

Testimony
by

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before the

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Committee on Armed Services
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Mr. Chairman and Members of this Subcommittee:

My name is Frank Press. I am a geophysicist, the Cecil and Ida Green Senior Fellow at the Carnegie Institute of Washington, and formerly President of the National Academy of Sciences. Thank you for the opportunity to appear before you to offer my views on the science and technology base of the Department of Defense and its importance not only to national security but to other national goals, such as economic security. In support of these views, I will in my testimony make several assertions. These are that:

- **The country's investments in science and technology in support of the mission of the Department of Defense have been spectacularly successful in maintaining a strong fighting force in a world that continues to be dangerous.**
- **The fundamental science and technology supported by the Department of Defense are as important to civilian goals as they are to maintaining our national security. In that vein, analytically differentiating support for civilian science and technology from that for defense makes no sense.**
- **The dynamics of contemporary research render meaningless the separation of basic from applied research, or fundamental science from fundamental technology. They are highly interconnected.**
- **Dependence on industry or even on other agencies to rectify cuts in support for the DOD science and technology base is wishful thinking that reflects mistaken assumptions about the role of industry in innovation and distorts the missions of civilian agencies.**

- **Finally, the enormous achievements of American research, including DOD's, depend on supporting the best people and institutions. That policy, which has rewarded the country so richly, must continue if we are to ensure that science and technology are marshaled in defense of the United States.**

Let me now expand on each of these assertions. They are rooted largely in a year-long examination requested by the Congress and done by a committee I chaired that resulted in a report entitled *Allocating Federal Funds for Science and Technology*.¹ A fundamental observation in the report is that historical forces shaped a federal research enterprise that is highly diverse—in funding sources and in the institutions that do the work. Rather than seeing this seeming “messiness” as a weakness, the committee came to regard it as the key to understanding the success of American science and technology. The very diversity and plurality of that system, one not centrally planned, made it highly responsive to new opportunities, protean in adapting to new circumstances, and welcoming to new ideas and to able men and women. This remarkable system meant that the rewards to the nation of federal investments emerged from many sources. Consider, for example, how this “messy” system created the Global Positioning System, whose enormous navigational value to the military is well known to this Subcommittee. GPS made possible, for example, flanking movements by our troops in the unmarked Iraqi desert. Our report noted that:

The Global Positioning System (GPS), a satellite-based system for finding one's place on earth with remarkable precision, is a contemporary product of a diverse R&D system. GPS evolved from post-war work on atomic clocks to test aspects of general relativity theory. Their possible value for navigation was recognized by the military, which provided years of “patient federal capital” to mature the technology. While the military's primary interest in what was to become GPS was to improve the delivery of tactical weapons and to reverse the proliferation of costly new navigation systems, its

¹ National Academy Press, Washington, D.C., 1995. The report is available on the World Wide Web at <http://www.nas.edu/fsrd/fsrd.html>

civilian potential was seen at the outset; i.e., early in its development GPS was recognized as a potential “dual-use technology,” and in fact the commercial GPS market now overshadows military demands.

The obvious point here is that this remarkable system emerged in part from quite fundamental and even abstruse research—examination of aspects of Einstein’s ideas. But through perceptive managers in the Department of Defense who understood both the science involved and its potential applications, this fundamental work has grown into such a remarkable gain for both the military and the country’s economy. The story is of course more complicated, and the creation of GPS also owes to DOD investments in satellites, solid-state devices, microwave communication technology, and many other programs. There are more stories like this; for example, the creation of Silicon Valley owes in substantial part to post-war investments by the Department of Defense in certain aspects of materials science and engineering, which became the basis for the “chip” that in turn has transformed the nature of warfighting and, not least, the US economy.

The diversity of federal funding sources for fundamental science and technology, combined with a belief that basic and applied research need to be treated together with fundamental technology, led our committee to suggest a new way of appraising federal investments, including those of the Department of Defense. We called it *the federal science and technology*, or FS&T, budget, to distinguish it from the federal R&D budget, of which it is a subset. This FS&T budget separates investments in fundamental science and technology from other parts of the larger R&D budget that, while important, don’t have as their primary purpose the creation of new knowledge or new technologies. Examples include DOD programs aimed at prototyping and testing new weapons systems, or aspects of the nuclear weapons programs of the Department of Energy.

Since our report came out, the National Academy of Sciences has issued two analyses of trends in the federal science and technology budget.² Overall, from FY1994 to FY1997 the FS&T budget has declined 5 percent, after inflation; and 10 percent if the budgets of the National Institutes of Health and the National Science Foundation are omitted.³The DOD part of the federal science and technology budget—that is, the Department’s investments for new science and technology—has declined over 11 percent in real terms between fiscal years 1994 and 1997, and that decline continues in the Administration’s FY98 budget request, reaching almost 19 percent below FY1994, again after inflation. Overall, in 1998 dollars, the DOD FS&T budget for investing in new knowledge and new technologies, as defined in our report, will have been reduced by \$1.7 billion since FY1994.

I certainly understand that fiscal pressures are driving cuts in the FS&T budgets of DOD and other agencies. I also believe quite strongly that the full impact of cuts of this magnitude must be considered. While these impacts need further examination, one palpable risk is that they may drain the capacity of the United States in fields that have proven vital to maintaining national security and that have been a well-spring of economic growth but that depend heavily on the DOD science and technology base. These fields include computer science, mathematics, and a wide spectrum of engineering research. Imagine, if you will, the immense harm that would have occurred if DOD had cut back on computer science funding in the late 1960s and 1970s. Not only would this have changed the face of computing; it would also have undermined the weapons employed in the Persian Gulf War. Even now, when science and technology can be so closely related, the lag times are long, and it takes a decade or more for the impact of science and technology budgets to be felt. The impact of the diminishing DOD S&T base will likely be felt by soldiers and sailors many years into the next century. In effect, budget priorities may have inadvertently driven science and technology priorities. And, again in terms of DOD needs, I have to question the implicit choices that have been made.

² Panel on FS&T Analyses, *The Federal Science & Technology Budget, FY 1997* and *The Federal Science & Technology Budget Request, FY 1998* Washington DC: National Academy of Sciences, 1997. Both reports are available on the World Wide Web at <http://www.nas.edu/fsrd/fsrd.html>

³ These are the only agencies whose FS&T budgets increased in real terms from FY1994 to FY1997.

I'll now expand on each of the assertions I made at the beginning of my testimony.

- **The country's investments in science and technology in support of the mission of the Department of Defense have been spectacularly successful in maintaining a strong fighting force in a world that continues to be dangerous.**

The science and technology investments of the Department of Defense have properly been shaped to its mission, which today of course is pressured by fewer resources. That reality suggests that investments in science and technology in the service of DOD's mission are even more important, as a force multiplier and to enable DOD to meet the new imperatives of national defense: rapid deployment; low casualties yet overwhelming force; and unambiguous dominance in logistical, intelligence, communication, and firepower capacities. History affirms that these goals are realistic. Simply look at the tools now used by our military that came out of the investments by the Department of Defense in fundamental science and technology. This Subcommittee will of course have its own examples, but let me list some with which I am familiar:

- Laser technology used in missiles, tank rangefinders
- Sensor technology, used in missiles, tanks, and satellites
- Materials—fundamental to sensors, and also to development of gas turbines in aircraft, ships, and tanks
- Control systems technology, including data processing
- Packet-switching communications technology and the defense communications network
- Propellants for missiles and satellite launching systems
- Lithium batteries for electronics
- Satellites for surveillance, targeting, battle damage assessment, communication, and navigation
- Electronic warfare systems for penetrating defensive sensors and weapons, information warfare systems that provide a global communication and data transmission network, and

electronic intelligence systems that monitor electromagnetic transmissions throughout the world

In Desert Storm, the US Army completely dominated a battle during a sandstorm that blinded the Iraqis but did not blind our soldiers thanks to their infrared vision devices. The same physics underlies the heat-seeking weapons that were also used against the Iraqis.

Improvements in tank armor—now lighter in weight but just as strong—save on fuel, simplify shipping, and enhance speed on the ground. And, as I've already noted, the GPS was indispensable to navigating rapidly in the desert. Desert Storm amply demonstrated the wisdom of three decades of S&T investment by DOD.

- **The fundamental science and technology supported by the Department of Defense are as important to civilian goals as they are to maintaining our national security. In that vein, analytically differentiating support for civilian science and technology from that for defense makes no sense.**

Federal investments in science and technology have conventionally been divided into civilian and defense budgets. But that is purely an input measure; i.e., how many dollars are going where. Measured in terms of output—how much has been gained by these investments—this distinction between civilian and defense investments is meaningless. As I said above, defense investments contributed greatly to Silicon Valley and indeed to the US global dominance in information technology. What we take for granted as computing in the 1990s—interactive programs, understandable graphics, and networks of computers—was driven in large part by deliberate DOD investment decisions following a vision of how computers could win wars. The same story can be told for optical technologies such as lasers now ubiquitous for uses ranging from CD players to eye surgery, for the Global Positioning System, and for a vast array of new medical diagnostic techniques. The science and technology investments made by the Department of Defense were in every way as fundamental as investments made by civilian agencies such as the National Science Foundation and the National Institutes of

Health. In the cases of computing and electronics, they were the best programs going on anywhere in the world.

If I may, I would like to add a personal note. My PhD thesis on underwater sound propagation was supported by the DOD, through the Office of Naval Research. That work led to devices for detecting long-range sound transmission and, hence, submarines. In the same vein, my work on measuring the waves sent through the ground by earthquakes was applied to the detection of nuclear tests. In both instances my work was intended to advance fundamental science, but found defense applications very important to the country.

The two charts attached to my testimony make the same point from another direction. The first chart shows how significant DOD investments are to fields that are of obvious importance not only to the military but also to the health of the US economy. For example, DOD investments account for 60 percent of support of computer science, 80 percent of research in electrical engineering—which of course is at the heart of our world leadership in microprocessors—and almost 60 percent of support for research in metallurgy and materials.

The second chart is to me even more dramatic, and I have to confess I was quite surprised when I saw it. This chart vividly shows the criticality of the Department of Defense in supporting the next generation of scientists and engineers. DOD supports almost half of all graduate students in computer science, over 20 percent in mathematics, and 40 percent in electrical engineering. As you know, our people are our future, and investments in technical personnel doubly so. The substantial decline since 1994 in support for fundamental science and technology at the Department of Defense cannot help but undermine our nation's capacity in these critical fields.

- **The dynamics of contemporary research render meaningless the separation of basic from applied research, or fundamental science from fundamental technology. They are highly interconnected.**

I would like to quote again from the report on *Allocating Federal Funds for Science and Technology*. The report comments that “the distinction between basic and applied science is often difficult to make and is rarely decisive in defining the federal role.” We went on to note that:

Even when a clear distinction between basic and applied research can be made, it is often not useful in guiding choices about whether it is a proper subject for federal support. A more severe problem is that most federally funded research is at once both applied and basic. In the standard definition, basic research is the pursuit of knowledge without thought of practical application. The first part is true—that science is intended to produce new discoveries—but the implication that this necessarily entails a sharp separation from thoughts of usefulness is just plain wrong. Sometimes it is true, but far more often it is not, especially in science supported by mission-oriented agencies.

The issue was put more succinctly by Lord Porter, a Nobelist and former President of The Royal Society, who observed that “there are two kinds of research—applied research and not-yet-applied research.” Such observations gain special force for the Department of Defense investments. As this Subcommittee well knows, these are conventionally parsed into 6.1 (basic research), 6.2 (applied research), and 6.3 through 6.7, which are different phases of development, testing, and evaluation of major systems. However, history shows that the distinctions among these often reflect budgetary convenience more than reality. Some of the most dramatic products of DOD investments came from a mix of these different programs. Thus, ARPANet, from which packet switching and the modern Internet and defense information networks evolved, was a 6.2 program. SIMNET, which illustrated and perfected modern networked simulation and training technology, was a 6.2 program. It was used to train troops for the desert operations in the Gulf War. We owned the night in the Gulf War, with night vision technology that flowed from decades of sustained 6.1 and 6.2 support for

materials to detect light, enabling night viewing devices. Laser-guided bombs, which are the basic weapon of the F-117 stealth fighter, were developed in a 6.2 program during the Vietnam war. The basic research in materials, and applied research in detectability and in computation, all of which led to the stealth fighter in the first place, were products of 6.1 and 6.2 research. The USAF's turbine engines R&D program begun in the 1960s led to every modern military and civilian jet engine; it was a 6.2 program, supported by 6.1 work in combustion and materials.

That history of seemingly separate programs blending in unexpected ways to produce immensely practical results again raises concerns about the decline of the DOD FS&T budget generally, and about the larger cuts in the 6.2 and 6.3 programs specifically. Thus, in the President's FY1998 request, 6.1 funds are increased, while 6.2 and 6.3 support is reduced, resulting in an overall reduction. Put another way, I am not comforted by the increase for 6.1 funds while 6.2 and 6.3 funds are cut.

- **Dependence on industry or even on other agencies to rectify cuts in support for the DOD science and technology base is wishful thinking that reflects mistaken assumptions about the role of industry in innovation and distorts the missions of civilian agencies.**

The distinguishing and unique role of federal investments in innovation is to provide sustained support for fundamental science and technology. Whether it is the global positioning system or rocket technology or long-range detection of acoustic signals from submarines or the many components of contemporary information technology, the role of federal investments has been to provide long-term and stable support for necessary fundamental work. That is not the role of industry, and I think every corporate R&D executive will tell you that. Product cycles in the computer industry are now about 18 months, so that company investments must be justified by payoffs within that cycle. That is understandable for a private company, but that criterion 20 years ago would have precluded

developing GPS or Silicon Valley, and the US dominance in those fields. It is the “patient capital” of sound federal investments in support of the DOD mission that made these possible.

The numbers do not support the hope that industry will make up for cuts in the DOD science and technology base. Quite the contrary, the 1996 *Science Indicators* report of the National Science Board⁴ points out (p. 4-10) that “between 1991 and 1995, the amount of funds spent by industry to perform basic research declined at an average annual, constant-dollar rate of 4.6 percent.” The same report points out that many companies have dismantled their central research facilities, have shifted their emphasis to short-term applied research, and that this research is increasingly placed within “individual business units in a concerted effort to speed commercialization of new technology.” Nothing wrong with that, but again it does not provide the long-term support needed to both create new knowledge and translate it into military application.

I am equally doubtful about other agencies making up for declines in the DOD science and technology budget. First, these agencies are having their own budget problems, as shown by the analyses of the federal science and technology budgets I cited earlier. And funding is most vulnerable in those areas that most depend on DOD, in contrast to the relative sparing of health-related research. NIH and even NSF simply cannot be expected to compensate for cuts in DOD’s science and technology base. Second, support of the national security mission is not the role of these other agencies, and so the notion that while already under heavy pressure they will reshape their programs to support DOD needs is simply not credible.

- **Finally, the enormous achievements of American research, including DOD’s, depend on supporting the best people and institutions. That policy, which has rewarded the country so richly, must continue if we are to ensure that science and technology are marshaled in defense of the United States.**

⁴ National Science Board, *Science & Engineering Indicators 1996* Washington DC: US Government Printing Office, 1996. (NSB 96-21), p. 4-10.

I'm an admirer both of the sustained quality of DOD investments in science and technology and the varied means that DOD uses to ensure that quality. DOD sometimes uses classical "peer review," in having external experts review a proposal. That is the system used by agencies such as the National Science Foundation and the National Institutes of Health. It is an excellent system. DOD also uses another system, one that I call the "scientific officer" system and that is used by DOD agencies such as ONR and DARPA. Here, technically skilled staff choose a promising area for targeted funding, and also pick the people to be funded. That approach has had some impressive successes, which have, I believe, easily offset the occasional failures, which are inevitable anytime "venture capital" is risked.

Both these approaches, and there are others, are excellent, and result in the outstanding contributions of DOD investments in science and technology to national security and the national economy.

The Department of Defense also uses different institutions to perform the work—industry, the universities, FFRDCs, and, of course, its own laboratories. Here I think the record is somewhat uneven. Where the canons of quality review and open competition have been followed, the work has over time been of high quality. Where quality assurance and open competition for the best ideas and people have been lacking, the work has sometimes been disappointing. I am pleased to see that the Department is moving to strengthen the quality review of the work done within its laboratories, and I strongly encourage it to continue in that direction. I note, for example, the recent request to the National Research Council that it evaluate the scientific and technical quality of the work of the Army Research Laboratory. In the same vein, the Department of Defense also seeks external evaluation of particular programs, such as its stockpiled chemical demilitarization program.

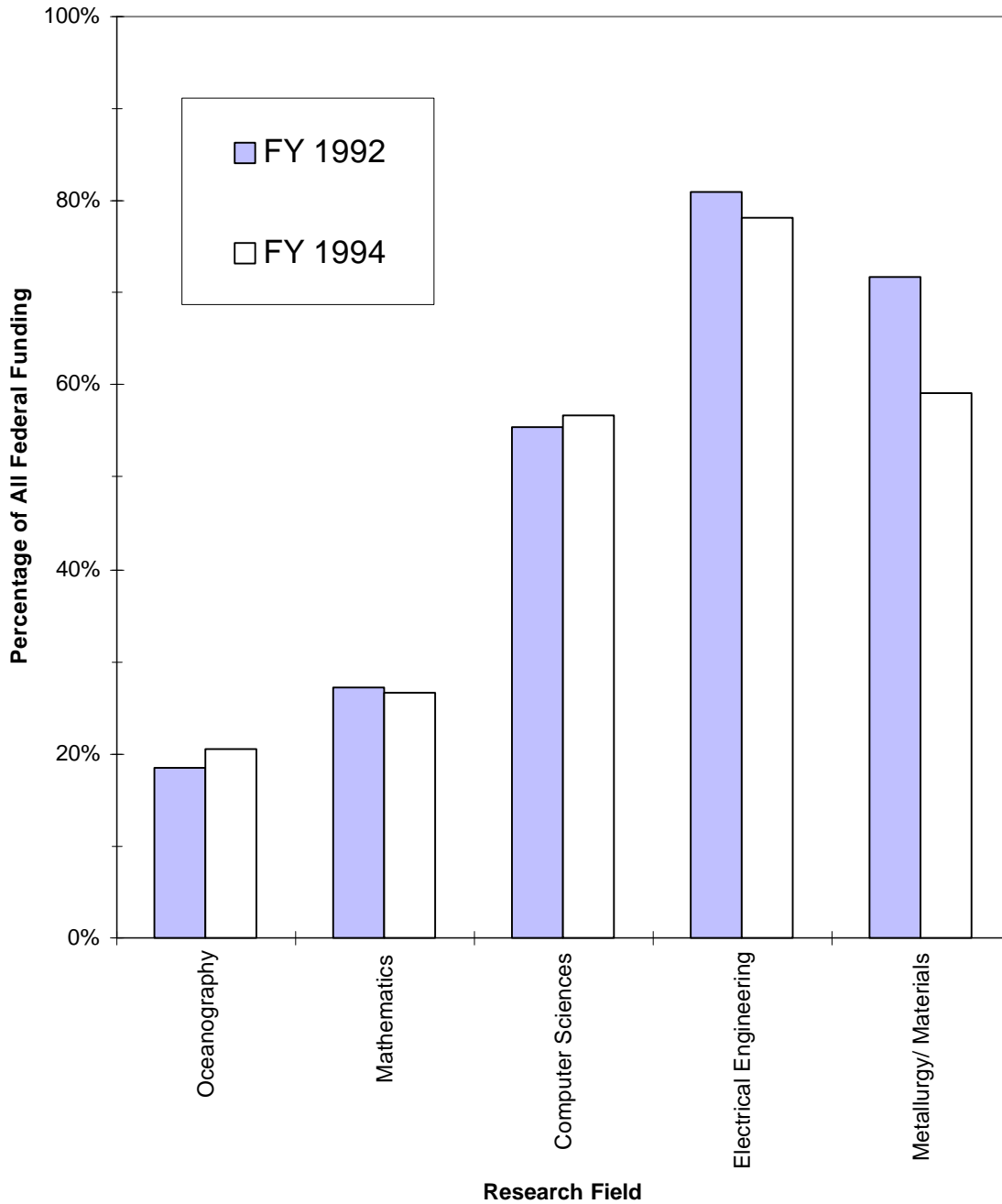
Again, I offer to you the counsel of the report on *Allocating Federal Funds for Science and Technology*, which noted that:

The committee believes that the principle of merit review—which emphasizes competition among ideas, diversity of funders and performers of S&T, and organizational flexibility—has been largely responsible for the remarkable quality, productivity, and originality of American science and technology in the past. Competitive merit review should be the method of choice for making future decisions about FS&T funding.

Mr. Chairman and members of this Subcommittee, that concludes my testimony. Thank you for the opportunity to appear before you today. I would, of course, be happy to respond to any questions.

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DOD Share of Federal Research Funding by Field, FY 1992 and FY 1994 (percentage)



Federally Funded Graduate Students Supported by DOD, Selected Fields, Fall 1995 (Percentage)

