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Physics and Government*

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In defining the powers and duties of the three branches of government, the U.S. Constitution never explicitly referred to Science, except in the patent clause. But many technical responsibilities are implied in references to weights and measures, the census, and the like. Thomas Jefferson, John Adams, and in particular Benjamin Franklin, were highly literate in science, but it was their disciple, President John Quincy Adams who promoted as a matter of policy a direct role of the government in science -- in particular with respect to astronomy, land surveys and navigation -- all physical sciences. Some agencies of government -- notably the National Bureau of Standards and the Department of Agriculture were founded in the early days of the Republic with scientific and technical missions. Since then the involvement of the government with science has waxed and waned but the major expansion of the interaction between physics and government occurred after World War II when physicists demonstrated the power of their craft during mobilization of science in support of the war effort.

In discussing the interaction of physics with government we should distinguish "science in government" -- scientific input into policy making -- from "government in science," which is the support and management of that part of the overall scientific endeavor for which the government has responsibility. Let me turn first to the subject of *physics in government*. An overwhelming fraction of governmental decisions today have scientific and technical components; decisions ignoring these components are wasteful at best and can imperil the nation. For this reason governmental bodies at all levels solicit scientific advice -- or at least give lip service to the need for such advice. When such advice was deliberately avoided, as President Reagan did before announcing his Strategic Defense Initiative in March 1983, the technically unattainable goal "to make nuclear weapons impotent and obsolete" was proclaimed.

Most societies generally vest the power to govern in non-scientists. Therefore the impact of scientific advice ultimately depends on the judgment of the advisee, rather than the necessity and merit of the advice rendered. Decision-makers easily over or under estimate the value of advice given by physicists or other scientists. During Congressional testimony, I have been confronted by over-estimates of the value of physics when a member of a Congressional committee insists, "Just give me the answer, Doctor." Conversely, an advisee may reject technical testimony by stating, "Do not give me all this technical stuff; what we need is practical advice." Such extreme attitudes are not unusual but happily the medium course -- that is, leaving decisions to non-specialists after giving them informed input -- is more the norm in governmental process. Political figures very rarely have subscribed to what has been described as the "flight from reason," the recent doctrine of denouncing science, including physics, as being on a par with beliefs in mysticism and religion and being simply a construct of the mind, unrelated to objective nature.

Most physics advice to government relates to decision-making in the face of projected or conjectured developments. Advice is firmly rooted in established scientific facts but must extrapolate beyond those facts based on the experience and judgment of the advisor and provide an analysis of future values and risks. It is in communicating risk -- that is, the product of probability of a future event times the consequences of the event -- where the physicist may face the greatest difficulty. Government decision-makers prefer to deal in absolutes. Is the decision certain to provide a beneficial product or solve a special problem? In the face of uncertainty, there is a tendency in the political process, when faced with highly dubious, but widely disseminated, physical evidence to play it safe by misinterpreting the need for "balance" by giving equal weight to unsupported conjectures and to solid evidence. The recent excessive attention paid to the alleged health effects of electromagnetic fields of power lines is a case in point.

There is another serious problem of physics advice to government reflected in the questions: Who owns the advice? Who owns the advisor? If advice from outside is sought by an agency of government, then presumably the advisor is also free to state his views to any other audience he chooses, be it public or private. However, if groups of advisors are impaneled as ongoing committees at a high level, then their advice becomes part of the functioning of government and the question of having these advisors speak publicly on issues before them can be problematic. This tension is best illustrated by events surrounding the rise and fall of the President's Science Advisory Committee (PSAC), whose membership initially was dominated by a majority of physicists.

After the Soviets successfully launched Sputnik in 1957, the alarm caused by that event persuaded President Eisenhower to elevate an obscure group of advisors (which had previously been buried in the Executive Office Building adjacent to the White House under the aegis of the Office of Emergency Management) to the exalted level of the Office of the President. Replacing I. I. Rabi, who had served part time, James R. Killian, Jr. became chairman of the new PSAC and also served as full-time Science Advisor to the President. PSAC subsequently became an important part of the decision-making process within the White House. Advice was rendered on a private, privileged basis. Presidents could, and of course did, avail themselves of many other inputs -- whether technical, economic or political -- to their decisions. Thus, the world generally did not know whether a Presidential Decision was carried out following advice of PSAC or by ignoring or rejecting it.

As long as PSAC considered itself to be part of the President's "family," or followed the rules governing full-time Presidential appointees, this privacy remained unbroken. Members of PSAC were prominent scientists, serving part-time, and continued to pursue their regular professional or academic roles. Being prominent individuals, they were occasionally asked to give their opinions elsewhere. For example, when President Nixon announced his decision to go forward with government support for development of a commercial supersonic transport plane (SST), he signaled that he received sound scientific advice but failed to state that the advice rendered by PSAC opposed pursuit of this adventure. When a member of PSAC subsequently testified on the SST before Congress, he explained that subsidizing the construction of an SST was inadvisable for economical and other reasons. PSAC members also publicly opposed Anti-Ballistic Missile (ABM) defense systems, contravening presidential policy. The independence of the advisors and lack of "political reliability" was the primary reason for the decreasing influence of PSAC and its eventual abolishment by President Nixon in early 1973.

Advice by physicists and other scientists to the Legislative branch of government faces similar problems. PSAC and its chairman were not obliged to testify before Congress. To remove this barrier, President Kennedy established in 1962 the Office of Science and Technology (OST) in the White House. The office was renamed OSTP in 1976. Here P stands for policy, signaling that the White House should establish policy, not line manage the science and technology operations of each Department. Under his "hat" of Director of OSTP, the chairman of PSAC and Science Advisor to the President is obliged to provide Congressional testimony on science policy.

In addition Congress can of course ask independent physicists to testify at hearings. Moreover the Congress maintains a Congressional Research Service which prepares documentation and analyses on various subjects using professional talent from a variety of disciplines. And because of the difficulty of using scientific witnesses who at the same time serve as advisors to the Executive branch, Congress created the Office of Technology Assessment (OTA) to provide technical and scientific analyses directly to the Congress. That organization employed an able professional staff, competent in various sciences and technological fields, who performed studies for Congress under the supervision of part-time boards of scientists convened on an ad hoc basis. OTA was governed by a bipartisan body selected by Congress. The reports generated by OTA were public, free from bias and frequently had major impact. But these reports also clashed occasionally with views espoused by Congressional leaders; as a result OTA was abolished by the new Congress in 1995, ostensibly as an economy move.

The role of PSAC was revived in weaker forms by President Nixon's successors, first as a White House Science Council and then as a President's Council of Advisors on Science and Technology (PCAST). PCAST and OSTP perform valuable functions, but currently PCAST meets only infrequently, and neither body has had much recent direct interaction with the President. This limited role is, of course, symptomatic of the fact that the impact of physics and other sciences at the Presidential level depends critically on the "chemistry" of the Science Advisor with the President. That chemistry depends on both personal relationships as well as the interest of the President in understanding scientific and technical issues. Presidents Eisenhower and Kennedy had frequent and cordial interactions with their Science Advisors George Kistiakowsky and Jerome Wiesner; other Presidents had substantially less.

One of the principal efforts made by PSAC had been to upgrade the role of science within the structure of all governmental departments so that competence in physics generally exists at a level just below the Departmental Secretary. Examples include the Director of Energy Research in the Energy Department and the Director of Defense Research and Engineering in Defense. In addition, most government Departments have their own external science advisory structure, such as the Defense Science Board in the Department of Defense, the Secretary of Energy's Advisory Board in the Department of Energy, and so forth. The National Science Board, containing several active physicists, establishes science policy for the National Science Foundation. Moreover, advisory committees -- some standing, some ad hoc -- are distributed at lower levels throughout the government.

While such groups fulfill necessary functions they cannot substitute for scientific input at the Presidential level. Counsel rendered by the chief of a governmental department is necessarily filtered through the policy objectives of that department. Most important, Presidential policy directives with science content are likely to be ineffective without follow-up by White House staff of scientific competence.

It is difficult to assemble advisors in physics who do not have some level of conflict-of-interest between the advice they are to render and their own interests and work. While there is a clear need for an advisor to be an "independent expert," it is difficult to find people, however capable, who are both sufficiently expert *and* sufficiently independent. For the above reasons, physics input to the government is also provided through non-governmental institutions, among them the National Academy of Sciences, chartered by President Lincoln in 1863 with the explicit mission of rendering advice to the government. It has a long tradition in doing so. Since members of the Academy are elected for their contributions to science rather than for their connection with government, it is somewhat easier for the Academy to put together truly independent panels of scientists. Indeed the Academy generally through its research arm, the National Research Council, has produced numerous studies in fields where science and policy interact, many of which are of interest to physicists. Recent examples among many include studies on future energy demand and alternate sources of supply, nuclear weapons policy, and the prospects for fusion energy. Additional non-governmental organizations, including the American Physical Society, have conducted studies and rendered advice to the government in selected subjects. Its Directed Energy Weapons study was an outstanding example of an independent influential assessment of a contentious technical program. The JASON group, founded by physicists, is an effective group of academic scientists which serves the Government through its studies while at the same time replenishing the pool of young academic physicists knowledgeable in security matters.

Now let me turn to *government in physics* -- the support of physics by government. There is universal agreement that basic research must largely be supported by the federal government. Private industry can hardly be expected to recapture the benefits of basic research within a time span that provides for a reasonable rate of return, and many basic research results do not lead to applications at all. The time span between initial results of basic research and practical applications has become so large that only the federal government can make the required investment.

Interestingly, support by industry of basic research peaked when certain industries, in particular the communications industry, were near-monopolies. Bell Telephone Laboratories, IBM, and to a lesser extent General Electric and Westinghouse laboratories, were major promoters of basic research, some of it resulting in Nobel prizes. Now with increasing pressure for short-term competitiveness, basic research in physics has become the almost sole ward of government.

The government, in particular its Legislative branch, continues to encourage physicists to do a better job in justifying support of basic research by the federal government. The latest statements by the American Physical Society on that subject, given before a Senate committee, summarize the common ingredients which underpin federal support. Federal investment in research clearly increases economic growth. While it is extremely difficult to provide an analytical audit trail between economic growth and federal investment in physics, most economic analyses show that since the end of World War II new technology has fueled more than half of all U.S. economic growth. Moreover, science deserves much of the credit for increased productivity, measured by work output per years worked, driven by technological innovation. In turn, federal investment in research is the basis of a large fraction of such technological innovation. Almost 75 percent of the citations listed in the U.S. Industrial Patent Applications reference publicly supported research. Science in general -- and physics in particular -- has been the underpinning of technical progress in most fields. The annual percentage return on federal investment in research is much higher -- the estimates range from 20-60% -- than almost all other forms of investment. Such arguments emphasize practical results, not intrinsic interest.

Depending on shifting political winds, support of science by the federal government has fluctuated. Conservative administrations have generally maintained that private industry should be responsible for supporting research targeted at specific applications, with the exception of military research and development. As a result, government support for applied physics has varied greatly among Administrations, depending on their political bent, while the need to invest in basic research has been generally endorsed by all.

Even with these persuasive arguments, the question remains: *How much* and *for what* shall governmental support be provided? There exists no generally accepted yardstick which answers these questions and therefore it is unavoidable that ultimately decisions are left to the political process.

Much ink has been spilled defining "criteria for scientific choice," to use a phrase coined by Alvin Weinberg in the 1960's. Such criteria rank different subfields of physics in terms of their intrinsic interest, economic promise, value to national security, and relevance to other fields of science. That latter factor is greatly subject to change. High energy physics was always considered to be of high intrinsic interest, but its intimate relevance to understanding the cosmos has emerged only recently. Nuclear physics before the war was thought to be only of intellectual relevance, but its dramatic applications emerged after the discovery of nuclear fission. And so it goes. Lately we have even seen a debate expressing doubts on the linkage between microscopic and macroscopic physics, where again that debate confuses the basic connectedness with the calculational difficulty of deducing the large from the small.

In view of the intractability of the ground rules for support, many attempts have been made to rationalize the process. Peer review is used extensively to evaluate the scientific soundness and expectation for success of proposals for support by the federal government, but such reviews cannot answer questions of the relative levels of support for different fields of science, let alone the total outlay for science. One of the failures of PSAC in its heyday had to do with the establishment of scientific priorities. While PSAC was highly successful in providing policy input at the highest federal level, it did little to sort out conflicting claims on the federal purse. In fact, PSAC (and other high-level sources of scientific advice) had to lean over backwards to demonstrate that its mission was to provide service to the federal government and that it was not a built-in "science lobby."

At the suggestion of PSAC, the National Academy of Sciences (NAS) began preparing multiyear surveys of the various subfields of science, including ground-based astronomy, high energy physics and plasma physics. In particular a series of "Physics Surveys" produced by NAS committees chaired by prominent physicists (Pake, Bromley and Brinckman) were of great value in identifying opportunities for creative research to governmental officers. Such panels can and do prepare excellent reports on the basic soundness of future undertakings in the respective subfields, and they successfully identify a "maximum responsible program" -- that is, a program that could be carried out productively by the talent available in the field. Thus, as a practical matter, the Academy's survey reports recommend feasible programs that are then cut by federal program officers in accordance with the financial constraints imposed by the Office of Management and Budget and eventually the Congress. Additionally, many government agencies maintain panels advising their program officers on the technical merit of competing plans. These panels such as the High Energy Physics Advisory Panel (HEPAP) and analogous panels on Nuclear Physics, Basic Energy Sciences, etc. provide valuable input to decisions on the distribution of resources within each subfield but can do little to affect total funding levels. This multifaceted system of determining support of physics by the federal government has evident flaws, but designing a better methodology has thus far proven elusive. In fact, the U.S. system has largely been emulated by foreign governments, such as those of the UK. and Germany.

Lately, in particular when dealing with "big science" projects, statements abound that the United States can no longer "afford" to pursue such projects nationally and that therefore international collaboration is essential. There is indeed broad human value in international collaboration in support of physics. Results in physics are universal and not owned by any one nation. There is such a thing as an international community of physicists sharing responsibility for the pursuit of their science. International collaboration in physics improves understanding among the world's nations and ethnic groups and creates a forum in which difficult international problems can be aired.

But the purely economic arguments for international collaboration are relatively weak. One must recognize that, notwithstanding the social benefits of international collaboration, the technical efficiency of carrying out a program internationally tends to be lower than that of national endeavors. The U.S. gross national product is over one-quarter of that of the entire world, notwithstanding that its population is only about four percent of the total. Thus the statement that the United States "cannot afford" pursuit of basic science above a certain level when that support is only a small fraction of one percent of the GNP is hard to justify logically. The level of support the government sets for physics is a matter of policy and politics, not affordability.

The ambivalence in U.S. policy about international collaboration can be illustrated by the history of the ill-fated Superconducting Super Collider (SSC). When President Reagan announced his support for the SSC he touted it as an example of "American competitiveness." Yet one of the criticisms strongly voiced in Congress before cancellation of the SSC was that sufficient international funds, in particular from Japan, were not forthcoming.

Physics research supported by the government occurs in a variety of modalities. Some is carried out by universities, some by industry, some by government-owned laboratories, and some by national laboratories operated either by profit-making or non-profit entities, including universities.

The national laboratories were created during World War II in part to avoid the bureaucratic restrictions, including Civil Service rules, that apply to government-owned laboratories and also in response to the limited research productivity of industrial laboratories before the war. During that war, physics at most universities was mobilized and supported through a government organization, the National Defense Research Council, which evolved into the Office of Scientific Research and Development under the leadership of Vannevar Bush. The obvious leap in research productivity due to this arrangement led to the dramatic increase in government support of science. Some wartime laboratories, created to discharge specific responsibilities in fields like reactor research and development, naval reactors, and nuclear weapons continued as national laboratories into peace time. In addition, new national laboratories were created for "big physics," supporting work largely of interest to universities but where no single university was able to carry out the work solely under its own auspices. The essence of national laboratories is that their facilities are available nationwide without preference given to the managing entity. While industrial contractors are selected competitively among qualified performers and directed by the government, the contractual relationships governing laboratories were generally designed in a spirit of *partnership* with the government. When issues of policy relating to nuclear weapons or to reactor design were discussed within the Executive branch of the government or before Congressional committees, for example, input was generally provided by representatives of the laboratories.

This partnership has now begun to erode. Some of the national laboratories have lost their primary mission and become multipurpose laboratories dedicated to various areas of applied research, with their main assets being their scientific talent and capable management. In such a role they are no longer unique and compete to some extent with one another and with industrial laboratories. However, several national laboratories remain "single-purpose" laboratories, in particular those operating in high energy physics and plasma physics. The nuclear weapons laboratories have been criticized for bypassing established policy by their direct access to the highest levels of government. Congressional pressures in the name of accountability have urged a more conventional contractor relationship. Such pressures can however result in government micromanagment of the laboratory work. An extreme example is the SSC. Here the government created an oversight organization consisting of more than one hundred civil servants, second guessing technical decisions at all levels of laboratory activities.

This evolution is symptomatic of a basic problem in the conduct of big or small physics research. Creativity in physics thrives best under a system of decentralized initiative, originating from capable and inventive performers, with management facilitating the work rather than directing it. Yet some "big physics" projects demand centralized and responsible management to generate large facilities, such as high energy accelerators and colliders, fusion devices, large detectors, and the like on a proposed schedule and within the allocated budget. Thus, a successful partnership between government and laboratories demands a delicate balance among decentralized initiative, responsible management, and economic accountability.

Let me close by identifying one contentious issue common to both physics in government and government in physics; this is the relation of physics to national and international security. Indeed physical scientists -- remember Archimedes providing "directed energy weapons" for the Defense of Syracuse in 540 BC! -- have been invaluable to governments in creating tools of war, and governments have supported them with that recognition in the background. But physicists have also been in the vanguard of groups urging governments to agree on meaningful restrictions on their armaments. When the agenda of PSAC became so overloaded with arms control items, it successfully promoted the creation of the Arms Control and Disarmament Agency, an organization now incorporated into the State Department, dedicated to increased national security and lesser burdens and dangers of armaments. Through new technical means to gather information and to facilitate communication worldwide, physicists have simultaneously increased national security while making this a more open world.

As we relate the experience of the twentieth to the twenty-first century, we must expect some shift of government involvement triggered by the rapid emergence of biotechnology and also by the understandable focus, in particular of the Congress, on health. While physical tools have been of overwhelming importance to the military in the past, the threat of biological warfare is becoming progressively real; moreover, diseases in war have killed more people than those who perished in combat. Thus any projection of physics and government into the next century has to be tempered by the likelihood that the importance of that connection relative to involvement of government with the biological sciences will shrink. But during the century reviewed here *physics and government* has been a unique and productive alliance. Indeed there remain problems and unresolved issues, but most of these are inherent to any interaction between the general public and what is fundamentally an intellectual endeavor.