An Industry Picture of U.S. Science Policy

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With regard to promoting the competitiveness of U.S. industry, federal science policy is performing unevenly. Federally supported basic research is not well aligned with industrial needs, although the National Science Foundation's Engineering Research Centers and similar programs are improving matters. Large-scale federal undertakings in science and technology, such as the Apollo program and now the Strategic Defense Initiative, actually tend to divert resources away from commercial research and development. Needed are federal and industrial leaders who will work together to serve the interests of both competitive industry and efficient government in the United States.

PEOPLE IN INDUSTRY TEND TO CONSIDER FEDERAL SCIENCE policy as being on a par with tax, trade, and regulatory policy. To be more specific, civilian industry tends to judge federal policy by a single standard—namely, how well it is coming to grips with the fundamental economic problems described by the President's Commission on Industrial Competitiveness (*1*).

By this standard, federal science policy presents a mixed picture. In recent years, there have been three notable developments in federal science policy: initiation of several large research and development programs; a renewed focus on supporting basic research at the universities; and increasing emphasis on promoting closer cooperation among government, industry, and the universities.

Taken together, these developments represent a formidable agenda, and they could have a major impact on the ability of American industry to compete in international markets, either for good or ill. However, they may well put unsustainable demands on the country's research and development system. Not that the government should abandon one or another of these calls on the system. Rather, having initiated such programs, it must now take vigorous steps to strengthen the R&D system so that it will be equal to our expectations. Despite the federal budget deficit, the departments and agencies must devise programs to ensure that the nation meets the dual necessities of new knowledge and excellent graduates to sustain the technology base.

There is also a need to diversify the system and to increase its flexibility. The U.S. R&D system is enormously creative, and federal initiatives can enhance that creativity. But even such a great strength, when carried to an extreme, can become a national weakness. Thus, we lead the world in producing innovative new companies that exploit the results of our research and development, but, for a variety of reasons, these companies frequently fail to grow beyond their first technological successes. And both large and small companies have faltered in the product design and manufacturing technology required to transform the results of R&D into internationally competitive products. By now it is not particularly original to say this. Nevertheless, we are still not acting on the lesson.

Megaprojects

The problems have been especially pronounced in respect to big federal R&D projects, or what I prefer to call federal megaprojects. In its first term, this Administration's science policy focused on increasing support for basic research while cutting back civilian development projects, especialy energy projects. Then, however, came the megaprojects, and a shift in emphasis from pure science to what I might call pure technology.

The most well known of these initiatives is, of course, the Strategic Defense Initiative (SDI). Others include the National Aeronautics and Space Administration's space station, and the U.S. equivalent of Japan's fifth-generation computer project—that is, the Defense Department's billion-dollar combination of programs centered around high-speed integrated circuits, artificial intelligence, and supercomputers. Not to be forgotten is the superconducting super collider proposed for the particle physics community. The total cost of these R&D initiatives is in the range of $25 billion to $50 billion, indicating a vast effort by industry and academia. Something more than pure science and pure technology had better emerge if we are to remain internationally competitive.

Quite apart from their specific missions, at least some of these projects are perceived as important to national progress in science and technology. Let me consider SDI from a somewhat different perspective than usual, without arguing the strategic issues that concern the critics and advocates. In 1973 President Nixon abolished the position of White House science adviser, as well as the President's Science Advisory Committee (PSAC). I remember these events well because I was the science adviser at the time. President Ford reestablished the position of science adviser, but no president has reestablished PSAC. Many science policy buffs look upon that as a loss to the nation. This leads to an interesting question. Suppose that we had a PSAC when SDI was still in the decision stage—what would it have said to "star wars"?

My guess is that PSAC would have supported SDI just as it supported the so-called "cancer cure" program in 1971, despite scientific doubts and clear opposition by the director and associate director of the National Institutes of Health. With regard to SDI, too, PSAC would have based its decision on the importance of sheer activity in science and engineering. Of course, PSAC did oppose the antiballistic missile programs of the late 1960's, and the supersonic transport program as well. However, the federal R&D funding situation and the corresponding level-of-effort, as well as the U.S. competitive standing, were very different in those days. Thus, the need for encouraging sheer activity was less.

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Whether or not SDI ever produces what is intended, it will produce something of scientific or engineering importance. One can go further and ask whether SDI is the best way for the government to produce such activity. The answer is almost certainly that it is not. There may be no better, politically feasible ways to channel net extra funds into the research and development community on a large scale. But, even so, a real issue is whether scientific and engineering activity can ever be a sole or sufficient justification for megaprojects. Despite my guess about PSAC opinion, this issue, which is hardly new, is perhaps the most important one for the scientific community and its political allies to debate. That is so because megaprojects have represented an opportunity, a temptation, and an intoxicating elixir for big government ever since the building of the pyramids and the Great Wall of China.

In debating the issue, we should weigh the intrinsic merits of SDI and other megaprojects in the context of international competitiveness for the United States in worldwide markets. In that regard, there is one generic problem—namely, a peculiar operation of federal megaprojects that resembles Gresham's law in economics (under which debased currencies drive undebased currencies out of circulation). In the federal realm, big science and engineering tend to drive out small science and engineering. That is, they drive resources, especially the most excellent people, away from smaller-scale, commercially relevant R&D and the associated basic sciences. This happened at NASA during Project Apollo in the 1960's and the shuttle project in the 1970's.

One way to counteract the impact of megaprojects is by exacting a tithe on them in order to put back what they are taking out of the R&D system. I understand that the plan is to tithe the SDI budget 5% on behalf of basic research. That would represent well over $1 billion during the next 5 years. Better that the tithe were 10% as any self-respecting tithe is supposed to be. But 5% is a step in the right direction. The next step should be SDI scholarships and fellowships and research grants to the small fields that will contribute most to the advance of both SDI technology and U.S. industry. For example, SDI funders should think about the grossly underfunded small science of mathematics, which continues to make discoveries vital to progress in computing, communications, engineering, and a whole host of client sciences.

Basic Research

These observations bear directly on the second development that I identified above: the federal government's increased emphasis on funding basic research. This strategy is real, and it is sound. Federal funding of basic research, primarily at the universities, has increased by more than 50% during the past 4 years. The Administration clearly means to continue on this path in future years, despite only a small overall increase for basic research. The Defense Department has, however, budgeted sizable increases for basic research (*2*). Nevertheless, what is unsettling about the emphasis on basic research is a clear tendency to tie funding closely to specific developments, a tendency that has its parallel in industry. Investigator-initiated research is clearly receding as a legitimate mode of action in both realms.

Regardless of the traditional arguments for basic research, there is a more contemporary issue here—that is, how to integrate fundamentals more efficiently with the total process of technological innovation. The Japanese and the Soviets, each in their own way, have demonstrated that they can stay at the leading edge of the technologies that interest them without a big commitment to basic research. And our technology-driven entrepreneurial businesses have demonstrated the same thing.

The point is not that the United States can do without basic research. Rather, it is that research activity must be focused on commercially important fields and that results must be exploited more rapidly—faster, for example, than our foreign competitors. Frustration with this problem accounts in part for the Pentagon's efforts to clamp controls on the flow of scientific information. Similar frustration accounts for industry's tendency to cut back on its own support for basic research, especially when economic conditions worsen.

Federal R&D must address more needs than those of commercial industry, but the fact remains that it is poorly aligned with industry objectives. For example, analysis of the federal government's $6- to $7-billion annual investment in university R&D shows little correlation with the fields important to the civilian companies that are doing the most to create jobs, enhance national productivity, boost competitiveness, and contribute to the growth of the economy. The discrepancy is even more marked when the entire federal R&D budget is taken into account. The federal priorities are defense, space, energy, health, and fundamental science in that order. The priorities of commercial industry are in approximate order: increased productivity, marketable products, education and training for employees present and future, health care, reliable and secure communication, efficient means for transactions, safety and environment, and air and ground transportation (*3*).

The only common element is health, unless the lists are translated into disciplinary fields. Then there are many more common elements—for example, mathematics; computer science; ceramics, composites, and other materials; condensed matter physics; fundamental biology; testing methods; molecular structures, processes, and chemical reactivity; and so on. However, this commonality does not offset the disparity in goals and functions between industrial and federal priorities, because in modern research, goals affect means and programs profoundly.

For example, in composites for high-performance aircraft and missile nose cones, performance is much more important, and economical large-scale production much less important, than is the case for automotive composites. Research for the Department of Defense rightly puts principal emphasis on performance, because defense materials will be produced on a much smaller scale than automotive materials. In contrast, research for commercially oriented firms often requires emphasis on the economics of large-scale production.

Even more important than their critical influence on program content is how federal goals influence the attitudes of researchers and students. Researchers and students quickly learn to prefer working on technologies constrained only by bid and contract economics rather than market economics. That is why many people in industry are particularly concerned about the "mix" of basic research being funded in the universities. That is why many of them, not just radicals, are concerned about the possible "remilitarization" of research on campus. That is why Arno Penzias, the research vice president at Bell Labs and a Nobel Prize winner, has voiced concern that too many of the best and brightest are being attracted by the prestige of high energy physics. What bothers him, he says, is a value system in science suggesting that the biggest, the most high powered, the most arcane, or the smallest is the most important thing for a scientist or research engineer to pursue (*4*).

The truth is that industry can benefit profoundly from the insights of fundamental research conducted in relevant fields. Consider, for example, the opportunities that new basic understanding would open up for the petroleum industry. The petroleum and petrochemicals industries have long been on the path that the hard goods manufacturing industries are now following in computer control. Indeed, the process industries have been implementing higher and higher levels of control and optimization for several decades. But as the industry has pursued the task, its difficulties have mounted, because it has such imperfect knowledge of its processes. The need for knowledge is most acute in regard to main reaction pathways; mass transfer effects; operability phenomena like coking, foaming, fouling, and agglomeration; and, most prominently, after Three Mile Island and Bhopal, the failure modes of modern process plants. Better knowledge could be the key to increased yields, efficiencies, selectivity, and safety.

In addition, the petroleum industry does not know enough about its processes to avoid the multimillion-dollar task of scaling up processes from the laboratory bench to commercial units. It does not know enough about satellite scanning and seismic wave transmission to use computers to construct images of the earth's interior. And it does not know enough about the molecular structure and chemical reactivity of coal and oil shale to devise processes that will produce synthetic fuels at the same cost as conventional petroleum fuels.

These are examples from but one industry. There are comparable issues in other commercial fields. Federal administrators should find better ways to accommodate industrial interests in the basic research that they support. In this regard, the program of the National Science Foundation for Engineering Research Centers has much to recommend it.

Industry-Government-University Cooperation

What are the ways to create closer relationships between scientists and engineers doing basic research and those developing technology? One is for industry to perform more basic research as at Bell Labs, IBM, or Exxon. Another is through new research consortiums, such as the Microelectronics and Computer Technology Corporation or the Semiconductor Research Corporation. But what about the great mass of smaller companies that cannot support or cannot be induced to support such research? For a time, it looked as if the answer was in California's Silicon Valley and Boston's Route 128. It was a paradigm thought better suited for creating economic growth and jobs than the old paradigm represented by the Manhattan Project and Project Apollo. But even that is not sufficient. Required are efforts that secure a careful match between local needs and capabilities on the one hand and academic and industrial capabilities on the other.

In attempting to secure this match, the states have gotten way ahead of the federal government. Often with state incentives, industry and the universities have entered into joint research efforts in such areas as catalysis, polymers, electronic chip design, computer-aided design and manufacturing, and biotechnology. Various governors' commissions on science and technology have fostered an extraordinary array of initiatives. In New Jersey, for instance, such an effort produced voter approval for a $90-million bond issue, and new or expanded "centers of excellence" at New Jersey universities in such fields as ceramics, polymers, biotechnology, and the treatment of toxic waste. More initiatives will follow—in education, in key scientific and engineering fields, and in the effort to improve the financial climate for growing new businesses.

In the drive to make U.S. industry more competitive, such local initiatives are among the most important being undertaken today. They mark the beginning of a realistic partnership between major sectors of our society, and the beginning of a transition from science policy to something more akin to innovation policy. It is important to note here that industry and the states have often found federal programs on which to build. The New Jersey Ceramics Center at Rutgers, for example, began as a cooperative research center with seed money from the National Science Foundation. The NSF has helped create more than 20 such centers that are now largely supported by private companies.

The NSF has also taken a welcome lead in efforts to upgrade university instrumentation, give greater access to computers and supercomputers, and remedy faculty shortages in the sciences, mathematics, and engineering. But the federal resources committed do not nearly match the needs of the universities. Because NSF cannot carry these burdens alone, it has required matching contributions from industry. Here, there are signs that industry cannot or will not assume the burden expected of it. For example, NSF launched its Presidential Young Investigators Program with expectations that industry would match $37,500 of the total $100,000 that each investigator is to receive. Industry has fallen far short of that goal, and NSF has now cut in half the number of awards it proposes to make in fiscal 1986.

Without exonerating industry from its responsibility, let me suggest one mitigating factor. The federal government has set up this program more or less unilaterally. Industry will always be reluctant to supply research funds when it can have little control or active involvement. For similar reasons, NSF should guard against industry reluctance to participate in the Engineering Research Centers. The centers are being located on university campuses and are supposed to focus on promoting interdisciplinary research in areas important to both industry and the universities. For that actually to happen, industry must be more than a supporter and a passive recipient of academic research. Rather, its people must be thoroughly entangled with the daily activities of the centers and that may cause some discomfort in certain sectors of academia, as well as in industry.

There are many other areas where important progress has been made, and others where much more is required as the nation moves from "science policy" to "innovation policy." A welcome move has been the relaxation of the antitrust laws to encourage joint research by industry. More effort should be expended to ensure that the intellectual property rights of U.S. companies are protected against the encroachments of foreign competitors. The R&D tax credit should be made permanent and probably extended to cover more than just incremental additions to R&D, particularly where academic institutions are involved. And that same law should be amended so as to give industry an incentive not just to donate equipment to universities as the law now allows, but also to donate the funds to maintain that equipment. Today, universities must sometimes refuse donations because they cannot afford annual maintenance costs that often represent 10 to 20% of the capital cost of the equipment (*5*).

Conclusion

My view of federal science policy is necessarily one-sided. Federal science policy cannot be entirely consistent—it must reflect the political process in the United States. But, it is clear that we have not yet found the right formula for Washington to help the industrial sector. We are still not inducing industry to perform more of its own basic research.

We are not interesting the great mass of small and middle-sized companies in forging closer connections with university research, and vice versa. We are not inducing industries to invest enough in new technologies, particularly our traditional bread-and-butter industries. As a result, the technologies of some of our most important industries have fallen behind the foreign competition—notably in fragmented industries like machine tools, some areas of instrumentation, and construction (*6*).

Finally, we are not educating enough engineers in product design and manufacturing, nor giving those fields the prestige required to attract the best people. That and inadequate technology, presumably, are important reasons why the average Detroit product requires twice the man-hours to produce as its Japanese counterpart. Not least, we are not maintaining a consistency of purpose. The American political fancy is again proving fickle. The Atari Democrats and Apple Republicans who worried for a while about something called "industrial policy" are now preoccupied with a new triad of concerns: Star Wars, trade wars, and border wars.

Those are the elements that the pessimist would stress. The optimist would note, first of all, that many people understand the problems and are making concerted attempts to implement some of the measures that I have described in connection with federal megaprojects, basic research, and cooperation among government, industry, and the universities.

Who might coordinate these efforts, particularly at the federal level? Total coordination for a government and a nation so diverse as our own is not possible, even if it were desirable. But, certainly, the President's science adviser and the Office of Science and Technology Policy could be empowered to do the job. For example, the science adviser might be given the authority to ensure that agency and departmental budgets are consistent with a policy of fostering industrial competitiveness. Or the science adviser might be given a mandate simply to make known the effects of agency actions and proposals on the competitiveness of our industry.

There are no final answers. But we can work for more thoughtful proposals for improving federal science policy so as to better promote industrial competitiveness. That in turn will require attention from both industrial leaders and federal administrators. There is, however, a natural reluctance by some industrial leaders to become involved with federal policy-making. There is a natural reluctance by federal policy-makers to allow industry to influence their affairs. Thus, many people on both sides tend to see federal and commercial activities as separate realms, albeit with some connecting lines.

That conception and its consequences are quite inadequate to the requirements of competitive, productive industry and efficient government in the United States. The chasm between these sectors must be reduced by finding common aims and pursuing them, by supporting common educational objectives, and by overcoming the single-mindedness that has often characterized both industry and government.

REFERENCES AND NOTES

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