mythology (springing partly from the New Left) that advocates, for example, quitting biomedical research completely and improving health care services. Even so, Congress more often than not encounters the myths and attitudes of pure science. These retard public understanding of, and honest, realistic support for, R & D in general.

2) *Anti-intellectualism.* A related issue is the actual and latent anti-intellectualism that is revealed in much of the public's response to campus unrest and in some congressional thought on R & D. Because of the latent anti-intellectualism, no federal official talks (very much, anyway) about the beauty of science or the curiosity of scientists. Such talk in a budget hearing would be regarded as elitist, escapist, or suicidal.

Then, too, legislatures at both the national and state levels have probably always felt uncomfortable about appropriations to long-range research. One reason for their uneasiness is that most research activities involve little or none of the legislators' political constituency. Intellectuals, after all, tend to be critics rather than supporters, and, unlike legislators, they are rarely held accountable by the public for the results of their proposals. But the central reasons for the shaky support of the intellectual community may be simply the feeling that action, not thought, is the American way and, further, that "experts get us into trouble." To the extent that the research community disdains work on major national missions or behaves self-servingly in mission-oriented work, anti-intellectualism will increase its influence on the fate of American science *(16)*.

3) *Utilitarianism.* Connected with the first two issues is the irreducible utilitarianism that, in the long run, guides all public investment. World War II showed the utility of science for national security, and post-World War II industrial growth reconfirmed the utility of science-based technology for economic prosperity. These are surely worthwhile national goals. Nevertheless, there is a pervasive feeling today that more technology may not be socially useful. People want to solve the problems of DDT, SST, ABM, LSD, smog, and so on before more of the same are created. According to this view, research projects presented without clearly designated, socially desirable purposes are worse than just vague or too intellectual: they are wasteful and may even be damaging. Thus research must conform to some utilitarian criteria or else be regarded, if supported, as a cultural activity requiring handouts. This unwritten, yet strongly felt, guideline for public support clashes sharply with the experience of the post-World War II researchers, who have become used to generous support for fundamental work. Make no mistake about this utilitarianism: society will not support research activity unless its general purposes are clearly related to society's purposes.

Organizational Choices

Three broad areas of organizational approach are also central to the current debates about public policy for mission-oriented R & D. First, the now classical strategy of federal pluralism in supporting R & D is being reexamined. Should a loosely coherent national program be formed by letting each agency continue to support its own R & D, including some basic research, and by asking OST and NSF to try to fill in the gaps? Or, should there be a central agency responsible for, say, at least half of the total federal scientific effort, thereby leaving the mission-oriented agencies to concentrate almost entirely on developmental, technological work? The latter strategy would run the risk of creating a speculative, vulnerable enterprise of limited vision, ruled by a czar: "speculative" because the ability to plan centrally (and reliably) seems incompatible both with the actual process of scientific research and with the differing long-term needs of many agencies; "vulnerable" (to budget slashes) because a central science agency would fill no concrete national needs, no "hard" mission; and "of limited vision" because unfashionable lines of research might not be supported if there were only one, possibly biased, source of funds for each field *(17)*.

A second operational choice is the degree of professional as opposed to lay review of R & D activities. At what levels of aggregation can and should nontechnical reviews be made? What are optimum ways for Congress to participate in forming national R & D priorities and in holding federal officials accountable for their stewardship of R & D? On the answers to such questions rests much of the future of mission-oriented R & D.

The third operational issue, which looms much larger today than it did even a few years ago, is the role of universities in the national R & D pattern. Beyond teaching and some closely related research and scholarship, what are the university's public service responsibilities? When large-scale research projects are undertaken for federal agencies, does the university sacrifice its ability or inclination to criticize those same federal patrons? Can a university manage a Job Corps Center and still be objective about the pros and cons of the concept of a job corps? Should universities remain the principal locus of basic research? Can university scientists effectively carry out research while the rest of the campus is debating profound and controversial issues of governance under conditions of intense campus turmoil and the threat of political retaliation for unpopular views?

Budgets for National Missions

Against this background, we should examine the recent trends in federal budgets for mission-oriented R & D. The five largest federal contributors to research (DOD, NASA, HEW, AEC, and NSF) account in FY 1971 for 86 percent of the total federal support of research, and the four largest federal supporters of development (DOD, NASA, HEW, and AEC) account for 96 percent of the federal support for development *(18)*. The growth in expenditures for R & D by agencies other than these five has been tremendous during the past 15 years. These smaller agencies accounted for about 4 percent of total federal R & D in 1954, but rose to 7 percent of total federal R & D in the FY 1971 budget request. Their proportionate increase looks small because it was during this same period that total federal R & D increased from about $3 billion to almost $16 billion. The funding for these smaller agencies rose from about $120 million to over $1 billion, a tenfold increase in 15 years.

However, there are even clearer indications of new priorities. In the period between FY 1968 and FY 1971 the total federal support for R & D declined by about 8 percent (practically all of which was the NASA reduction), from its high point of $17 billion in FY 1968 to $15.7 billion in the FY 1971 request. Yet the total support of R & D by agencies other than the top five increased by about 21 percent, from $0.95 to $1.15 billion. In effect, the newer agencies got enough money to keep up with inflationary increases, while the major agencies declined steadily.

In the FY 1972 budget request, these trends of the late 1960's have been both reversed and reinforced. Overall, the R & D budget has increased instead of continuing to decline. Obligations are scheduled to increase by 7.6 percent, from the estimated $15.6 billion in FY 1971 to the requested $16.7 billion in FY 1972. Expenditures, however, are estimated to increase by only 3 percent from $15.3 billion to $15.7 billion; thus, the actual level of effort will probably continue to decrease *(19)*. As far as priorities are concerned, the picture is mixed: the DOD request for R & D accounts for more than three-fourths of the increase in total obligations, and for two-thirds of the increase in total expenditures; NASA and AEC continue to decline; HEW gets a less-than-inflation increase; the Environmental Pro-

tection Agency, Transportation, Justice, and NSF get healthy increases; and OEO and HUD receive less R & D funds.

If we focus on DOD, AEC, NASA, and HEW as the mainstay mission-oriented agencies (accounting currently for about 85 percent of total federal R & D) and examine the combined budgets of these four with the total budgets for all other federal agencies that support R & D, we find that: (i) expenditures of the big four from FY 1970 to FY 1972 have been essentially constant and (ii) expenditures for the rest during the same period are expected to increase by 50 percent, from $1.4 billion to $2.1 billion (*19*). As far as federal support for academic R & D is concerned, again from FY 1970 to FY 1972, DOD, NASA, and AEC have been and will be declining in actual expenditures and in their proportionate contribution to the increasing federal total. At the same time, HEW and NSF expenditures are expected to increase 17 and 10 percent, respectively, and the expenditures of "all other agencies" are scheduled to increase by 83 percent, from $72 to $132 million. A general pattern that emerged during the 1960's and that appears to be continuing is for more agencies to become involved more heavily in R & D —a welcome trend toward experiment in the old-line agencies. A more recent pattern puts greater emphasis on applied studies, a trend of rather unpredictable significance which the President underscored in the section on "Science and Technology" in his FY 1972 budget message (*20*).

One problem for would-be science policy analysts is the difficulty of understanding summaries of federal R & D budgets. Some of the worst statistical bear traps lie in the path of understanding federal support for academic science. For one thing, in their overall budget presentations to Congress, most agencies make no distinction among the various kinds of jobs that universities do for the government. For example, universities undertake basic research, applied research, development efforts (often off-campus), consulting, and management contracts. Another complication is the obvious tendency of each agency to support much more work in some fields than in others (for example, DOD in the physical sciences, HEW in biological sciences); yet all expenditures are lumped together in the category of academic science. These problems, combined with the traditional reluctance of mission-oriented agencies to be explicit about their support of graduate education in tandem with research, make it difficult for most people to understand the picture.

It is important to understand the degree to which federal agencies are doing R & D, for, as Hunter Dupree pointed out, one of the sadder themes in the history of the U.S. government's support of science is the lack of foresight in those operational agencies which had little serious R & D. He recalls that the Army cut its budget for R & D only shortly before the country entered World War II because "the crisis was much too serious to wait for research" (*21*). Are we reliving this outlook today as we begin to try to solve the crisis of the environment?

In the future, the federal government probably will be less inclined to support university research, owing to the universities' apparent instability and to their continuing reevaluation of the role they wish to play in society. Thus, the national role of industrial research groups and, particularly, of nonprofit research centers will probably grow, perhaps strikingly, and may include their participation in research that has been almost exclusively the province of universities.

The trend toward more "social relevance" in federal R & D funding may accelerate. Critical, long-range, fundamental research in the physical sciences, and perhaps in the social and biological sciences as well, could be slighted in the next few years. The country seems to have lost sight of the many past proofs of the importance of sustained R & D in reaching major national goals. While thoughtful observers knew that the growth rate of roughly 15 percent annually of 10 years ago could not persist, few foresaw the reductions that occurred in the late 1960's. Furthermore, a nation's overall technological strategy is becoming more, not less, decisive in reaching its goals (*22*). Unfortunately, contemporary America seems disenchanted with long-range science and technology: the federal budget has been saying this in the clearest possible way.

A Few Suggestions

It's not easy to diagnose accurately the health of the American scientific community. Despite the confidence-shattering fiscal pinch of the last few years, despite the talk of crisis in science, American R & D is hardly a pauper, with federal support of $16 billion and a total national effort costing at least $25 billion. American R & D remains the general standard of excellence for the rest of the world; nevertheless, problems obviously exist. No fully satisfactory pattern of solutions is yet in sight.

The British have been struggling for years with the kinds of problems we have just begun to have. Their view, as Sir Harry Himsworth has recently underscored (*23*), is that basic research must be put into the context of overarching, long-range national goals. The political market place will make the broad decisions on how much to invest toward each national goal. R & D must then be bound to these goals in a pluralistic fashion, merging utilitarian criteria with scientific judgments. A new and fresh logical framework, however, would not be a godsend. We do need more enlightened dialogue about R & D policies, but greater financial support, even for the major national missions, will not come about through enlightened dialogue alone. Eric Ashby noted: "Often the spur to action has been fear, beginning with the alarm expressed as long ago as 1887, that educated Germans were penetrating Britain's oriental markets, and still continuing at the time of the 'Sputnik hysteria' of 1957" (*24*). Perhaps only a widely understandable crisis, such as much stiffer competition from Japanese and German high-technology products, an environmental disaster, or a destabilizing technological surprise by Russia or China in defense or space, will send the pendulum of public opinion back toward reasonable growth for R & D. Reasonable growth for the next few years is certainly not less than 6 to 7 percent per year, and probably cannot be more than 10 percent per year. While there is no magic to these boundary conditions, there have been signs that Washington is adopting this view (*25*).

Without counting on fresh rhetoric as a cosmetic, and surely without hoping for the bizarre benefits of crisis, how can we make a good case for reasonable growth? Could a major new technological "fix," perhaps an event as gripping as the early space flights, give the R & D community new life? On the one hand, we must beware of counting too much on technological fixes. Some fixes won't be hurried, whereas others could come quickly if given large fi-

nancing. Yet, how much are these fixes worth? Can we muster the political will, organizational skills, and financial commitment necessary for them? The role of technology in solving population and food problems reveals these issues clearly (*26*).

On the other hand, we must not hold scientists and engineers solely responsible for the problems of a society enriched, freed, yet distressed by its uses of the products of technology. By any reckoning, science and technology have served the world brilliantly.

No single fix is likely to sustain the justification for R & D in general or to explain the deeper impacts of R & D on most national goals. What else might work? Everyone concerned must recognize the simple fact that one's conceptions of utility are rooted in one's values. As Goethe said of science: "To one man it is the highest thing, a heavenly goddess; to another it is a productive and proficient cow, who supplies him with butter." If we wish to maximize the socially desirable uses of R & D, we must create and encourage mechanisms that put most of the decisions about R & D into the hands of the actual users. In this way, they can impose their own values on goals and applications. Let us look at this proposition from the local, industrial, and federal points of view.

Metropolitan and state governments should consider additional (and more competitive) R & D programs designed to meet the peculiarly local problems of environment, health, transportation, and education. In some ways the R & D community is too national in orientation, because our R & D patterns were framed for defense, atomic energy, and then space. Now, many nationwide social problems might be solved more efficiently through metropolitan and regional R & D consortia. These could be funded through greater federal revenue sharing and could be staffed by the many professionals now unemployed.

From the standpoint of industrial R & D, most economists agree that our principal, if not our only, past advantage in international trade was our technological edge. While it is not possible to develop the point here, strong evidence indicates that this advantage may not persist much longer (*27*). We do still have some advantages in scale and in management know-how. Our best course is to renew our commitment to vigorous national R & D that is organized around national missions, but is perhaps tilted to provide new incentives for greater corporate investment in R & D.

At the same time, the federal government must assume its responsibility for the country's stable scientific and technological health. It would be helpful for the President to elaborate on how the country can, as he stated, turn "the wonders of science to the service of man" (*28*) and on how the necessary increases in economic productivity can be made through "the investment of capital for research, development, and advanced technology" (*29*). Specifically, the federal government must try to ensure that major university research centers established over several decades are not permitted to crumble in the wake of multiple cuts in mission-oriented agency research budgets, compounded by rapidly increasing research costs and campus disorganization (*30*). For the federal government to permit the basic research community in the universities to decline into an isolation forced by bankruptcy would be ruinous. Quite simply, more research funds are needed, and it doesn't matter very much in the short run whether they flow through the major mission-oriented agencies or through NSF.

How about the federal organization for R & D? Some degree of centralization of basic research and higher education activities [through, for example, the proposed National Institutes for Research and Advanced Studies (*31*)] may be worthwhile. But, more important, the federal government must insist upon and be able to count upon each agency's doing its share of basic research.

One necessary action that requires no major organizational change is a more forceful and continuous effort in the President's office and in Congress to answer coherently the questions about reasons for various R & D efforts. To do this, it might be wise to increase the number of senior appointees in OST, perhaps through some variation of the often-proposed Council of Scientific and Engineering Advisors, which would substitute three people for the single director. Expanding the roughly 20-man OST staff by perhaps 50 to 100 percent also seems imperative to achieving more comprehensive planning, including more penetrating assessments of the impacts of technology on many social and economic goals.

For Congress to play its role well in the long run, we will need to elect more men with scientific, engineering, and medical training. Scientists who devote much of their time to influencing public priorities should consider seeking local or national public office. At the very least, scientists must be prepared to commit a growing fraction of their time to the continuing task of explaining to political leaders, if not to the public in general, what science and technology are doing, why it's important, and where it may lead.

In the short run, Congress must invent mechanisms for more comprehensive reviews in appropriating national R & D resources. Rather than forming a new committee, Congress might do well to create a special joint technical staff that would report directly to both the House and Senate Appropriations Committees. This might be a way of obtaining information linking all mission-oriented R & D programs with the funds requested by the several agencies for reaching their operational goals. One important benefit of preparing more coherent plans, and then debating them widely and publicly, as William D. McElroy has urged (*32*), would be the restoration of confidence in our ability to rationally control technology in society's interests. The erosion of that confidence has been largely responsible for the present crisis in mission-oriented R & D.

Although time for solving the "crises" which assault us appears to be running out, it probably really isn't, at least not at fast as some doomsayers suggest. R & D, after all, expands our range of alternatives: it opens rather than closes options, and it enlarges rather than constrains the destiny of society. Science and technology will remain friends with a free society, humanely governed, if we but gather the wit and the courage and the resources to ensure it.

Summary

Mansfield's Section 203 has triggered a searching review by DOD of its research. Using the general budget constraints of the past few years as an effective springboard, Mansfield went on to question and then challenge all of the federal government's policies for R & D. The entire post-World War II institutional machinery and rhetoric for R & D are now in some disarray and, thus, are open to imaginative, constructive

change. Mission-oriented R&D, still central to progress toward our national goals, must be comprehensively rethought in order to restore the public confidence necessary for adequate support of science and technology.

References and Notes

1. Abbreviations: Department of Defense (DOD); research and development (R & D); General Accounting Office (GAO); National Science Foundation (NSF); Department of Health, Education, and Welfare (HEW); Department of Commerce (Commerce); Atomic Energy Commission (AEC); National Aeronautics and Space Administration (NASA); fiscal year (FY); National Bureau of Standards (NBS); National Institutes of Health (NIH); Planning, Programming, and Budgeting Systems (PPBS); chlorophenothane (DDT); supersonic transport (SST); antiballistic missile (ABM); lysergic acid diethylamine (LSD); Office of Science and Technology (OST); Office of Economic Opportunity (OEO); Department of Housing and Urban Development (HUD). Throughout this article I use the terms "R & D," "national science," and "science and technology" more or less interchangeably. In addition, I try to be relatively precise in referring to research as opposed to development, despite the difficulty in making clear-cut, consistent distinctions.
2. Letters referred to in this article are available through the Office of the Assistant Secretary of Defense for Public Affairs and have been included in various congressional hearings and issues of *Congressional Record*.
3. *Congr. Rec.* 10 July 1970, p. S11063.
4. *Ibid.*, 21 August 1970, p. S13932.
5. *Ibid.*, 10 July 1970, p. S11063.
6. *Implementation of 1970 Defense Procurement Authorization Act Requiring Relationship of Research to Specific Military Functions, B-167034* (General Accounting Office, Washington, D.C., 23 June 1970).
7. *Congr. Rec.* 28 August 1970, p. S14553.
8. *Ibid.*, p. S14559.
9. Conference report accompanying H.R. 17123, Report No. 91-1473, House of Representatives, 91st Congress, 2nd Session.
10. The new phrasing was passed in P191-441, FY 1971 Military Procurement Authorization Act.
11. *Congr. Rec.* 1 October 1970, p. S16927.
12. Report of the House Subcommittee on Science, Research, and Development, 91st Congress, 2nd Session, Serial S, 15 October 1970.
13. Development projects are, of course, much more susceptible of planning than research projects are. Yet even research could be "planned" in the gross statistical sense that, say, one out of every five projects or one out of every ten investigators will turn out to be much more significant than the rest. We can't predict the significant ones in advance, however, so we must plan on supporting most of the clearly qualified investigators if we wish to maintain steady progress (and, perhaps, international leadership) in those areas of science upon which our national goals depend. Such a "statistical" theory of research planning wouldn't satisfy many congressmen.
14. See, for example, "Conflicts between Federal Research Programs and the Nation's Goals for Higher Education," 18th report of the House Committee on Government Operations, H.R. 1158, 89th Congress, 1st Session, October 1965.
15. H. Brooks, *Can Science be Planned?* (reprint No. 3, Harvard University Program on Technology and Society, Cambridge, Mass.).
16. See, for example, R. Hofstadter, *Anti-intellectualism in American Life* (Knopf, New York, 1963), pp. 34, 45–46, 397–398.
17. One of the best summaries on this issue is *Centralization of Federal Science Activities*, report to the House Subcommittee on Science, Research, and Development, Serial B, 29 May 1969 (Government Printing Office, Washington, D.C., 1969).
18. Bureau of the Budget, *Special Analysis Q* (Government Printing Office, Washington, D.C., February 1970), p. 256.
19. *Special Analysis R, Federal Research and Development Programs*, from *Budget of the United States, 1972* (Office of Management and Budget, January 1971).
20. R. M. Nixon, "FY 1972 budget message to Congress," *New York Times*, 30 January 1971, p. 13.
21. A. H. Dupree, *Science in the Federal Government* (Harvard Univ. Press, Cambridge, Mass., 1957), p. 367.
22. R. Gilpin, *Science* **169**, 441 (1970); J. S. Foster, Jr., address given at the 16th Annual James Forrestal Award Dinner, Washington, D.C., 12 March 1970 (available from the Office of the Assistant Secretary of Defense for Public Affairs, Department of Defense, Washington, D.C.); *Science, Technology, and American Diplomacy: The Evolution of International Technology*, prepared for House Subcommittee on National Security Policy and Scientific Developments by Legislative Reference Service, Library of Congress (Government Printing Office, Washington, D.C., December 1970).
23. H. Himsworth, *The Development and Organization of Scientific Knowledge* (Heinemann, London, 1970).
24. E. Ashby, *Technology and the Academics* (St. Martin's, New York, 1966), p. 65.
25. D. S. Greenberg, *Science* **170**, 952 (1970); V. Cohn, *Washington Post*, 25 January 1971, p. A5.
26. A provocative summary has been offered by (P. R. Ehrlich ["Population and panaceas: A technological perspective," *BioScience* **19** (No. 12), 1065 (1969)].
27. R. Gilpin, *Science* **169**, 441 (1970). See also unpublished data compiled and analyzed by M. Boretsky in the Department of Commerce.
28. State of the Union Message, 22 January 1970.
29. R. M. Nixon, "Economic Policy Message," *New York Times*, 18 June 1970, p. 24.
30. See, for example, *Mission Agency Support of Basic Research*, report to the House Subcommittee on Science, Research, and Development, Serial L, 25 February 1970 (Government Printing Office, Washington, D.C., 1970).
31. P. Handler, statement before the House Subcommittee on Science, Research, and Development, 21 July 1970.
32. W. D. McElroy, statement before the House Subcommittee on Science, Research, and Development, 29 July 1970.

33. I thank N. Ammerman, W. Donnelly, A. Gold, S. B. Levin, J. A. Shannon, C. E. Sunderlin, F. Seitz, and N. Zinder for their comments.

NEWS AND COMMENT

Technology and World Trade: Is There Cause for Alarm?

For several years now Europeans have been complaining bitterly about an alleged "technology gap" between the United States and Europe which supposedly gives American corporations such an advantage in world trade that they can beat down foreign competitors with the flick of a computer switch. American opinion has long regarded that image as grossly overdrawn, but leaders of the American technological community have recently been nourishing some fears and apprehensions of their own. For the past year or so, technology experts in this country have voiced increasing concern that the United States is in danger of losing its preeminence in advanced technologies, particularly those technologies that are important in world trade. The most pessimistic of these experts predict that foreign industrial powers—usually Japan and West Germany—will eventually overtake the United States and gobble up a major share of the world market in high-technology products, thus threatening future economic growth in this country and causing a severe balance of payments deficit to boot. The irony in the situation is apparent. While foreigners seem worried that the American technological colossus will get so far ahead that it can't be competed with on equal terms, the Americans seem alarmed that the hot breath of foreign competition is already on their necks.

Perhaps the highest ranking government official to feel the foreigners closing in has been Secretary of Commerce Maurice H. Stans, who told the Joint Economic Committee on 17 February that "the trend of our trade balance is of great concern." The thrust of Stans's testimony was that the United States has relied on exports of "technology-intensive" manufactured products to provide a favorable balance of trade, but in recent years our exports of these products have not been sufficient to make up for rising deficits in other goods. Moreover, according to Stans, our imports of "technology-intensive" products have been increasing more than twice as fast as our exports of these products. "Our technological superiority is slipping," he warned.

Similar concerns have been expressed by a number of leaders in the scientific and engineering communities. Patrick E. Haggerty, board chairman of Texas Instruments, Inc., told a con-