# What future for medium-energy physics?

**Will the extent of financial support be determined by the cultural, economic, social and structural value of the discipline? If so, the outlook should be good.**

George A. Kolstad

According to Harvey Brooks, there are four main reasons for the support of scientific research: cultural, economic, social and educational. Needless to say, opinions differ as to the proper measure of Federal responsibility for each of these purposes. Brooks, who is chairman of the US National Academy of Sciences Committee on Science and Public Policy, goes on to describe[1] four models of the research system based on these reasons for support:

- Science as a quasiautonomous, self-structuring activity that ultimately benefits society but must be left to develop according to its own internal dynamics if the social benefits are to be realized most efficiently (model attributed to Michael Polanyi and Derek de Solla Price)
- Science as a social overhead on applied research and development, aimed at specific social objectives and missions (model attributed to Alvin Weinberg)
- Science as a social overhead investment, in which research and education —in the broadest sense of the development of institutional and individual capacity to the maximum potential— are inseparable objectives (unattributed)
- Science as a tertiary industry or consumption good, representing the nonmaterial, nonproduction aspect of the goals and activities of an increasingly affluent society (model attributed to Stephen Toulmin)

These four models correspond only partially to the four purposes for the support of scientific activity mentioned at the outset. I shall discuss medium-energy physics in the context of these purposes and let you draw your own conclusions as to which model you prefer.

Medium-energy physics is defined by the US Atomic Energy Commission to include all nuclear and particle physics carried out with accelerators or other devices whose primary radiation exceeds 50 MeV but does not exceed 1000 MeV per nucleon or electron accelerated. This definition, adopted by the AEC for practical and fiscal reasons, was first proposed by the Bethe Panel in 1964.[2] It is reasonably workable but does include "exceptions that prove the rule."

### Cultural viability

The cultural or intrinsic merit relates *primarily to the scientific opportunities* offered. In the US, government responsibility for the support of the arts and other cultural activities has been accepted only recently, although there is a long tradition of tax exemption for cultural and educational gifts and institutions, which constitutes an indirect form of government subsidy. After World War II, the Federal Government did assume responsibility for the support of basic science, but primarily for reasons of national security rather than culture.

How does medium-energy physics rate in terms of intrinsic merit or cultural value? Because of the existence of new concepts, new experimental or theoretical approaches, or new instrumentation and observational techniques, some fields promise more immediate rewards than others.

Until now, the detailed study of the nucleus has brought about an understanding of the general properties of nuclei, and high-energy physics is unravelling some of the mysteries of nucleon structure. But there has been no adequate means for detailed and systematic study of the local structure of nuclei, or of the arrangement of nucleons inside the nucleus, or of the forces between these nucleons in their free and bound states. Medium-energy physics is bridging that gap.

Particle physics is concerned with the subnuclear particles, such as negative pions, negative kaons, and hyperons, and their various interactions, combinations and excited states. Nuclear-structure physics deals with the arrangement of nucleons inside a real nucleus, that is, the nuclear model. Common to both is the problem of the forces between nucleons and negative pions. These forces are clearly relevant to particle physics, but they must also be the basis for a proper understanding of the structure of complex nuclei.

New facilities, such as the Los Alamos Meson Physics Facility (LAMPF) and the new MIT electron linac, will provide intense beams of protons and electrons and increase energy resolution by at least two orders of magnitude. The increased intensity of the primary beams

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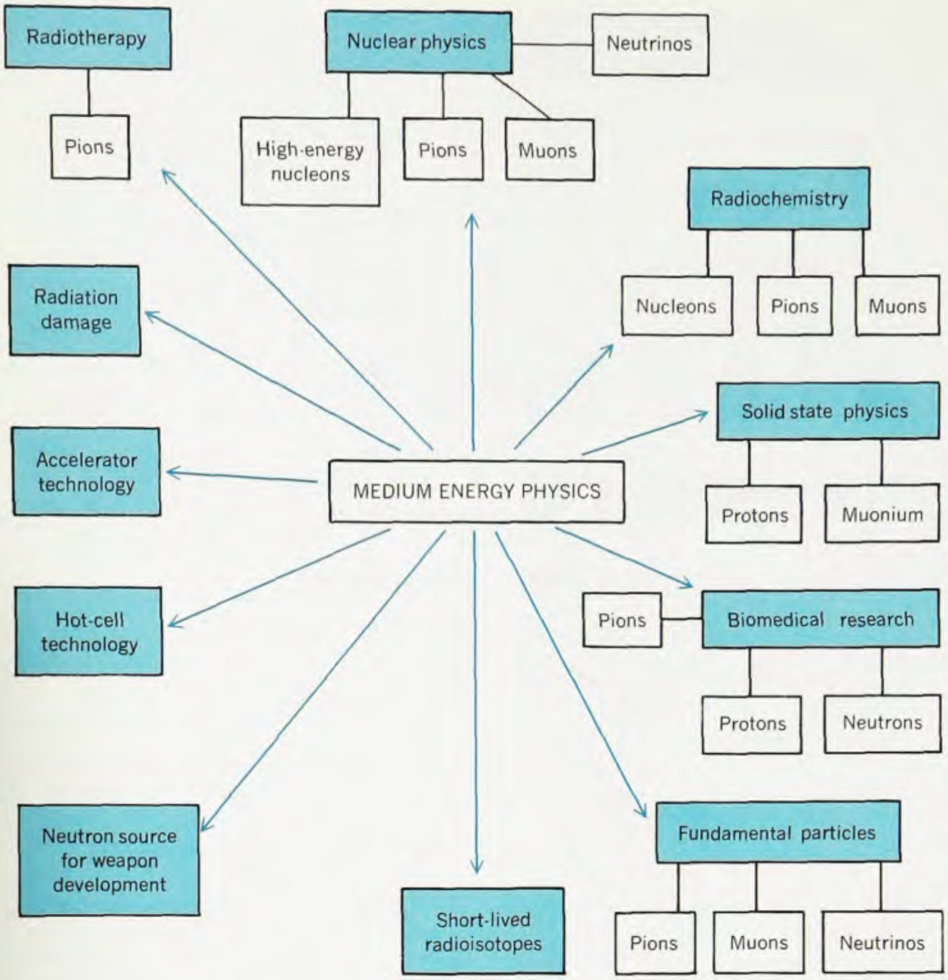



**Impact of medium-energy physics** on other sciences. The interrelations are many, so that the potential effects, particularly when high-intensity sources become available, will be great.
Figure 1

of protons at LAMPF will provide secondary beams of pions and muons sufficiently intense that they can be used for the first time as the primary probes for quantitative studies of nuclear and subnuclear phenomena. History has shown that whenever qualitatively new probes are introduced—probes that make it possible to study nuclear and subnuclear phenomena in new ways—new phenomena and a new understanding emerge. Some of the specific problems of interest are pion–nucleon elastic scattering, pion–pion scattering, nucleon–nucleon forces, meson production, all the various form factors, ejection of clusters from the nucleus, pion charge exchange, pion and muon capture, $\pi$-mesic and $\mu$-mesic atoms, weak interactions and neutrino physics. These examples serve to illustrate the intrinsic richness of this area of science.

### Needed by other sciences

The cultural impact of medium-energy physics, especially where it involves high-intensity sources, is not limited to nuclear and particle physics. Its impact on other areas of science is illustrated by figure 1, which was developed by Louis Rosen of LAMPF.[3] Radiochemistry, solid-state physics, the ability to produce new neutron-deficient nuclides, the biological and medical sciences—all stand to gain substantially from medium-energy physics and its new high-intensity tools.

Clearly the field is ready for exploitation: It addresses itself to truly significant scientific questions, and it has a great potential for discovering new laws of nature or extending the range of validity of presently known laws. Medium-energy physics is drawing to itself substantial numbers of the most able members of the scientific community. For example, attendance at the first formal meeting of LAMPF users, in the spring of 1969, was 223, and by this past fall attendance had grown to 759; much of the increase has been in fields other than nuclear and particle physics. A similar multidisciplinary interest is developing at MIT, at the Princeton Particle Accelerator, at the Berkeley Bevatron–Superhilac and elsewhere.

This broadened interest in the use of particle accelerators may be partly attributable to the current financial crunch and the growing sensitivity of the scientific community to socially related problems such as cancer therapy. But in any event, it is clear that medium-energy physics, and the new tools and techniques it brings with it, rate high in cultural impact or intrinsic merit.

### Economic and social values

It is perhaps reasonable to treat these two aspects of the intrinsic merit of medium-energy physics together. Except for agriculture, serious US Government concern with the relationship between publicly supported science and technology on the one hand and the structure and growth of the economy on the other dates only from the early 1960's. (The National Bureau of Standards grew up to serve the needs of industry but was never part of a comprehensive policy for the development of the industrial sector.) Federal support of basic science in the universities developed as a byproduct of research for other national purposes: first in defense, later in atomic energy, then space and most recently in health. Although the debate about the extent and nature of the Federal responsibility for basic science continues, we are now seeing a gradual recognition that research whose benefits are not uniquely applicable to any private interest may be more appropriately funded from the tax sources. Knowledge that can be used for many purposes and by many different private groups is best developed by sharing the cost among all the potential beneficiaries, and Government support of basic research was at least partly justified in the 1960's because of its long-term economic benefits.

Recently, however, the goal of economic growth without regard to quality or direction has been severely attacked. Growth for its own sake is being replaced by directed growth, the channeling of economic growth in ways that enhance the "quality of life." James Wakelin Jr, Assistant Secretary of Commerce for Science and Technology, expressed this view in a recent talk.[4]

> "A proper Federal strategy for technology enhancement. . .should embrace the following criteria:
> "The Government should move to provide basic research when competent scientists identify phenomena which offer a potential which technologists and economists believe could lead to the creation of whole new industries. Direct energy-conversion devices, desalinization systems and means for recovery of ocean and seabed minerals are three examples. . ."
> "The Government should undertake basic technology when a great variety of payoffs can be expected but the profitability to any private firm or consortium is questionable. Social research in city problems and educational innovations are examples. . ."
> "The Government is particularly justified in sponsoring new technological development when the consensus is that such efforts will accelerate the coupling of new technologies to new products for export. The problems of our world trade balance are sufficient, in my opinion, to justify the Government in sharing with the private sector in the costs of technology development to meet import competition."

Wakelin's remarks bear primarily on Government support of technology, but the history of Federal support of science, at least by the mission-oriented agencies, is related to the technological goals of those agencies.

The economic and social justifications for Federal support of science are therefore becoming intimately intertwined. For example, the most immediate applications from the development and operation of LAMPF are likely to be in two major areas: radioisotopes for industry and for diagnostic and therapeutic medicine, and negative pions for therapeutic medicine. The waveguide structures developed at LAMPF are already being used in several dozen US hospitals for high-energy x-ray therapy, and many more such waveguides are being built. According to the American Cancer Society, there are 700 000 new cancer patients each year in the US alone. In 1970, about half of the one million people being treated for cancer were receiving radiation therapy from over 200 accelerators and other sources of ionizing radiation. Clearly the manufacture, sale and use of these accelerators is economically important to the nation. The fight for human lives, on the other hand, is primarily a social matter. Here we see that Brooks's

**Table 1. Some Proton-Rich Nuclides from Medium-Energy Bombardments**

| Product | Halflife | Daughter | Halflife |
|---|---|---|---|
| $Ga^{67}$ | 78 hours | | |
| $Ge^{68}$ | 280 days | $Ga^{68}$ | 68 minutes |
| $Se^{72}$ | 8.4 days | $As^{72}$ | 26 hours |
| $Sr^{82}$ | 25 days | $Rb^{82}$ | 75 seconds |
| $Rb^{83}$ | 83 days | $Kr^{83}$ | 1.9 hours |
| $Xe^{123}$ | 2 hours | $I^{123}$ | 13 hours |
| $Hf^{172}$ | 5 years | $Lu^{172}$ | 6.7 days |
| $Ti^{44}$ | 47 years | $Sc^{44}$ | 4 hours |

**Table 2. Scientific Man Years in Medium-Energy Physics Supported by the AEC Physical Research Division**

| | Fiscal Year | | | | | |
|---|---|---|---|---|---|---|
| Laboratory | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
| Ames | 6 | 7 | 6 | 5 | 4 | 2 |
| Argonne | 4 | 5 | 2 | 1 | 1 | 1 |
| Brookhaven | 0 | 0 | 1 | 2 | 2 | 2 |
| Lawrence Berkeley | 32 | 34 | 28 | 31 | 33 | 26 |
| Los Alamos | 33 | 40 | 43 | 47 | 64 | 80 |
| Oak Ridge | 48 | 50 | 43 | 42 | 38 | 36 |
| Educational institutions | 68 | 48 | 61 | 77 | 56 | 62 |
| Medium Energy Physics Total | 191 | 184 | 184 | 205 | 198 | 209 |
| (Low Energy Physics Total) | 705 | 707 | 689 | 657 | 589 | 550 |

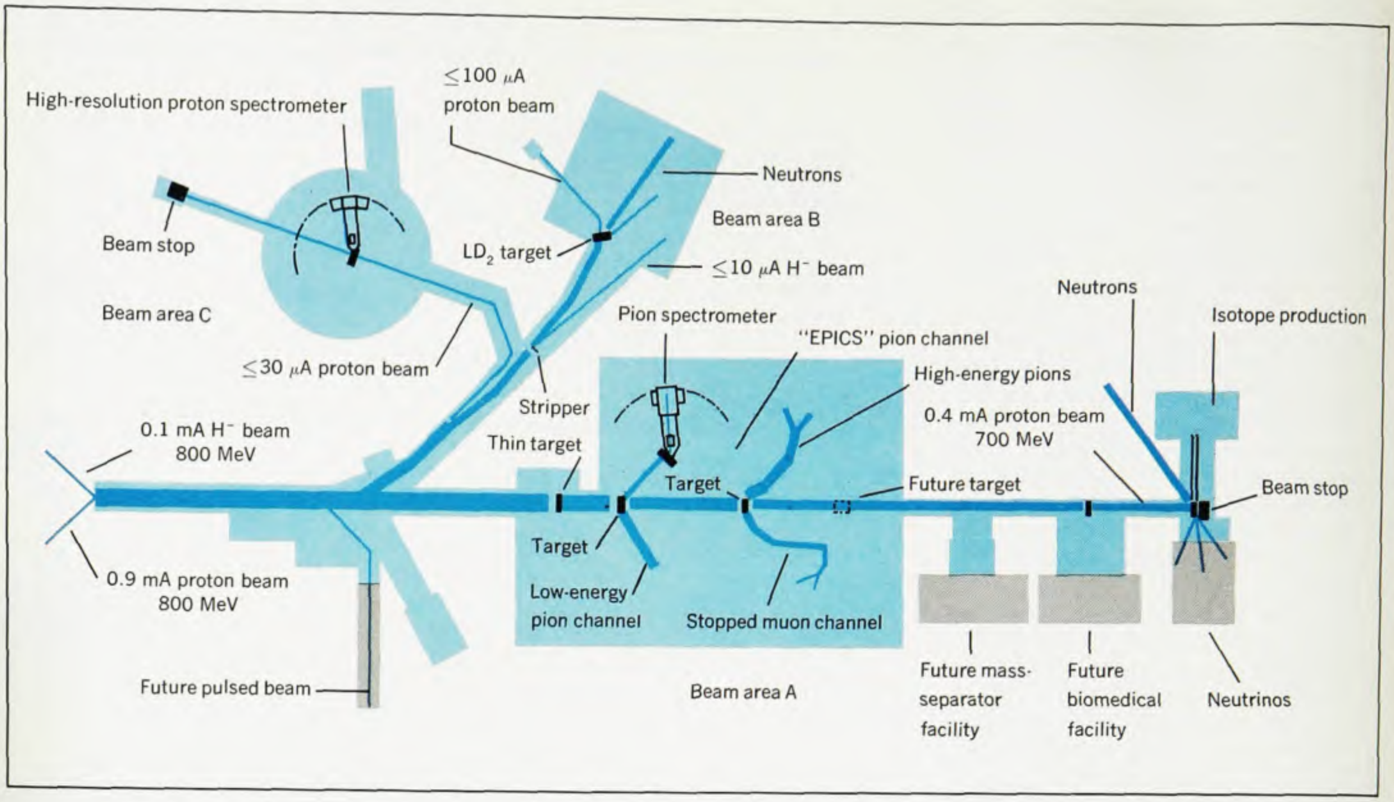
**Table 3. US Government Funds for Medium-Energy Physics Operating Expenses and Capital Equipment**

| | Funds (millions of dollars) per fiscal year | | | | | |
|---|---|---|---|---|---|---|
| Agency | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 |
| AEC (Medium Energy Physics) | 12.5 | 12.3 | 13.1 | 15.5 | 15.7 | 15.6 |
| AEC (Chemistry) | 2.3 | 2.5 | 2.8 | 2.5 | 2.5 | 2.5 |
| AEC (Division of Military Applications) | 0.9 | 0.9 | 0.9 | 0.8 | 0.6 | 0.5 |
| NSF | 1.9 | 2.0 | 2.2 | 2.0 | 2.2 | 2.2 |
| NASA | 1.8 | 1.7 | 1.5 | 1.3 | 1.2 | 0.8 |
| NRL | 1.8 | 1.7 | 1.9 | 2.0 | 2.1 | 2.1 |
| NBS | 0.7 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 |
| Total | 21.9 | 21.7 | 23.1 | 24.8 | 25.0 | 24.4 |

**Table 4. US Government-Financed Construction for Medium Energy Physics**

| | Funds (millions of dollars) per fiscal year | | | | | | |
|---|---|---|---|---|---|---|---|
| Facility | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | Total cost of base project[1] |
| LAMPF | 0.8 | 1.8 | 7.7 | 17.4 | 15.4 | 7.7 | 56.0 |
| MIT linac | 0.0 | 1.1 | 2.7 | 1.0 | 0.3 | 0.4 | 5.7 |
| Nevis conversion | 3.9 | — | — | — | — | — | 4.4 |
| Indiana cyclotron | — | 4.0 | — | 1.1 | — | — | 5.6 |
| Maryland cyclotron | 0.9 | 1.1 | 0.8 | — | — | — | 3.0 |
| University of California, Davis, cyclotron | 0.1 | — | — | — | — | — | 2.5 |
| Texas A&M cyclotron | 1.7 | 0.4 | — | — | — | — | 3.0 |
| NBS linac | — | 0.3 | — | — | 0.6 | — | 7.0 |
| NRL cyclotron | 0.2 | — | — | — | — | — | 5.5 |
| SREL cyclotron | — | — | — | — | — | — | 14.5 |
| Total | 7.6 | 8.7 | 11.2 | 19.5 | 16.3 | 8.1 | 107.2 |
| Cumulative total | | 16.3 | 27.5 | 47.0 | 63.3 | 71.4 | |

1. Figures include costs in years up to and including 1967.




**Experimental areas at LAMPF.** Areas A, B and C will provide high-intensity beams with high resolution, for studying nuclear and elementary-particle phenomena. At the isotope-production area (right) a small trial program has been authorized; the beam stop here would also produce large quantities of neutrons and neutrinos. Three of the experimental areas are at the proposal or authorization, rather than the building stage: The future pulsed-beam area (left) would be the location of the Weapons Neutron Research Facility, and mass-separator and biomedical areas are also planned.
Figure 2

second and third purposes are closely linked.

Accelerators in the medium-energy domain open up a whole new area of application for the production of radioisotopes for industry and for medicine. Some of these isotopes (see Table 1) offer advantages not presently available. For example, $I^{123}$ appears to have much better properties for various medical studies than does the currently available $I^{131}$; it has a shorter halflife and emits only gamma rays (that is, no particles). Because of these two characteristics, $I^{123}$ should provide a more precise scanning capability and much less dose to the patient than does $I^{131}$.

In solid-state physics or radiation-damage studies, medium-energy physics offers an opportunity to examine the formation of gas pockets through high-energy neutron interactions, for example (n, p) or (n, $\alpha$) reactions, and to study the changes in metals and alloys exposed to very high-level integrated irradiations (thousands of megawatt-days). This phenomenon, a major technological and economic problem for fission or fusion reactors, cannot be simulated by other known methods. The social implication lies in the future of breeder and fusion reactors, when and if they are developed, as our society demands cleaner and better energy sources.

Evidently then, medium-energy physics scores high in economic and social value (extrinsic merit), especially as it pursues the high-intensity frontier.

### Educational or structural

Brooks has chosen "educational" as his fourth main reason for the support of scientific research, but it appears to me that the "structural" aspects of the field, which include its impact on education, are broader and therefore more appropriate. Science is a complex and interdependent social system. Disturbances in one area of science often interact directly or indirectly with the entire fabric of our culture, of science and of technology.

It is, for example, no mystery why LAMPF is being built at the Los Alamos Scientific Laboratory rather than adjacent to the campus of a major university. The institutional integrity, viability and future of LASL were some of the serious motivating factors in the minds of the AEC Commissioners, the President, and members of the Congress. LAMPF would also provide an important contribution to the scientific, educational and economic growth of the Rocky Mountain region; its location at LASL would bring about significant economies through the availability of existing Government-owned land, adjunct facilities and services, and it would help ensure appropriate control of health and safety problems and radiation health hazards. Last, but not least, Los Alamos had a core of capable and dedicated scientists to whom AEC could look with confidence for efficient and effective solutions to the complex construction, operation and organizational problems involved.

I have dwelt on LAMPF because it is the major facility in medium-energy physics, but several other laboratories and institutions are also involved. AEC is supporting medium-energy accelerators at MIT, the Lawrence

**Table 5. AEC Supported Programs in Medium Energy Physics 1967–1976**

| | Operating costs (thousands of dollars) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Laboratory or group | 1967 | 1968 | 1969 | 1970 | 1971 | 1972[1] | 1973 | 1974 | 1975 | 1976 |
| Los Alamos | 2885 | 3199 | 3681 | 5250 | 6000 | 7200 | 12 000 | 13 000 | 15 300 | 16 500 |
| Medium Energy Physics users groups | 462 | 406 | 510 | 765 | 769 | 1131 | 2551 | 3400 | 4650 | 5900 |
| Ames | 400 | 400 | 349 | 300 | 175 | 50 | — | — | — | — |
| Lawrence Berkeley | 1887 | 1912 | 1906 | 1900 | 1650 | 1600 | 1940 | 2100 | 2200 | 2300 |
| MIT | 98 | 150 | 401 | 600 | 628 | 800 | 1700 | 1800 | 2000 | 2100 |
| Oak Ridge | 2004 | 1878 | 1747 | 1745 | 1630 | 1450 | 1900 | 2000 | 2100 | 2100 |
| Maryland | 180 | 299 | 378 | 550 | 664 | 500 | 750 | 800 | 850 | 900 |
| University of California, Davis | 874 | 729 | 705 | 778 | 663 | 175 | — | — | — | — |
| Texas A&M | 231 | 559 | 612 | 660 | 548 | 190 | — | — | — | — |
| Carnegie-Mellon | 679 | 550 | 375 | — | — | — | — | — | — | — |
| Minnesota | 637 | 479 | 210 | 14 | — | — | — | — | — | — |
| Rochester | 521 | 301 | 175 | — | — | — | — | — | — | — |
| All others | 117 | 271 | 217 | 228 | 263 | 4 | 359 | — | — | — |
| Total operating costs | 10 975 | 11 133 | 11 266 | 12 790 | 12 990 | 13 100 | 21 200 | 23 100 | 27 100 | 29 800 |
| | Capital equipment costs | | | | | | | | | |
| Los Alamos | 163 | 234 | 624 | 463 | 1124 | 1710 | 2140 | 1900 | 1640 | 1900 |
| All others | 3364 | 2525 | 2086 | 988 | 862 | 840 | 1160 | 1900 | 2360 | 2200 |
| Total capital equipment costs | 3527 | 2759 | 2710 | 1451 | 1986 | 2550 | 3300 | 3800 | 4000 | 4100 |

1. Figures for 1972 are estimates; figures for 1973–1976 are projections.

Berkeley Laboratory, Oak Ridge National Laboratory and the University of Maryland. Seven other Government-supported medium-energy accelerators are located at the Columbia, Indiana, Michigan State and William and Mary campuses, the Naval Research Laboratory (two) and NBS. Up until this year, AEC supported a 50-MeV cyclotron at Texas A & M University, and a 55-MeV cyclotron at the University of California, Davis, but support has been ended because of budgetary limitations. Some support for continued research with these two cyclotrons is being provided by the National Science Foundation.

In addition, the electron synchrotron at Ames Laboratory, Iowa, is being closed this year, and AEC is currently considering a proposal from Ames for a new electron linac. Finally, an 88-inch cyclotron (58-MeV protons) is supported at LBL under AEC's Chemistry Program, and is used, of course, for physics as well as for chemistry experiments. All of these facilities, and especially the newer ones, make demands on industry and on the scientific community for the development of new instrumentation and techniques.

It is clear that the institutional structure of medium-energy physics includes universities, Government laboratories and "GOCO" (Government-owned, contractor-operated) laboratories. The role of industry is, at the moment, more that of an interested observer than a participant. Industry does participate, however, through membership in the LAMPF Users Group, and, should the applied aspects of the field pay off, say in cancer therapy or radionuclide production, the medical industry as well as other areas of industrial activity (for example, tracer-chemical producers, accelerator manufacturers, those concerned with radiation effects on materials) could be expected to blossom. The discipline, then, appears to have a potentially high structural impact on society.

### Manpower data incomplete

We do not yet have a good handle on the detailed structure of manpower and age distribution in medium-energy physics. Some idea of the institutional distribution can be gained by looking at the affiliation of participants in LAMPF research proposals (these are the people whose names are associated with proposals submitted to LAMPF for beam time rather than proposals submitted to AEC or other Federal agencies for support). Of the 294 participants, 174 are from US universities, 74 from Los Alamos, 33 from other US Government laboratories and 13 from institutions outside the US. The lack of industrial participation is evident. On the other hand, some members of the LAMPF Users Group are from industry, and this industrial interest may in time develop into actual participation. Institutional participation is diverse, including hospitals and medical centers, and this interest is spread geographically throughout the US and, indeed, the world.

The overall AEC-supported manpower devoted to medium-energy physics (excluding that carried out at LASL in divisions other than the Meson Physics Division and exclusive of the Chemistry-supported 88-inch cyclotron at LBL) is seen in Table 2, which presents information on the scientific-manyear effort devoted to the Medium Energy Physics program of AEC's Division of Physical Research. The number of scientific manyears for the major AEC laboratories and educational institutions is presented for fiscal years 1966 through 1971.

Some trends are obvious. For example, funds for LBL and ORNL have been decreasing since 1966. One then expects the observed decline in the number of scientific manyears of effort supported at these laboratories in medium-energy physics. On the other hand, for LASL, funding to the Meson Physics Division has been increasing year by year, and we may expect to see a substantial increase in the number of scientific manyears for this division at LASL as LAMPF moves from the construction phase into operation. Similar correlations are apparent for Ames, Argonne and Brookhaven. The figures for scientific manyears of effort at the educational institutions, on the other hand, are more difficult to understand. The numbers go down and up and up and down, and in fiscal 1971 do not quite achieve the magnitude achieved in 1966. A detailed analysis of the data on manpower at educational institutions shows that, for a variety of reasons, the data are not very meaningful. I am hopeful that we shall be able to develop better manpower information in the future, and on a broader basis than just AEC. It would also be interesting, for example, to develop valid information on the age distribution in the field; such information is being developed for nuclear physics as a whole by the Physics Survey Committee of the National Academy of Sciences, but I do not believe that it reflects a breakdown between manpower in low-energy and medium-energy nuclear physics.

#### A closer look at LAMPF

What kind of work, exactly, is planned in medium-energy physics? The layout of the experimental area of LAMPF (figure 2) shows that the diversity of interest and activity possible at a medium-energy facility of high intensity, such as LAMPF, is very great indeed. Experimental areas A, B and C span the domains of nuclear and subnuclear physics to an extent never before possible. High-energy pions, low-energy pions, high-energy muons, low-energy muons: These hitherto elusive particles will now be available in sufficient quantity and energy resolution that they can be used for primary beams, and the study of particle and nuclear phenomena will gain a whole new dimension.

Following down the beam line, we find an isotope separator, which, when fully operational, will permit the study of numerous short-lived nuclear species formed by 800-MeV proton spallation and fission reactions. It should be particularly useful in the halflife range from several minutes to one second and should keep the nuclear chemists occupied in a new domain of the table of isotopes for some time to come. I should point out, however, that this construction project has not yet been authorized.

The next tap-off point from the beam leads to the biomedical facility. Here the outlook is quite good, given the President's announced multimillion-dollar "war on cancer." However, even before that announcement, AEC had been discussing the matter with the Department of Health, Education and Welfare's National Cancer Institute (NCI). Informal agreement had been reached between AEC and NCI that NCI was very interested in the use of negative pions as a possible therapy for inoperable cancers. NCI had also agreed informally to assume responsibility for clinical trials at LAMPF. Last fall, after it became clear that AEC was not going to be able to include the biomedical facility in its fiscal-year 1972 budget, the then AEC chairman Glenn Seaborg, who strongly supported the project, suggested that we try to work out some kind of joint funding with NCI. After a few meetings between the staffs of the two agencies, an inter-agency agreement was signed, providing \$1 000 000 in NCI funds for the design, procurement and installation of the necessary equipment in this facility, including a biomedical-beam transport and control system. The new facility will permit the use of pion beams for biomedical studies without interference from other programs that use LAMPF, and will provide the first pion-beam intensities fully adequate for therapeutic applications. The growing number of medical participants in the LAMPF Users Group attests to the medical community's keen interest in pions.

Moving on down to the penultimate beam stop, we find an isotope production area. At the moment, the AEC Division of Applied Technology, which would fund this facility if it is built, is committed to the experimental production and market analysis of neutron-deficient nuclides at the 200-MeV linac injector for the Brookhaven Alternate Gradient Synchrotron. This injector is known as "BLIP," the Brookhaven Linac for Isotopes Production. To explore the feasibility and relative merits of producing neutron-deficient radioisotopes at LAMPF, LASL has authorized the use of some modest funds to build a small experimental production facility. Thus, although this area of application of medium-energy, high-intensity beams is currently under study and debate within AEC and elsewhere, if the estimated radioisotope sales given in the AEC publication *Nuclear Industry*—\$59 million in 1969, \$71 million in 1970 and \$86 million in 1971[5]—can be extrapolated to 1975, we might expect LAMPF to play a significant role here.

The beam stop should, of course, also be a prolific source of neutrons and neutrinos. Here is an area where more accurate and quantitative basic, as well as applied, scientific information is vitally needed.

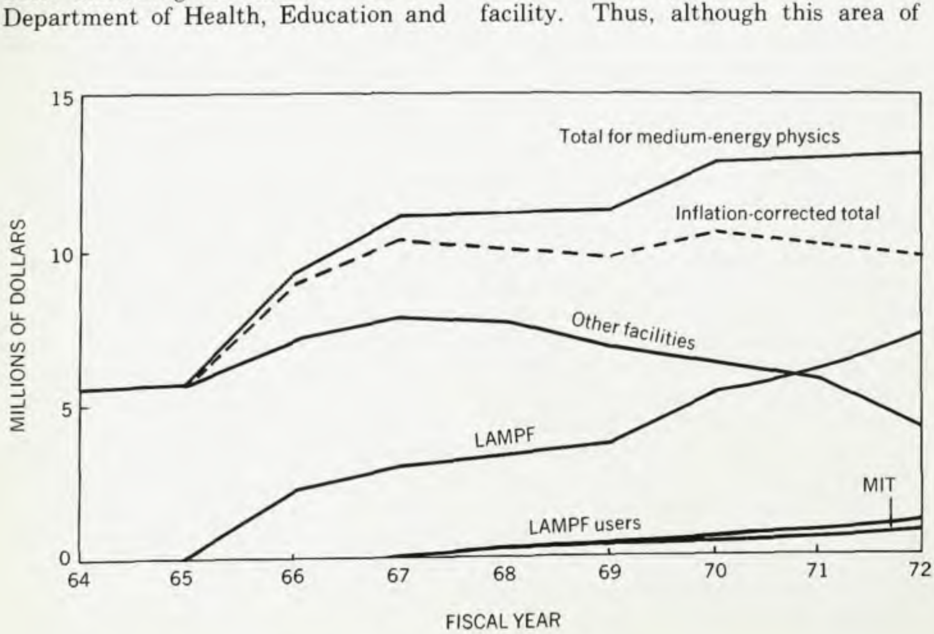
Finally, moving up beam to just after the switchyard, we find an area marked "future pulsed beam"; this is the area of the proposed Weapons Neutron Research Facility. Funds have been provided to stub off the beam line and the Congress has authorized and appropriated funds for design of the experimental area, should this facility be built. To quote the recent report of the Joint Committee on Atomic Energy:[6]

> "the weapons neutron research facility would contribute to the national defense in several ways, including the testing of complex computer calculations used in designing nuclear weapons, the testing and calibration of sophisticated instrumentation for underground weapons tests, and the training of new nuclear defense scientists in applied research."

It is, therefore, evident that the structure of medium-energy physics is broad, diversified, and potentially more so. Thus on all four grounds, cultural, economic, social and structural, I would rate the field highly deserving of public support.

#### Funding philosophy

On 1 July 1965, a new budget and reporting classification titled "Medium Energy Physics," as defined by the




**AEC funds for medium-energy physics.** Total operating funds provided by the Physical Research Division are increasing. A closer look shows that all the increase is in support for LAMPF and the MIT linac, while support for other laboratories is decreasing.
Figure 3

Bethe Panel,[2] was established by AEC. For fiscal 1966, the activity was established with the transfer of synchrocyclotron programs at Berkeley, Carnegie-Mellon and Rochester, all from High Energy Physics, along with the transfer of research programs at Ames, Argonne, Columbia, ORNL, Yale, UCLA, University of California at Davis, Maryland, Minnesota and Texas A & M from Low Energy Physics. In addition, one new program was included without transfer consideration: the preconstruction research and development for LAMPF. One of the principal reasons for establishing this new activity was to provide an appropriate "home" for the LAMPF budget and to attempt to insulate, so far as possible, the low-energy physics program from the expected high costs in the medium-energy field.

But we should bear in mind the testimony of Paul McDaniel, director of AEC's Division of Physical Research, before the Joint Committee last February:[7]

> "One caution I would make: physics research covers the entire field of physics. Although we have divided it up for clarity into high-, medium-, and low-energy physics and within each one we have subcategories, there is a big temptation to assume that these are really compartmentalized activities. I can't stress too much that this entire field of science is interrelated—one area depends a great deal on another."
> "We should not try to compartmentalize all of our thoughts too rigidly. There is a thing called medium energy physics and it is somewhat different from high energy physics, but I would urge that we not push this categorization too far."

LAMPF is not only a major component of the Los Alamos Scientific Laboratory, it is also a *national facility*: Although funds for the construction and operation of LAMPF are provided primarily by AEC, access to the beams is based on scientific merit, and the facility is available to scientists throughout the US and from abroad. Thus, the sources of funding for LAMPF users or users of other medium-energy accelerators will be many and varied.

It may be instructive to take a look at the funds that have gone into medium-energy physics over the past six years from Government agencies. Table 3 is a breakdown of operating funds, by agency, for medium-energy nuclear physics. These data cannot be related to Federal budget figures in any direct way. Other Federal agencies have not formally adopted the same definition for medium-energy physics as has AEC. And the numbers here include both operating costs (salaries, travel, overhead and so on) and the equipment associated with the experimental programs exclusive of major facilities. In some agencies these are budgeted separately, in others, not. Even at AEC, the accounting definition "medium-energy physics" applies only to the support provided by the Division of Research. The work at LASL, for example, in divisions other than Meson Physics is most likely supported by the Division of Military Applications of AEC. The AEC (Division of Military Applications) funds therefore represent an estimate by the Laboratory management rather than an auditable total at LASL for medium-energy physics. Similarly, the data from the other agencies (for example NBS, NRL) represent responsible Laboratory-management estimates, not accounting categories by which detailed costs are reported in the Government. Nevertheless, I do believe that the numbers are reasonably sound and probably the best available. The decline in the NASA support represents the planned phase-out by NASA of the Space Radiation Effects Laboratory and its users.

Table 4 shows Federal support of new facilities for medium-energy physics since 1967. The Government has been making substantial investment in such facilities despite the downward trends for the overall support of physics and the special budgetary problems that have been experienced in AEC.

It is evident from Tables 3 and 4 that the growth in operating funds for medium-energy physics has not been commensurate with either the size of the Federal investment in the field or, as we have already noted, with its promise. Unless the total Federal funding here shows a marked upward trend in future years, it is doubtful that medium-energy physics will remain viable. Certainly the US scientific community will not be able to exploit its full potential for either basic or applied science.

### Support by AEC

In figure 3 we see the total operating funds, exclusive of capital equipment, provided by Physical Research Program of AEC for medium-energy physics from 1964 to 1972. The figure shows totals (raw and inflation-corrected data are given) as well as data for LAMPF and other laboratories. The most striking aspect of these curves is the impact of LAMPF on the rest of the medium-energy physics program: Rightly or wrongly, we have given LAMPF and the new MIT electron linac, together with their users groups, top priority within this program.

Table 5 shows the details, by laboratory, of what has happened in the AEC Medium Energy Physics program since 1967. It is evident that by 1971 substantial reductions in the support of medium-energy physics at Ames, LBL and ORNL had occurred. The first casualties were the Minnesota proton linac and the Rochester and Carnegie-Mellon synchrocyclotrons. In the cases of Minnesota and Rochester, other factors than the budget squeeze were involved in the closeout decisions. Carnegie-Mellon, however, started a trend, illustrated in Table 5; AEC has had to end its support of the Texas A & M and the University of California, Davis, cyclotrons this year (fiscal 1972). The Ames electron synchrotron is also being closed down this year because of a combination of budgetary factors and the need at Ames for access to more modern facilities.

Fortunately, in reducing AEC's research budget, the Administration added funds to NSF's budget request and Congress has given additional funds to NSF specifically earmarked for the support of projects terminated by AEC and other agencies; NSF has already taken steps to provide at least partial support for the Texas and Davis machines for the coming year. I am sure, however, that the additional funds available to them will not fully cover the work terminated by the AEC actions. A more orderly interagency transfer was apparently not possible.

Note that Table 5 also shows the official AEC projections for Medium Energy Physics through 1976 for both operating costs and equipment.[8] It is often said that budgetary projections are among the softest numbers in Government: Year after year these projections show a sharp upward "bump" or "bow wave" for the fiscal year beyond the one being considered for submission as a firm budget to the Congress. The process is well illustrated in Table 6, which shows the fate of the AEC budget for fiscal 1972 as it progressed from the Division of Research request, the Commission's request to the Office of Management and Budget, and finally the official Presidential Budget request to the Congress. Each stage in the decision-making process from the division request through Congressional action nearly always involves reductions. These reductions in the actual Agency budget request, however, do not appear to dampen the optimism of those of us responsible for administering the programs, and we are right back in there with projections based on a combination of our best judgment of program needs and what we consider to be a reasonably realistic request.

To many of us involved in science administration, the experience is frustrating. To others it is a continuing challenge to cajole, convince and sell those in the decision-making line of command on the importance of our

**Table 6. Progress of 1972 AEC Budget**[1]

| Program | Funds (millions of dollars) per fiscal year | | | | |
|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | | |
| | | | Division request | Office of Management and Budget estimate | Congress estimate |
| Total physical research | 277.8 | 271.4 | 315.0 | 286.6 | 259.5 |
| High Energy Physics total | 120.5 | 118.6 | 137.0 | 125.5 | 114.4 |
| Princeton–Penn Accelerator | 4.1 | 2.0 | — | — | — |
| Cambridge Electron Accelerator | 3.5 | 2.4 | 3.0 | 2.3 | 2.2 |
| Alternating Gradient Synchrotron (BNL) | 21.2 | 21.8 | 24.8 | 23.3 | 21.8 |
| Zero Gradient Synchrotron (Argonne) | 17.3 | 16.7 | 18.6 | 17.4 | 15.5 |
| Berkeley Bevatron | 13.2 | 12.8 | 14.5 | 13.4 | 12.2 |
| Stanford Linear Accelerator | 23.8 | 24.3 | 27.3 | 25.2 | 23.6 |
| 200-GeV accelerator (NAL) | 6.6 | 9.2 | 15.8 | 13.2 | 11.9 |
| General research and development | 30.8 | 29.4 | 33.0 | 30.7 | 27.2 |
| Medium Energy Physics | 12.8 | 13.0 | 19.0 | 14.7 | 12.8 |
| Low Energy Physics | 29.4 | 27.6 | 31.0 | 28.9 | 25.3 |
| Mathematics and Computer Research | 5.8 | 5.4 | 6.0 | 5.6 | 4.8 |
| Chemistry Research | 53.9 | 51.6 | 57.7 | 54.0 | 49.0 |
| Metallurgy and Materials Research | 27.7 | 26.8 | 30.0 | 28.0 | 25.2 |
| Controlled Thermonuclear Research | 27.7 | 28.4 | 34.3 | 29.9 | 28.0 |

1. From reference 8.

particular area of responsibility. Each number on Tables 5 and 6 represents the end result of a large amount of talking, arguing and letter writing, all of which comprise the politics of the administration of science. You can argue about how the money is distributed among the disciplines and, indeed, the Physics Survey Committee is doing just that. In the end, however, these detailed decisions must be based upon the good judgment of the science administrators involved and on the political process.

At present, we are supporting 14 users groups at Argonne, Brookhaven, Yale, UCLA (two), Carnegie-Mellon, Case-Western Reserve, Houston, Rice, Temple, Virginia and Wyoming for a total of $1 213 000, and, as of the end of 1971, we have on hand some 19 proposals from prospective LAMPF users totalling about $900 000. Clearly if LAMPF is to be operated effectively as a national facility, and the MIT Linac as a regional facility, substantial growth is needed to support users groups at both facilities. We have continued to press this point with the Administration, and now we can only hope that the funds to be made available will be adequate for the job.

### Outlook for the future

You may wonder how, after all these depressing statistics about how the support for the field has fared over the years, I can say unequivocally that, in my opinion, medium-energy physics will fly, not die. My opinion is based, I admit, on my faith in the ultimate good judgment of the people who constitute the US electorate and in the expression of that judgment through the Administration and the Congress; the views I express here are, of course, my own and not necessarily those of AEC or the Administration.

I have shown, however, that in terms of all four of the main reasons for the support of scientific research—cultural, economic, social and structural—medium-energy physics ranks high. Sir Brian Flowers, Chairman of the British Science Research Council, put the matter well:[9]

> "In the affairs of science there are two sets of forces acting; the external [forces] representing the aims of society and the internal forces representing the natural development of science; and there must be some balance between them or the system collapses."

Conversely, I would say, if that balance exists, the field will thrive.

To me it appears necessary, in medium-energy nuclear science as in other areas of science, to distinguish between the "strategy" and the "tactics." I believe it is possible, at this point in time, to determine broad areas of strategic emphasis in terms of potential applicability of this field. These areas are most clearly delineated at LAMPF by the biomedical, isotope-separation, radioisotope production and weapons neutron research facilities. Basic research in medium-energy physics provides the scientific underlay for all of these applied areas. The "tactics," on the other hand, for the pursuit of medium-energy physics are based partly on judgments about the relevance of the potential applied areas of medium-energy nuclear science and partly (perhaps predominantly) on the internal forces representing its natural development. The finer the scale of choice within the field, the more necessary it is that the choices of problems and projects be made in terms of the internal criteria if the field is to advance efficiently and economically, in terms of the advancement of medium-energy physics and the advancement of society's goals. Granted that complete objectivity is never possible, it does appear that in the continuing power struggle—the competition for a share of that scarce commodity, namely, the attention of the decision-makers—medium-energy physics, as an underlying part of medium-energy nuclear science, stands as a rational and balanced discipline.

* * *

*This article has been adapted from a talk given this past November at the fifth LAMPF User's meeting in Los Alamos, New Mexico.*

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