The APS in 1977: public service in an era of limited growth

Public service and concerns for human rights accompany The American Physical Society's primary function of advancing and diffusing knowledge of physics.

George E. Pake

Some truly great figures have served as presidents of The American Physical Society. I am absolutely certain that I cannot measure up to the standards they have set, not just for the presidency of the society but also for their leadership within the science of physics and the community of physicists. Yet I would venture to guess that only my most recent predecessors found the presidency of APS as demanding of time and effort as I did, and that future presidents will encounter the same substantial demands on their energies that characterized my year. The presidency of the society has evolved into this circumstance as physics has entered a new, more complex, and a more difficult era. In this article marking the end of my term as APS president, after reporting on the activities of the society during the past twelve months I will offer some reflections on the characteristics, the differences and the challenges that this new era in physics presents.

POPA's share in APS activities

Although the overwhelming preponderance of APS financial and human resources is expended in publishing research journals and holding meetings to report research results, these operations run so smoothly out of the APS office that the president of the society tends to view his year in terms of the nonroutine items that occupied his attention.

In 1977 much of my effort was directed toward matters in which physics has an important bearing on the public interest. Throughout these efforts, the work of the Panel on Public Affairs under the chairmanship of Herman Feshbach was more than just helpful; it was indispensable. Experience of previous officers had led Council to establish POPA, which began operation in 1975 under its first chairman, Philip Morse. The resource backup provided by POPA and frequent consultation with the POPA chairman are essential if the APS president is to be reasonably well informed as a spokesman for the society. My experience strongly indicates that the president cannot responsibly choose to be silent on a substantial fraction of the many issues about which his views are sought. The responsibility to speak carries with it the necessity for factual accuracy and exercise of judgment; in summoning both, the president is materially aided by consultation with POPA.

Human rights of scientists

Part of our heritage in the United States is a deep concern for human rights. This concern is a legitimate province for The American Physical Society when physicists or scientists anywhere have their basic human rights abridged, because the fundamental purpose of APS as a scholarly society is thus inhibited. That purpose is stated in the APS Constitution to be "the advancement and diffusion of the knowledge of physics." If the governments of nations interfere on political grounds with the ability of physicists to engage in research or with their freedom to publish or travel in diffusing knowledge of physics, there is interference with achieving our purpose. APS presidents before me have spoken out with respect to specific cases of abridgment of human rights for physicists, and I have continued in that tradition, basing my actions on factual determinations by POPA. Despite the one bright spot I will mention below, my perception is that the world picture for human rights generally and for scientists in particular has not improved and is probably worse than it was a year ago.

As I took office in early February 1977, William A. Fowler, the retiring President, reported his unanswered communications to Academician Alexandrov of the USSR concerning Mark Azbel and the Moscow Seminar on Collective Phenomena. The arrest of some members of the seminar and of other Refusniks, and the interference with mail delivery of APS journals to the seminar, had led to Fowler's last communication of protest. A reply from Alexandrov in early March was discouraging. The bright spot is that in the late summer Azbel was permitted to emigrate from the USSR to Israel. In November he visited the United States and spoke informally to Council at the Miami Beach meeting. His description of circumstances for Refusniks in the USSR indicates that we cannot lessen our concerns; still, it was encouraging to see Azbel and realize that he is once again able to pursue his research interests and to move freely in the world physics community.

Elsewhere there is nothing promising to report. Both Fowler and I sent follow-up letters to President Videla of Argentina. President Videla has failed to respond for a period exceeding a year to the two letters from Fowler and to two subsequent letters from me concerning the fate of scientists who have not been heard from. On receipt of information developed by POPA, I also wrote to several Argentine bishops sending copies of my Videla letter. The Secretary General

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of the Episcopal Conference in Argentina has replied, sympathetic to our concern but otherwise expressing no hopeful note. We have kept the Organization of American States informed and we joined in supporting a human rights resolution before it.

Early in the year I wrote to President Marcos of the Philippines concerning Roger Posadas. Receiving no response, I wrote a second letter, in mid-August. In late August Posadas wrote me a letter from the stockade in which he is, so far as I know, still being held—a beautiful letter that thanked APS for its efforts.

Most recently, POPA has investigated the facts relating to two physicists in Rumania and assisted me in drafting a letter to President Ceaucescu seeking their freedom to pursue science.

In addition to specific cases, we have tried to work through other organizations and agencies. I mentioned the Organization of American States and the human-rights resolution we have joined in endorsing. We also have communicated with Secretary of State Cyrus Vance supporting expansion of the Inter-American Commission on Human Rights. Amnesty International was apprised of our efforts to help Posadas in the Phillippines, and is doing what it can.

From this brief run-down, representing only a fraction of the countries in which scientists face abridgement of human rights, you can understand my lack of optimism. President Carter, as you know, has taken an outspoken position on human rights generally. It is difficult to see what effective steps the Physical Society might take in the interests of these persecuted scientists, beyond the kinds of efforts POPA and APS officers have made in the recent past. Again I want to emphasize the significant role of the Panel on Public Affairs and its staff assistant, John Parmentola, in finding the facts surrounding these difficult human rights cases.

Responses to the Federal Government

On three separate occasions during the past year, I have responded to requests from Washington for advice in the area of science policy. Three other matters relating directly to the health of US physics were the subject of statements initiated by me, with guidance from POPA and Council.

The first and most extensive effort began in response to an invitation to testify before the Senate Committee on Governmental Affairs concerning the organization of research in the proposed new Department of Energy. Examination of the bill proposed by the Administration suggested that the new department might fragment its research efforts, to the detriment of the nation's energy needs and perhaps also of science. After discussion with the Executive Committee at its 20 March meeting in San Diego, Herman Feshbach and I were asked to prepare a preliminary version of my testimony, which called for an Assistant Secretary for Research to serve as the focal point for research concerns in the department.

My formal testimony was presented on 25 March. Questions, notably from Senator John Glenn and Senator Charles Percy, focussed on the importance of basic research and whether mission-oriented agencies such as the proposed new DOE could abondon basic research and depend upon NSF for basic research; I answered strongly in the negative. After the testimony, there were numerous inquiries from Federal agencies and congressional staffs, as well as from the scientific community.

It became clear that too many forces were pressing on Congress to write particulars into the bill. As a result, the final legislation did not specify all the Assistant Secretariats but did provide for an Office of Energy Research. The scope of that office was to some extent left in doubt, but in July Frank Press, the Presidential Science Adviser, arranged for a knowledgeable group of about twelve or fifteen interested scientists to meet with James Schlesinger in the White House to discuss the structure for overseeing research in the forthcoming new department. I was asked to join that group, which consisted primarily of several high-level university administrators and the heads of some of the national laboratories. Both as an officer of a non-energy company that is not dependent on Federal funding for its research and as president of the society that encompasses most of the nation's research physicists, I found myself selected by the group to make the opening statement to Schlesinger. He was attentive and responsive to the discussion that followed. Subsequently as you have no doubt read, John Deutsch of the MIT chemistry department has been appointed as the first head of the DOE Office of Energy Research with administrative responsibility for the $400-million basic research program inherited from ERDA and for conducting R&D throughout the DOE. This is exactly the kind of position POPA and I viewed as necessary if DOE is to optimize the effectiveness of energy research.

A second area in which advice was sought, on very short notice, was in connection with President Carter's reorganization project to reappraise all parts of the Executive Offices with a view to reducing the size of the Executive Offices and the number of advisory groups. The new Office of Science and Technology Policy had just been set up in 1976, following elimination of the President's Science Advisory Committee and the Office of Science and Technology in 1973. Questions were put to me as to the value of OSTP and the office of the science adviser. The time allotted for reply was so short that I had no opportunity to consult POPA. My response to the various questions emphasized the necessity for science advice to the Executive, and it pointed out the growing need for this counselling now that environmental, energy-related, economic, defense and disarmament issues all appear to have larger and larger technological components. The outcome was a moderate reduction in the projected size of Press's office, but it did survive the reorganization curtailments and remains, I believe, an effective part of the Executive Office of the President.

A third request, of a more general nature, was that of Senator Adlai Stevenson III to meet with APS officers to discuss the health of science in the US and the appropriate tasks that might be undertaken by the new Subcommittee on Science, Technology, and Space. This subcommittee of the Committee on Commerce, Science, and Transportation is chaired by Senator Stevenson and is part of the new committee jurisdictional structure relating to science that was put in place in 1977 by Congress. We met with Senator Stevenson and his principal aide during the April meeting of the APS.

Initiatives taken with the Government

The three matters upon which I took initiative to communicate to Congress or the Executive Branch related to loss of irreplaceable helium reserves to the atmosphere, tax policy for scientists attending meetings abroad and funding of the Jupiter Orbiter with Probe.

Upon learning of concern in other parts of the scientific community about the dwindling of helium gas reserves as our natural gas wells containing helium are gradually depleted, I asked POPA to examine the issue. A statement was prepared recommending resumption of stockpiling, and I forwarded it to Press. He responded that in his view there is inadequate economic justification now for stockpiling, but he mentioned that the matter will be under study by the National Academy of Sciences, to which I have offered APS assistance through POPA.

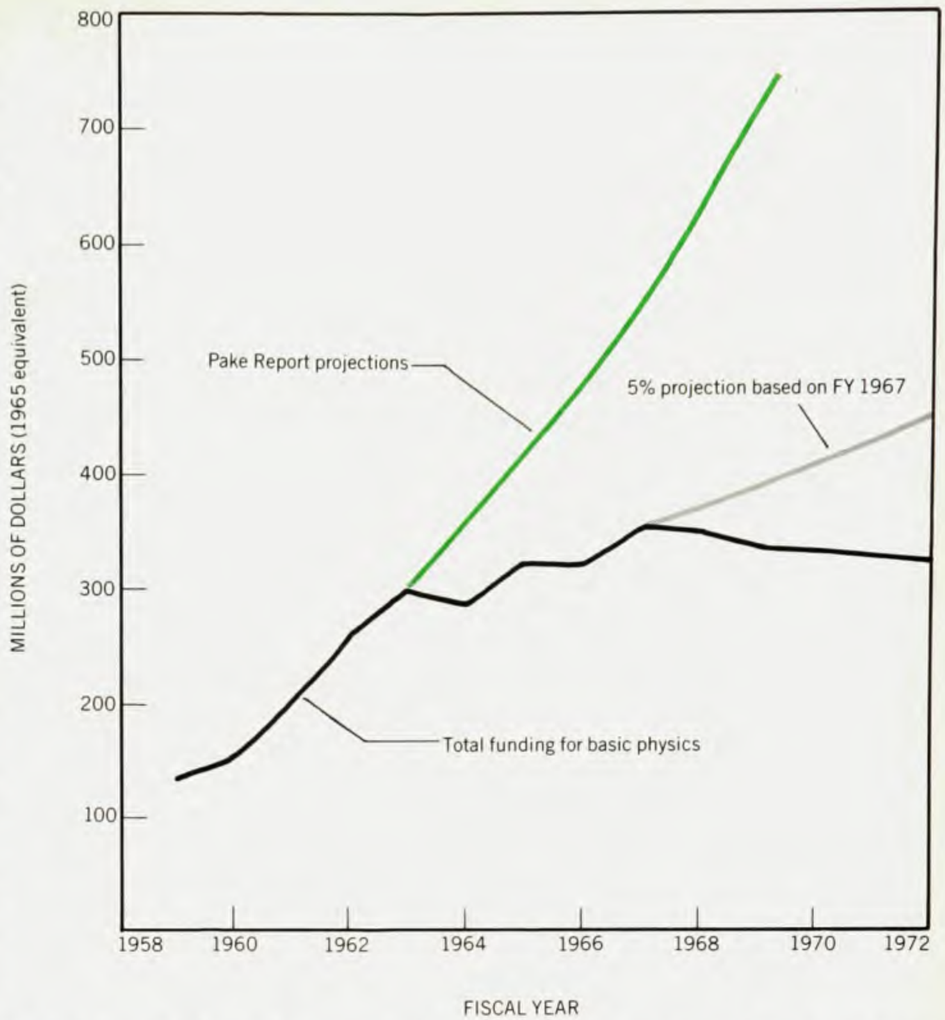
The Tax Reform Act of 1976 prohibits business corporations from counting as business costs the travel expenses of any of their scientists to more than two scientific conferences abroad during one tax year. It also requires onerous restrictions and record keeping on the number of hours of scientific meetings for the two allowable trips. This legislation, which was aimed at alleged tax abuses by professions other than physics, is at least a minor impediment to easy diffusion of physics throughout the world at scientific conferences, and I regard it as discriminatory against industrial scientists in the US. My letter of protest and many others to the chairman of the House Ways and Means Committee have brought the likelihood that the offending provision of the tax law will be re-examined in 1978.

With respect to the Jupiter Orbiter with Probe, I was at first hesitant to speak as president of the Physical Society. My personal interest and support for the planetary exploration program is enthusiastic. But should I write to Congressmen on APS letterhead expressing my concern that threatened cancellation of the JOP would cause the decay of our planetary exploration and space probe tracking resources, including teams of scientists that had been built up over the years? The APS normally does not, and in my view should not, take a position on approval or disapproval of a particular proposed research project. But what if the project in question is one of such magnitude that an entire field or subfield of US science survives or withers with the project? After extensive examination of the facts and a discussion with the APS Executive Committee in June, I decided that the physics of planetary exploration would be put in serious jeopardy if JOP was cancelled. My strong letter of endorsement to several Congressmen was but one of many from the scientific community. The JOP project ultimately was approved.

Only a tiny fraction of APS funds were involved in all of the activities I have discussed here in relation to national science policy. But these matters are anything but routine and require careful and responsible thought as to whether and how the APS president will respond.

APS Studies

On 25 April at the Washington meeting, the principal conclusions and recommendations of the APS Study on nuclear fuel cycles and waste management were released. The full report appeared in the fall, and is now available as a supplement to Volume 49 of the *Reviews of Modern Physics*. The October 1977 issue of



Federal support for basic physics. The colored line shows the projections of the Physics Survey Committee (of which the author was chairman) published in 1966 in *Physics Survey and Outlook*—popularly known as the "Pake Report." The overoptimistic projection resulted from a misinterpretation of the future of academic physics since the mid-1960's. Figure 1

PHYSICS TODAY carried a concise summary prepared by the Study Group.

The report made a major contribution in assessing the problems of potential hydrogeologic transport of radionuclides from a geologic repository to the biosphere. It specifically recommended that two satisfactory geologic test storage facilities be completed in different media, for example bedded salt and granite, and that the more favorable facility ultimately be licensed and expanded into a full repository. While extensive geologic modelling and other significant research investigations were urged, and the needs for institutional and political safeguards were discussed, the Study Group was willing to make the following forthright statement in its summary in PHYSICS TODAY:

> "For all LWR fuel-cycle options, safe and reliable management of nuclear waste and control of radioactive effluents can be accomplished with technologies that either exist or involve straightforward extension of existing capabilities. However, technical choices, including those for geologic waste disposal, require further delineation of regulatory policies. For normal operation of all fuel-cycle options studied, potential radiation exposures from either wastes or effluents do not appear to limit deployment of nuclear power."

The Study Group performed an outstanding service in developing its careful analyses and thoughtful recommendations. The effort proved to be quite timely, because national attention, early in the new administration, was focussed on general issues relating to energy needs, and specific issues relating to nuclear generation of electric power, to breeder cycles, and to nuclear proliferation. The membership of the Society owes a substantial debt of gratitude to the twelve members of the Study Group, to the Review Panel, and to POPA for laboring under unforeseen pressures to complete the report as quickly as possible consistent with high standards of objectivity.

The fuel-cycle and waste-management study, of course, complements the 1974–75 APS study of light-water reactor safety. I believe that the Physical Society has now proceeded sufficiently far that we can make an assessment of the value of

". . . given our seriously clouded energy future . . . a strong case can surely be made for expansion of the research capability of Federal agencies."

our selected studies on those issues of public interest that are illuminated by a knowledge of physics.

The sponsorship by APS of selected studies as a public service was begun in something like its present format during the summer of 1974. The petroleum embargo of the 1973–74 winter had finally attracted public and government attention to the predictable facts of shortages and cost rises in various energy resources. Many of the issues relating to energy supply and use call for substantial understanding of physics. At a time when the science-advisory apparatus was relatively inoperative in the Federal government, APS president Wolfgang Panofsky, the other officers, and Council encouraged summer studies dealing with important energy-related issues.

A report by physicists with implications for public policy obviously differs in kind from the typical report of a physics research investigation. In studies of matters relating to public affairs, questions arise of how to ensure an objectivity consistent with the standards we have set over the years in our reporting of physics research results. To this end, the studies examined only problems with high physics content, and for each study Council commissioned an independent review panel to examine the report for quality and objectivity.

Three reports emerged from the 1974 summer studies. They were "Efficient Use of Energy: A Physics Perspective," "The Role of Physics in Combustion," and "Energy Consumption and Window Systems." Each study made a particular contribution to understanding the problems and opportunities inherent in the "energy crisis."

A fourth study report, "Radiation Effects on Materials," reviewed the state of research and development in order to identify scientific problems that limit progress in energy applications of materials, particularly throughout fission and fusion reactor technology. This report was published as a supplement to Volume 47 of the *Reviews of Modern Physics* in 1975.

All four reports mentioned thus far were of primary interest to the professional communities of scientists, engineers and architects who either practice energy technology or pursue underlying research for those technologies. The four study topics held relatively little opportunity for controversy in a broader arena.

It was a different story, however, for the report on Light-Water Reactor Safety, released in April 1975 and also published as a supplement to *Reviews of Modern Physics* Volume 47. Opportunity for public controversy was great indeed, as anyone who lived in California during the 1976 campaign surrounding the ballot proposition that sought further restrictions on development of nuclear power can verify. Those individuals heard the APS quoted—and, I am sorry to say, misquoted—on both sides of the issue. Even though some factions in the debate may have discredited themselves by misuse of the APS report, I feel confident now that the APS itself was not discredited in any way. My own conclusion is that on balance the report was of substantial benefit in illuminating some of the issues before the public. The strident California campaign offered perhaps the first major test of whether the APS can survive untarnished when one of its public-affairs studies is caught in the wild crossfire of highly emotional political campaigning.

The report on "Nuclear Fuel Cycles and Waste Management" emerged in 1977 into the thick of political contentions over possible risks of waste leakage into the biosphere, and over the proliferation and contamination risks of plutonium *versus* the fuel-extending benefits of the breeder reactor. Again, although not all APS members may agree with the report's conclusions and recommendations, the high standards for objectivity and quality appropriate to The American Physical Society have in my opinion been thoroughly upheld.

The preservation of APS credibility throughout these activities is no accident. With each study and report, the experience gained has led to improved and clarified guidelines for APS studies. The most recent refinement of the guidelines, approved by Council at its November 1977 meeting, appeared in the February 1978 *APS Bulletin*, and I commend it to your study. I believe that, with indispensable assistance from POPA in evaluating APS study experiences to date, Council has incorporated essential protections for the Physical Society while fully enabling education of the public through our analyses of public issues that are informed by knowledge of physics.

The new guidelines spell out in some detail how POPA and Council both select a topic for a proposed study, and how POPA appoints a chairman and other members of the study group and Council appoints an independent review panel. Guidance is also given for the procedure to be followed when the study is essentially complete, and the group's report is submitted first to the review panel and then to POPA for each to recommend to the president and Council whether or not it should be released to the public.

When I first entered my apprenticeship as Vice President-Elect, I must confess that I had real doubts whether The American Physical Society should conduct these public-affairs studies. But watching two major studies reach fruition—and noting the conscientious performance by study groups, review panels, POPA and Council—has erased those doubts. I am a solid proponent of these APS studies as a genuine public service.

At its November meeting, Council approved a new APS study on Photovoltaic Energy Conversion, which is being chaired by Henry Ehrenreich of Harvard. The Review Panel has been appointed, and I am confident this study will continue the high standards set since 1974.

Fellowship Programs

Another public service of APS is the operation of two fellowship programs. The first of these, instituted several years ago, is the APS Congressional Fellowship program. It is clearly successful on several counts:

- Congressional Fellows selected each year are quite impressive and are in great demand for Congressional staffs
- runners-up to whom APS could not make awards are frequently interviewed for regular Congressional or other staff roles and often take such positions. (APS supplies names of runners-up only if they consent)
- Several scientific societies now have programs supporting one or more Congressional Fellows
- Many fellows stay on in Washington, after their fellowship year, in regular staff positions with Congress or with Federal agencies and departments.

The net effect of the Congressional Fellow program is that much higher quality staff help in relation to science- and technology-related issues has been placed in Washington and is continually being added to. Furthermore, the men and women so involved clearly enjoy the work, and a new career path has been opened up for physicists. Congress, the nation, and physicists all benefit.

The second APS fellowship program, just underway this past fall, is the APS Industrial Postdoctoral Fellowship Program invented jointly by Joseph Burton, Treasurer of the APS, and Sidney Millman, Secretary of the American Institute of Physics.

Awards of the first three Industrial Fellowships were announced in late June. The new program was established to broaden the interaction between physics and industry by demonstrating that physics is applicable to a wide variety of industrial problems. These problems may be found in smaller companies that have hitherto employed few if any scientists or in larger companies that have employed few if any physicists. The first three fellows are working for Colgate-Palmolive, for W. R. Grace and Company, and for International Paper.

There are some unique features in the task the Industrial Fellowship Selection Committee must perform. It must make not only a quality ranking of the candidates, but also a judgment of the industrial work opportunity and its potential. Then there must be an effective matching of candidates to opportunities. On considering the several dimensions of quality for both the candidates and the work opportunities, we see that the selection process is a complicated optimization problem in an hyperspace!

Neither of these fellowship programs is large, but I believe they can do much as demonstration examples; indeed the Congressional program already has.

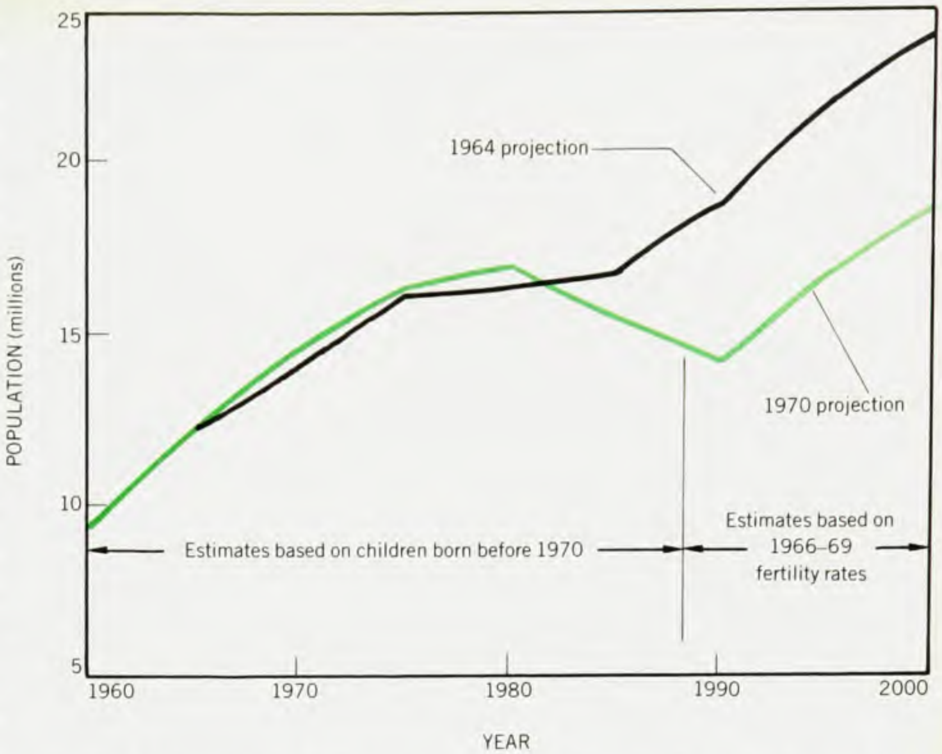
Other notable activities

The core activities of APS are holding scientific meetings and editing and publishing research journals. These activities account for about 90% of APS annual expenditures, and they are presided over with great efficiency and effectiveness by the APS office staff, particularly Executive Secretary William W. Havens, Jr, Treasurer Joseph Burton, Deputy Executive Secretary Mary Shoaf and Assistant Treasurer George Carroll. The Regional Secretaries are pillars of strength in arranging many details for meetings around the country.

The March meeting in San Diego continued the growth trend of recent March meetings. Its 1421 contributed papers and 131 invited papers exceeded the largest number of papers submitted to any previous meeting of the Society. But the number of papers submitted for the 1978 March meeting in Washington has already set a new record.

Another event of note was the establishment by Council of the Leroy Apker Award for outstanding achievement by an undergraduate physics student. The award, which will be made annually beginning with the current academic year, consists of a $2000 prize plus a travel allowance to the APS annual meeting for presentation of a paper at an appropriate technical session. Arrangements for the talk and award presentation will be in collaboration with the AAPT and the Society of Physics Students. The Physical Society is deeply grateful to Jean Dickey Apker for donating an endowment to fund the award as a memorial to her husband and our late friend and colleague, Leroy Apker.

Let me now turn from the past to the future and examine the prospects for physics in the present era. The word "era" may be too pretentious a term for the period in which we now find our science. But I shall use it for emphasis.



Projections of US college-age population. 1964 estimates suggested a 1990 college-age population of almost 19 million. By 1970 the estimate had already dropped to 14 million, which is about 2.5 million below the actual present population. Figure 2

Outlook for the present era

From my perspective, activity as we would define it today has experienced three eras and, in about 1970, entered a fourth. The first, which began to flourish in the 19th century, I think of as bringing order to a large body of experimental observations through elegant mathematical elucidation of classical physics—the mechanics of point masses, rigid bodies and continuous media, the establishment of Maxwell's equations, of the Boltzmann equation, and so on. It is the Classical Era.

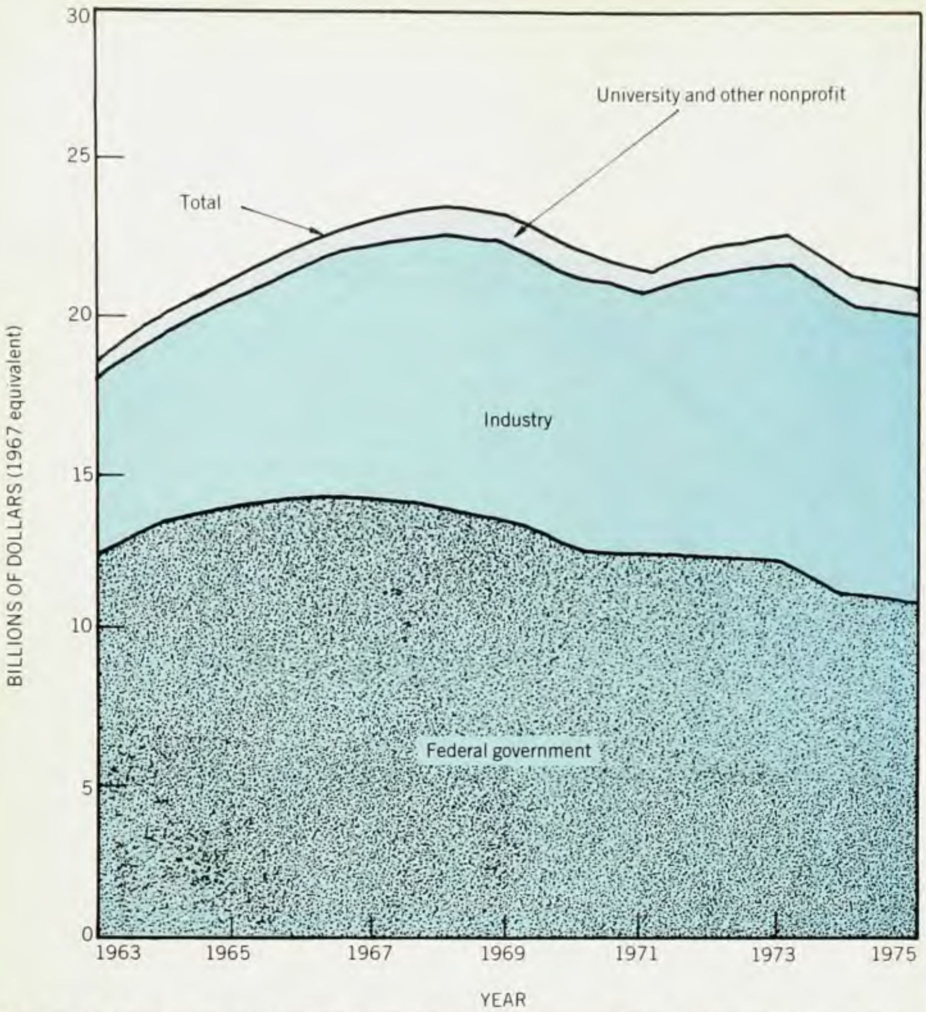
The second is the Era of Quantum Mechanics, entered during a period approximated by the decade 1910–20. This era saw American physics begin the process of achieving parity with European physics, and it is characterized by the marvelous revelations quantum theory provided for us. I would also suggest that, although the special theory of relativity was discovered well before the Quantum Mechanical Era, physics could not effectively exploit relativity until quantum mechanics and the experimental astrophysical, atomic, and nuclear measurements of the second era were available.

The third era was entered during the decade 1940–50. It began simultaneously with the beginning of the Atomic Age, more properly called the Nuclear Age. If characterized in terms of funding to support research in physics, the third era would have to be called the Golden Era. It is less easily described in terms of any particular scientific advance within physics, which may well be indicative of a golden period of funding—many successes across the broad frontier of physics. The whole science flourished as never before, whether it was astrophysics, nuclear physics, particle physics, plasma physics, quantum electronics and optics, or solid-state physics. The Golden Era of physics, like many golden ages, was all too short-lived.

The present era was entered in the late 1960's and early 1970's. Because it is in its early stages, the new era cannot be characterized with certainty. Historical periods are more accurately named retrospectively, and prudence suggests that I simply call it the Fourth Era.

It is interesting to note that the three transition periods after the Classical Era each contained a war that had major impact on the political, social, and economic fabric of the United States—indeed the world. That a new era in physics began at about the time of the first World War is mostly an unrelated coincidence. But there was a direct relationship between events of World War II and the launching of the Golden Era in physics. And the Vietnamese War at least hastened the arrival of the Fourth Era, even though many of the causes of the Fourth Era are rooted in the excesses of the Golden Era.

The Fourth Era seems to be one in which physicists are coming to grips with



Research and development funding plotted in terms of constant 1967 dollars. Projecting trends is a complex problem, but guarded optimism for a continuing gradual increase in the industrial sector appears to be merited. (NSF data; chart based on a *New Scientist* design.) Figure 3

the limits to growth. But let us examine the activities of physicists to see how limited we believe the growth will be. For such purposes, I will analyze physics into five activity sectors:

- Academic: colleges and universities
- Government "in-house" laboratories
- Government "science policy" activities
- Independent non-profit research institutes
- Industrial: companies and business corporations.

The academic sector

I believe the prospects here are for a static physics economy, possibly even until 1990. But experience shows that we should treat such statements with care. Fourteen years ago I was chairman of the Physics Survey Committee organized by the National Academy of Sciences, and after about 18 months of work we produced the report called *Physics Survey and Outlook*. Although we had excellent quantitative data on physics in colleges and universities, our prediction of future growth in the sector proved to be a major pitfall of that report (see figure 1). As William W. Lowrance kindly acknowledges in his evaluation, published in *Science*,[1] of ten NAS Committee on Science and Public Policy Surveys from 1964 through 1974, nearly every assumption—and even some of the bench marks—were shifting rapidly underneath that first physics survey.

A look at these shifts affecting the academic physics model in that survey is instructive:

- The US college-age population for 1990 was projected in 1964 to be almost 19 million, whereas by 1970 that estimate already had dropped to 14 million, which is about 2.5 million below its present number (see figure 2).
- The projected fraction of present and future college age population that will attend college is much below the fraction predicted in 1964.
- The fraction of students attending college who choose a physics major or take any physics courses at all is below the 1964 level, and is decreasing rather than increasing as projected at that time.
- University funding, whether from state legislative appropriations or from endowment income and private gifts, has failed to keep pace with inflation. Where faculty turnover or enrollment growth occurs, teacher/student ratios tend to fall rather than rise as the first Physics Survey assumed in making room for more research activity.
- Research did not in fact spread more widely through the academic system—for reasons ranging from anti-research feelings on campus to the Mansfield Amendment in Congress. The result was level funding or even a decline in federal funds for academic research as measured in real dollars, since about 1967.

But any extenuating circumstances affecting the academic physics model of the Physics Survey Committee (the "Pake Report") still do not excuse us for failing to understand and emphasize that there are real limits to growth, which eventually must assert themselves. Our academic-physics model had the majority of physics PhD's going into academic positions and producing new PhD's at such a high rate that each faculty member would train his potential replacement several times over during his first decade as a faculty member—and he still would have at least two faculty decades to go. Even allowing for the two-year and four-year nongraduate institutions, the net effect of such a system would be to feed a continuing rapid expansion of the academic enterprise for which, at some point, the demographics could surely not supply enough students. How could we miss such a basic point? We were of course lulled by the early 1960's shortages of teachers, of industrial researchers, and of government scientists for space and defense research; the Bureau of Labor Statistics supplied us with projected demand for physicists that appeared to be unmeetable. Those projections were wildly wrong, but so satisfying to us that we did not examine the implications critically enough.

The other non-industrial sectors

At this moment a prudent projection for government "in-house" laboratory research is for a static economy. I cannot quite imagine Congress increasing appropriations for these laboratories appreciably faster than inflation. Yet, given our seriously clouded energy future and the need for better understanding of physical processes that bear on environmental issues, a strong case can surely be made for expansion of the research capability of Federal agencies. If there is such expansion, it seems likely to be gradual; no rapid expansion of the early 1960's NASA variety is in the cards as I see them.

On the other hand, it may well be that government science-policy activities, including such tasks as technology assessment and environmental impact evaluations, will create a substantial demand—or at least opportunity—for physicists at all levels of government. I am much impressed by the opportunities open to our Congressional Fellowship "graduates." There is a rapidly growing involvement of federal, state, and local governments in policy making, assessment and regulation

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roles that benefit from a fundamental science background. Unfortunately I do not know how to quantify this need or opportunity. The influences that create whatever opportunity may be here are closely allied with those that have brought The American Physical Society to establish the Panel on Public Affairs and to pursue APS studies in the public interest. These influences are clearly one mark of the Fourth Era.

The present time does not appear to be propitious for establishing new independent non-profit research institutes such as SRI International or the Mid-West Research Institute, although the established institutes may very well experience modest controlled growth. If they do, they represent a rather small segment of the US research system, and could not provide many new opportunities for physicists.

Physics in industry

Because none of the first four sectors holds promise for major stimulation of the physics research economy in the near future, it is natural to look toward the last sector, industrial physics. The history of US R&D funding over the last dozen or fifteen years supports the notion that industry at least is more steadfast than the federal government in its commitment to R&D.

Figure 3 shows R&D funds since 1963 in terms of constant 1967 dollars. I believe that the outlook is for continuing gradual increase, even allowing for inflation, in the real dollar outlay of American business for R&D.

My prediction of a steady increase, in constant dollar terms, in US industrial support of R&D can surely be questioned. There are many forces at work to upset the prediction. Perhaps most important is the impact of government policies on industrial investment in R&D. Among the critical policy areas are, of course, direct government investment in R&D and tax policy toward all kinds of business investment including R&D. Other factors, such as severe price competition from abroad, place countervailing pressures on R&D spending: our nation's best hope to meet foreign competition, given US labor costs and taxation policies, is technological superiority. But loss of revenues and profits reduces the ability to invest in the R&D to achieve or maintain the technical superiority. Analyzing all of these factors is beyond both my capability and available time. There are many danger signals and there is plenty for the US to worry about here. Aware as I am of all the danger signals, I nevertheless believe American industry will maintain its steady gradual increase in real R&D investment.

If my guarded optimism is vindicated as history unfolds, there are still two critical questions to be answered before we can interpret the prediction in physics terms:

(1) What fraction of industrial R&D will be "R"?

(2) What fraction of the "R" will be physics or physics-related?

A variant on question (2) is: What fraction of the R&D will be done by physicists? Thereby arises a comment that I should like to make from my vantage point as a physicist with responsibility for a research center in industry.

During what I called the Golden Era of physics, and certainly during the World War II transition into the Golden Era, physicists were sought for many challenging engineering and technological roles. The physicist's background in fundamentals and his ability to devise, understand, and adapt to new technologies was highly prized. This appears to be much less the case in the present Fourth Era. Part of the reason for the change is undoubtedly that engineering education in the 1930's had not kept pace, whereas engineering training in the last decade or so has co-opted much of the background and outlook that formerly only physics training seemed to offer. At least some of my counterparts in industrial research management are concerned that physics graduate education may have lost some of its contact with the background and skills applicable to the technological roles on the development side of R&D. I do not know whether that is in fact the case. From the point of view of the market for physicists, we should bear in mind that the "D" portion of R&D is much the larger portion in terms of the resources required. If physics becomes so defined—and physicist's interests and skills so confined—that there is little role for physicists in the development activities of industry, then in my opinion both the physics community and the vigor of the US technological development effort will suffer. I believe that the community of physicists possesses, to a degree unmatched by any other science, a depth of understanding, an awareness of the na-

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ture of the evolving edifice of a true science, an appreciation of the interplay of experimental and theoretical forces throughout the structure, and an ability to elaborate that structure *and* to extend it in new technological directions. If that perception is correct, then the *entire* US R&D enterprise needs a substantial physicist presence.

What of the impact that a gradual expansion of US R&D effort in industry could have for physics in its Fourth Era? My conclusion is that much depends upon the physics community itself. The world will not beat a path to our door as it did in the Golden Era. But there are real needs to be met, and physicists have much to contribute toward meeting them. We should be persistently alert to opportunities for physics and physicists to make those contributions.

National Research Centers

In recapitulating this little examination of the five sectors of physics activity, I have arrived at the unsurprising forecast of limited growth but of some opportunity to make significant contributions. Only one of the sectors seems to me to have really serious internal troubles, and that is academic physics. The absence of entrance opportunities for young physics faculty is a critical problem both for physics and for higher education. And if there is a critical problem for university science, it ultimately has a serious impact upon those of us in industrial research, because we depend upon universities to build the fundamental science base upon which we rest our efforts to solve our applied problems, and we of course depend upon the universities to train those scientists we shall hire in the future.

As the first APS president to come from industry since Harvey Fletcher in 1945, let me take advantage of my non-university affiliation for a personal endorsement of a proposed federal program that would designate a number of university science departments as National Research Centers to provide new research opportunities in the university setting. I will quote from the originator of this idea:

> "Each Research Center might receive start-up funds, coherent area grants, with funding for 3- to 5-year periods from government agencies .... The Centers would be staffed primarily by recent PhD's who would be supported full-time by government grants. The universities would undertake to grant rolling 3-year periods of tenure .... Faculty members in departments might become researchers at the centers for periods of 1 to 3 years, and vice versa. These centers would enable universities to bring young scientists into the university community, in close connection with established departments, and in this way assure the flow of the best young minds into the basic research structures of the universities."

These are the recent words of Frank Press,[2] the President's Science Adviser, concerning a suggestion he had published in *Science* magazine prior to assuming his present duties.

The National Research Center idea is receiving study, and Press has impressed President Carter with the young faculty scientist problem in universities to the extent that the President drew attention to it in his remarks preceding the award of the National Medals of Science last November.

Clearly the vigor of physics activity in the Fourth Era will be strongly affected by public policy toward university science, toward fostering—or at least not inhibiting—industrial R&D, and toward bringing our nation's scientific resources to bear on energy and environmental problems.

No review of this past APS year would be complete without taking pride in major recognition achieved by our members. I mentioned above President Carter's awarding the National Medals of Science for 1977; no fewer than six of the fourteen awards were to APS members. From the viewpoint of your officers, we rejoiced that Samuel Goudsmit, whose journal-editing talents served the APS so long and so well, was recognized along with, of course, George Uhlenbeck.

Two of our members shared the 1977 Nobel Physics Prize with Sir Nevill Mott: John VanVleck, who was president of this Society in 1952, and Philip Anderson.

I have been proud to serve as APS president. As Norman Ramsey takes the reins, to be followed by Lew Branscomb and Marvin Goldberger, we all can be assured that the future leadership of the Society is in superb hands.

References

1. W. W. Lowrance, Science **197**, 1254 (1977).
2. F. Press, interview published in *Research Management*, September 1977, page 11. □