NAS Report Finds Physics Strong, But Serious Strains Developing

Physicists are duly celebrated for the part they played in developing the novel technology of World War II—radar, the proximity fuse, the bomb. They have also created techniques and instruments which afterward were applied with revolutionary effect in chemistry, in biology, and in industry. In the process, physics, or at least some types of physics, became the prototype of Big Science, a label that implies generous and rapidly rising federal support of research and education in a particular discipline, usually entailing support of progressively more expensive research facilities.

Both the achievements and the special role of physics in the last generation provide the context for the latest in a series of major National Academy of Sciences reports on the accomplishments, past and potential, and the needs of particular fields of science. Two years in preparation, the new report *Physics: Survey and Outlook** is what the subtitle suggests, "A Report on the Present State of Physics and its Requirements for Future Growth," as seen by a picked group of the discipline's insiders.

The surveys are produced under the aegis of the Academy's Committee on Science and Public Policy (COSPUP). The physics report is signed, for COSPUP, by George B. Kistiakowsky of Harvard, who was chairman of the committee during preparation of the report but has been succeeded by Harvey Brooks of Harvard. Kistiakowsky, who served as President Eisenhower's science adviser, was one of those who felt that the growth of federal support of science could not proceed indefinitely at the rate reached in the late 1950's and early 1960's. The academy surveys were conceived as an effort by scientists themselves to provide critical appraisals of important fields of research with a view to setting reasonable goals for federal support of research and education—goals which would be helpful in the event of a serious tightening of federal funds.

In the last 2 years a leveling off of funds in several areas of research has in fact occurred, raising problems of allocation earlier perhaps than Kistiakowsky and others anticipated. The war in Vietnam is now the chief depressant on the science budget, and Washington planners acknowledge that this pressure is unlikely to grow any lighter in the immediate future.

The academy reports were conceived some 4 years ago, and the work on the physics survey was begun seriously about 2 years ago. Relevant statistics are at best imperfect, and the latest available to the committee were for 1963. Using that year as a base, the committee sought to project requirements for both funds and manpower to 1969.

In the report, the committee takes note of the leveling off in the rate of growth of funds for science in the last 2 years, but chooses to hew to its original goals, noting simply that average growth rates will have to be increased in coming years because of the shortfalls in the past 2 years.

The survey committee chaired by George E. Pake, provost, Washington University,† recommends that by 1969 support of physics (exclusive of geophysics and biophysics) by federal agencies be increased by a factor of about 2.5 over the 1963 level of some $500 million for physics and astronomy. (This sum represents about a third of the roughly $1.5 billion in annual federal support of basic research.) The average rate of increase in physics support over the 6 years was set at 16 percent. Because the rate of increase in funds for physics dropped off in 1964 and 1965, however, spending would have to rise 21 percent annually to achieve the level recommended by 1969. A return to an annual growth rate of 16 percent is envisioned after 1969.

The recommendations for support are at what the committee calls "a reasonable minimum—certainly not a lavish level." The rate of growth in support of physics and astronomy between 1959 and 1963 is estimated in the report at a booming 41 percent a year. This, however, includes expenditures by the National Aeronautics and Space Administration, which in those years was experiencing explosive growth. Between 1959 and 1963, annual expenditures by all agencies except NASA rose from slightly over $100 million to well over $200 million, while expenditures for NASA alone, which was established in 1959, reached about $200 million by 1963. The 1959–1963 growth rate in physics support was, therefore, affected drastically by the advent of NASA.

Physics, is, of course, proliferating into an increasing number of subfields, and one of the useful services performed by the report is identification of these subfields and separate assessment of major ones. A summary, from the report, of "state of the art" assessments by six subfield panels is given on page 1364. A seventh panel considered aspects of theoretical physics, classical physics, and applied physics which were not specifically treated as part of the surveys of the other subfields. A second volume, containing reports of the subpanels, is to be published in the reasonably near future, and is regarded by committee members as an important complement to the report itself.

Some of the special problems faced by the committee and panels were suggested by Kistiakowsky in a letter at the beginning of the report. Kistiakowsky wrote, "The task of the Physics Survey Committee was complicated by the organizational inhomogeneity of the field, some of which is 'little science' but which also includes much of 'big science'—nuclear particle accelerators, large devices for plasma research, etc. As a result the report suffers occasionally from compromises that are unavoidable when some members of a

* Copies available from the printing and publishing office of the National Academy of Sciences, 2100 Constitution Avenue, Washington, D.C. 20418. $5.

† Other members of the committee were L. H. Aller, University of California, Los Angeles; the late Samuel K. Allison, University of Chicago; Harvey Brooks, Harvard; Geoffrey F. Chew, University of California, Berkeley; Henry A. Fairbank, Duke; E. L. Goldwasser, University of Illinois; Vernon W. Hughes, Yale; Clyde A. Hutchison, Jr., University of Chicago; R. Bruce Lindsay, Brown; Edward P. Ney, University of Minnesota; W. K. H. Panofsky, Stanford; David Pines, University of Illinois; Emanuel R. Piore, International Business Machines Corporation; Richard F. Post, Lawrence Radiation Laboratory; Roman Smoluchowski, Princeton; C. H. Townes, M.I.T.: and Eugene P. Wigner, Princeton. Lewis Slack, of the National Academy of Sciences–National Research Council staff, was secretary to the committee.

From New NAS Report: An Assessment of Relative Strength of U.S. Physics

Astrophysics, Cosmic Radiation, Gravitation, Space Physics. Our strength in observational astrophysics with optical telescopes has been long established with the 200-inch telescope on Mount Palomar, but we have many more bright astrophysicists and astronomers than have access to the two U.S. telescopes most suited for frontier research. Our relative strength will be altered with the implementation of plans for construction of several large telescopes in the Soviet Union. Any nation can, by placing a large telescope in the Southern Hemisphere, assume leadership in the observational astronomy of stellar evolution and cosmology, because the Magellanic Clouds are the nearest of all external galaxies. The United States has taken the initiative in the expensive but highly promising field of space-based optical and x-ray astronomy.

In radioastronomy, the United States now has an impressive group of major radio telescopes, but the U.S. position is not pre-eminent. Even the new instruments nearing completion at the California Institute of Technology and the National Radio Astronomy Observatory are inferior to existing instruments in Australia and the Soviet Union and to new large cross-type arrays nearing completion near Sydney and Moscow. The U.S. position in space physics and cosmic radiation is good, with some question whether present conditions permit further strengthening of that position. Research on gravitation is at present not a large sector of research, but the U.S. effort is of very high quality and is being increasingly recognized.

Atomic and Molecular Physics. In the broad field of atomic and molecular physics and quantum electronics, the U.S. position is generally strong and leads the world in several of the major subdivisions of the field. United States physicists initiated the study of radio-frequency and microwave spectroscopy of atoms and molecules, and continue to lead in this field. Quantum electronics had its primary origin in the United States as an outgrowth of microwave spectroscopy, and a large fraction of the world's activity is in this country. Although the resurgence of interest in atomic collisions since World War II was led by British scientists, the U.S. position in this large field is now very strong. Our theoretical work in the entire field of atomic and molecular physics is broadly based and of very high quality. The field of optical spectroscopy is relatively weak in this country. Although the United States now enjoys a position of strength in atomic and molecular physics, the U.S. effort is rather modest and it will be essential to provide for a substantial growth rate if we are to maintain our present position in the field and provide trained atomic physicists needed in other branches of pure and applied physics. The U.S. activity in the more applied aspects of atomic and molecular physics, which includes much of quantum electronics, is extensive, and the outlook for its adequate growth appears good.

Elementary-Particle Physics. The present position of the United States in elementary-particle physics is very strong, but the outstanding Western European laboratory, the European Center for Nuclear Research, is certainly competitive. Furthermore, present Russian competence, together with their commitment and progress in constructing the world's largest accelerator, serves notice that there will be a continuing high level of activity in this field in the Soviet Union. The United States now stands at a point of critical decision as to whether it will undertake the next logical steps in this area of research rapidly enough to prevent the dissipation of its existing strength.

Nuclear Physics. The United States has widespread and good experimental facilities in this field. However, exploitation of these facilities has been adversely affected by the recently imposed limitation—indeed, reduction—of operating funds. Moreover, too few young theoretical physicists are entering the field in this country, in contrast to the strong theoretical groups abroad.

It has been recognized that accelerators of intermediate energy (between 100 and 1000 Mev) will also be important tools in nuclear physics. Both in this country and abroad, plans are under discussion to upgrade existing accelerators in this range (now primarily used for elementary-particle physics) or to construct a new high-intensity facility. Our relative position in this emerging field will depend on the implementation of these plans.

Plasma Physics. Pressure to achieve applied goals—utilization of nuclear fusion, together with space and military research—has resulted in an explosive increase in U.S. plasma research activity since the 1950's. A high price was paid for this rapid growth. Relative to the total effort, too little attention was directed toward achieving basic understanding, and our universities have too little concern in the field. Though awareness of this deficiency is growing, and research of increasingly high quality is being done, nevertheless at the present time some parts of the U.S. plasma research effort do not compare advantageously with the effort elsewhere. In particular, the United States is clearly behind in the quality of education for advanced plasma research. Since plasma research bears an obvious and intimate relationship to coming important scientific and technological developments, weakness in this field should be a matter of national concern, and steps should be taken to establish more quality plasma-physics graduate programs in university physics departments.

Solid State and Condensed-Matter Physics. The United States has unique strength in this field, as exemplified by the fundamental advances in semiconductors and superconductivity made primarily in this country. This strength is in part a direct result of a close dependence of American industrial and defense technology on basic solid-state physics. Faltering federal support and the limitation of industrial support to a few large laboratories make the present situation precarious. In particular, industry based on the use of structural materials has not given enough backing to this area. Continuing broad federal and industrial support is essential for maintaining U.S. excellence in basic solid-state physics.

group believe in the overriding importance of preserving the opportunities for individual creativeness in research and for training of graduate students on their own research problems, while others are committed to group efforts of 'supercritical' size, usually associated with centralized and costly research facilities essential for some frontier types of research."

The problem of "critical size" to which Kistiakowsky alludes is not limited to physics, but it affects physics more profoundly than it affects any other field. In many areas of physics—high-energy physics, astronomy, and, to a lesser extent, nuclear physics—attainment of critical size for effective research depends on a single expensive facility, a "big machine," plus supporting instruments and logistics. Critical size can also entail the assembling of researchers and technicians with a variety of complementary skills, as in the so-called IDL's (interdisciplinary laboratories). The materials research centers established in recent years provide an example.

The report sums up the problem this way. "The requirement of a minimum critical size for effective research in certain areas of physics has a number of important consequences. First, the funding agencies are caught on the horns of a dilemma when budgets are short; if budgets are cut generally, many operations may be threatened with falling below critical size. The alternative is to squeeze out some of the smaller activities not subject to critical size factors. Therefore the requirement for critical size, together with limitations of funding, increases the difference between the 'haves' and 'have nots.' Where critical size is caused by the need for expensive facilities (as in elementary-particle physics), the solution lies in sharing the facilities. Where the critical size arises from the need for cooperation among scientists, the solution is less clear."

It happens that, in fields like high-energy physics and astronomy, facilities which impart critical size to a research endeavor are growing more costly by leaps and bounds. These same fields are also those in which direct public benefits are most difficult to establish.

The attitude of the survey committee is that basic science is the foundation of technological advance and that physics is the most basic of sciences. A dual argument for the federal support of physics is made. Physics should be supported for its own sake, since the United States should "strive for front rank in all constructive aspects of human endeavor." Physics is also worth supporting for the sake of applications both direct and indirect.

Table 1. Panels' projections of support (in millions of dollars) for basic physics for fiscal year 1969 in relation to panel determinations of fiscal year 1963 support.

Field	Fiscal year 1963			Fiscal year 1969		
	Total	Non-federal	Federal	Total	Non-federal	Federal
Astrophysics, solar system physics, and cosmic rays	59	10	49	105	20	85
Atomic and molecular	17	2	15	52	6	46
Elementary particles	125		125	330		330
Intermediate energy physics				55		55
Nuclear physics	69		69	99		99
Plasma	50	7	43	100	15	85
Solid-state and condensed matter	173	78	95	380	171	209
Theoretical physics not covered by other panels	4	0	4	8	0	8
Totals	497	97	400	1,129	212	917
Ratio fiscal years 1969/1963				2.3	2.2	2.3

The contributions of physics to national defense, to microbiology and molecular biology, to research medicine, and to industry—in particular, to nucleonics and communications—can certainly be cited. The only difficulty is that, while the rewards are evident in fields such as solid-state physics (the panel on solid-state physics makes a cogent case), in particle physics, for example, "the diffuseness and unpredictibility of the benefits tend to increase." Investment by industry in research in solid-state physics is perhaps sufficient evidence of relative direct yields (see Table 1).

In the academy report on chemistry (*Science*, 3 December 1965) the Westheimer committee did a remarkable job of searching out facts on the economic significance of research in chemistry. There is, however, no physics industry analogous to the chemical industry, and to a certain extent the rationale of federal support of research, in chemistry on the one hand and in some areas of physics on the other, can be compared to the doctrine of justification by works versus that by faith.

A cost-effectiveness analysis is, however, the last thing the committee would apply to physics. Elementary particle physics now receives the largest total of federal support in both absolute and proportional terms, and, under the recommendation, this support would continue rising from $125 million in 1963 to $330 million in 1969.

The subfield panels' recommendations on the education of physicists (Table 2) represent an attempt to calculate the level of physics manpower adequate for a "mature system" of higher education and the admittedly hard-to-predict requirements of industry and government in 1969. While, at the levels projected, physicists would still be in short supply, the panels estimate that an acceptable number of physicists would be available for teaching and research. A mature system of higher education is one in which teaching and research at college level and above are "inseparable" and in which teaching techniques have been improved.

Table 2. Number of physics Ph.D.'s: 1963 and projections for 1969.

Field	1963 (from panels)			Panels' 1969 projections	
	Total physicists	Total Ph.D. physicists	New Ph.D.'s per year	Total Ph.D. physicists	New Ph.D.'s per year
Astrophysics, solar system physics, cosmic rays	1,180	590	50	670	90
Atomic and molecular physics	1,260	620	118	1,400	270
Elementary particles	1,630	950	110	1,500	200
Nuclear physics	3,200	1,540	154	2,300	230
Plasma physics	800	400	35	800	75
Solid-state and condensed matter	7,080	3,260	226	4,800	340
Total	15,150	7,360	693	11,470	1,205

The committee is concerned because graduate education in physics is taking longer than it used to. This is in part because increasing specialization has made a period of postdoctoral study virtually obligatory before a research physicist begins independent work. Because of changing conditions the committee suggests establishment of a strong intermediate program betwen the bachelor and Ph.D. programs, intended for the student not headed for intensive research.

Another recommendation is that stronger incentives be provided for "more students to pursue studies and careers in applied physics." Implied in this is the suggestion that graduate education is biased in favor of research on the farther frontiers of basic research and against applied physics.

It is true that the proportion of federal funds invested in research in applied physics and university involvement in this work are much smaller than the investment and involvement in, for example, elementary particle physics. One reply to this is that a number of the ablest physicists are engaged in research in the field of elementary particle physics and that many of their students, also of high calibre, move into other specialties, and with great effect. More on this interesting point is apparently included in the panel surveys to be published later.

George E. Pake

When allowance is made for the passage of time, the report's recommendations on particle physics are substantially in accord with those of the so-called Ramsey report, the *Report of the GAC-PSAC Panel on High Energy Accelerator Physics* (*Science*, 31 May 1963).

Times, particularly in respect to budget trends, have changed, however, in the past 3 years. The survey committee nevertheless has stuck to its 1969 projections on the grounds that they represent the effort necessary if the United States is to maintain world leadership in physics and meet the quantitative and qualitative needs of a rapidly expanding system of higher education. The committee is disturbed, however, over the consequences of the flattening curve of support of research in physics. It expresses particular concern for young physicists attempting to get a "foothold" in research. The panelists note that only 7 or 8 percent of the proposals from these young investigators were approved last year.

An awareness of another specific effect of the funds squeeze is reflected in a recommendation in the final pages to the federal agencies: "When severe budget curtailments are forced upon the agencies, as is now occurring, the high visibility of large physics enterprises should not influence the agencies to apply a disproportionately large share of the budget squeeze to small and medium-size research groups."

What is clear in this passage and in others is an acknowledgment that, under prevailing conditions, with organized physics facing a time of scarcity although not of famine in funding, circumstances are defining more sharply than ever before hard choices between big physics and little physics.

—John Walsh

Medicare: Awaiting the Avalanche

While Congress is preparing to take up the relatively modest health proposals outlined by President Johnson in his message to Congress last week, agencies in the executive branch are working on implementation of the major legislative innovations passed last year.

Chief among current activities is the tooling up of the Department of Health, Education, and Welfare for the giant medicare program, which goes into effect 1 July. All citizens over 65 are eligible automatically for the hospital insurance offered under medicare. Enrollment for medical insurance, however, is voluntary, and officials in the Social Security Administration have spent the last several months encouraging the elderly to sign up by the 31 March deadline.

A seemingly slow start was causing anxiety in officialdom a few months ago. By early December only 40 percent of the eligible had enrolled. A national survey undertaken to investigate the reasons "somehow got out of hand," according to one official, and began providing data too detailed to be of value. But some of the survey's insights, coupled with common sense, did help clarify the causes of the poor response: people were concerned and confused about possible duplication of their existing insurance policies, and many were worried about the cost. (Medical insurance involves a $3 monthly payment from the enrollee; the government pays another $3 for each individual.)

An intensified sales campaign and the assistance of insurance carriers who have been writing letters to their policyholders and placing ads recommending enrollment in medicare seem to have played a role in drastically increasing the number of enrollees. Unprecedented efforts have also been made by the government to make sure that all of the country's more than 19 million elderly know about the program and understand why experts agree almost unanimously that it is a bargain. The $36 annual premium will cover 80 percent of the charges for physicians and sur-