BROOKHAVEN NATIONAL LABORATORY

Physics manpower: present and future

This summary of the APS Physics Manpower Panel's report explores the employment paths of recent PhD's, looks at attitudes and expectations, and makes projections for future supply and demand.

Ralph A. Alpher, Milan D. Fiske and Beverly Fearn Porter

The decade of the 1970's has been a time of turmoil and transition for the support of physics and physicists, especially of young physicists just completing their graduate years. Science, the Endless Frontier, had come to have financial horizons quite close in during the late 1960's and early 1970's. A whole generation of physicists had become accustomed to automatic careers, in which demand so far exceeded supply that the greatest problem was to choose among desirable alternatives. The great expansion of higher education had created limitless opportunities in the mode most familiar to the graduate student, and academic research—perforce with some teaching—became the normal career goal.

There were warnings in the 1960's and plenty of signs (especially to the retrospective eye) that the days of glory were limited, but demography and the federal budget finally broke the spell. It suddenly appeared that there weren't enough babies to fill, some years ahead, classrooms already built; and since science hadn't done anything for the country lately, wise heads in Washington decided federal largesse should be diverted to more pressing demands. The cutback in federal funding of research had really started in 1967 or so, but its impact was clear and present by 1970.

The Council of The American Physical Society in 1969 established the ad hoc Economics Concerns Committee, chaired by Lee Grodzins of MIT, to gather the facts on the employment situation in physics, particularly of new PhD's, and to make projections of future employment. A series of reports by the Committee and by Grodzins documented the seriousness of the situation and forecast the lean times ahead that the physics community has experienced through the 1970's. There followed an increasing involvement of APS in matters much more concerned with professional aspects, public policy, and employment of physicists than had traditionally been the case. New instruments were created: the standing Committee on Professional Concerns, the Panel on Public Affairs, the Committee on the Application of Physics; recently, the Congressional Fellowships and the Industrial Fellowships, and, in 1976, the Physics Manpower Panel.

By the mid-1970's the initial trauma had passed, and it had become clear that a permanent or at least long-lasting

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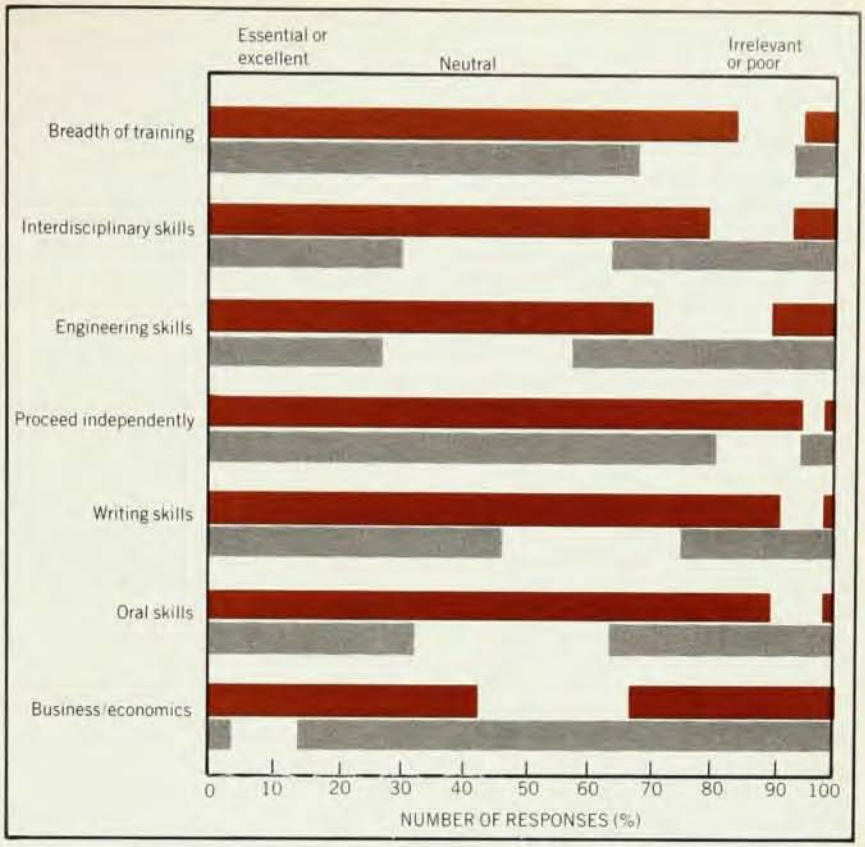

Views of industrial respondents on the need for some aspects of graduate physics (colored bars) and the adequacy of training in those aspects (gray bars). The length of the tinted bar to the left of each white gap denotes the percentage of respondents rating the need or adequacy as "essential" or "excellent" (1 or 2 on a scale of 1 to 5); the tinted bar to the right denotes the percentage ranking the need or adequacy as "irrelevant" or "poor" (4 or 5 on the 1–5 scale). The white gaps reflect "neutral" responses. Each question was answered by around 1500 respondents. The views of current graduate students on the adequacy of their training did not differ significantly. (See page 49.)

change had occurred. Future growth in physics employment would lie mostly outside academe, in directions not too well seen, in activities not currently among the central aspirations of embryonic physicists. What these new opportunities would be, and how many of them there might be, and indeed a reliable figure for traditional employment prospects—these were largely unknown. Furthermore, there was a strong feeling that the physics community should know what had happened to it and especially to its young, growing edge through the years of change. Especially there was a demand for forecasts, for an early-warning system foretelling and giving wide cognizance to such changed circumstances as had shattered the hopes and plans for so many during the previous decade.

The APS Council established the Physics Manpower Panel in February, 1976, with one central task: "to identify and to quantify long-term trends in the supply and demand for physicists" (Task I). Auxiliary to this was the charge "to discern those changes which may be needed in the training of physicists to prepare them better for future occupational demands" (Task II). In response, the Panel proposed (and Council funded) a series of studies for Task I; specifically they proposed searching out the employment paths of recent physics PhD's and identifying the attitudes and expectations associated with these paths, and then projecting supply and demand for PhD physicists into the foreseeable future. The Panel was unable to devise and implement any comprehensive approach to the second charge (Task II), but it did explore three new and different programs related to graduate physics training. Limitations of space in this present article preclude discussion of these programs of Task II, for which the interested reader is directed to the full report of the Manpower Panel.

Of the employment paths taken by physicists, those in academe were most familiar, at least in a general sense. Yet what had happened to the thousands of young physics faculty and postdoctorals who had left universities and colleges in the 1960's and 1970's without receiving tenured appointments? A decade previously they would have been secure in a position of their own choice, typically in academe. Where were they now and how had they got there, how did they regard their investment in physics, what measure of fulfillment did they achieve—these are important questions, particularly for young people now considering career alternatives, physics among them.

Of the major non-academic employment centers, faculty and students were most familiar with national laboratories, such as Brookhaven or Oak Ridge, less so with government laboratories such as the National Bureau of Standards and Naval Research Laboratory, and even less with industrial laboratories, especially the smaller ones. Of the lives of the consultant, the small entrepreneur, the government adviser, essentially nothing was known. There was clearly a need here for greatly improved understanding of what physicists did and what they thought about it in these strange lands.

Three studies were carried out in pursuit of these questions, two following the careers of young faculty and postdocs, one focussed on the industrial physicist. We will discuss these studies in the following three sections.

"Supply" and "demand," poorly defined terms when applied to employment of PhD physicists, become exponentially murky when projected even as much as a decade into the future, and this is especially true of demand. Nevertheless, a careful analysis of the elements of each can be enlightening. The final study reported here looks into the next decade with some optimism for the future of physics employment.

Mobile young faculty

During the 1960's and 1970's thousands of young faculty left the universities and colleges where they taught and conducted research in physics, without receiving tenured appointments. With tenured positions becoming increasingly scarce, this pattern is expected to continue during the coming decade.

In the fall of 1976 a survey was conducted of nearly 400 junior faculty who left seventeen major physics departments between 1962 and 1975. The primary purpose of this study was to explore what happened to junior faculty who did not receive tenure at selected major physics departments. The major concern centered around the question of whether physics, particularly physics research, was increasingly losing many of its best and brightest prospects because no room could be found for them at the top universities. The spectre of the cartoon physicist forced to drive a taxi cab haunted many in the physics community. We sought then to determine where these physicists had gone, the ways they used to get there, what they were now doing, and

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how they felt about their past experiences and current positions.

The mobile faculty were sent a nine-page questionnaire including demographic, employment, work history, and attitudinal items. A 73% response rate brought replies from 273 individuals.

The study population. The assistant professors who left seventeen top universities without receiving tenure were predominantly young, male, US citizens who had received their PhD's at the top US and foreign physics departments during the early and mid-1960's. Their dissertation subfields were concentrated; over 80% came from the four major physics subfields of elementary particles, nuclear physics, solid-state physics, and atomic and molecular physics. Elementary-particle physicists represented an unusually high proportion, over one-third of the total group. When these assistant professors began their junior faculty positions, their career goals were clear. They wanted university careers in basic research and teaching, although not necessarily in their dissertation area. They did not want straight teaching careers; they did not want to become involved in industry, government, or administration.

Departure. The junior faculty positions that these assistant professors left were heavily research based. During this period the group published heavily, gave invited papers, and received awards and grants.

However, they left—with actual or anticipated tenure denial being the primary factor influencing their departure. As indicated in the table on page 49, while those who left in the early 1960's faced a quite good job market, there were clear signs of change even by 1966. By the late 1960's the scene had sharply changed with well over half of the respondents finding a tight physics job market; and by the 1970's the picture was very serious with all but a few realizing they were facing a difficult situation. More than two-thirds of the respondents left their assistant professorships during these later difficult periods.

Despite the tightness of the academic job market most of the respondents sought tenure-line university positions. Some explored research positions in Federally Funded Research and Development Centers, industry, four-year colleges, and abroad. Very few considered employment in government, any non-academic development or administration, junior colleges or high schools or in areas outside of physics.

Although several respondents noted that they had to search extensively, three-quarters of them had found a new position within six months. Few experienced any periods of unemployment. In looking for new employment, the major means used and the most successful at all periods of time remained personal contacts made by former professors and colleagues; few made successful use of such formal means as journal and newspaper ads, placement services or employment agencies.

Current employment. In the fall of 1976 only slightly over one-half of the original group of 273 assistant professors were employed at colleges and universities in the United States. One-third were employed in FFRDC's, industry and other non-academic areas while over 10% were employed abroad, most returning to their home countries. Those who left their positions in the 1970's and late 1960's were less likely to have found academic employment and more likely to have turned to non-academic employment than those who had left in the early and mid 1960's.

Changes also occurred in subfield concentration. Since writing their dissertations one quarter had changed to another physics subfield while 12% had left physics altogether. Those no longer in physics, dominated by the group that left faculty positions during 1971–76, went heavily into non-academic employment, in such areas as mathematics, computer science, engineering, geology, environmental science, medicine, political science, business and general administration.

Job satisfaction. Despite the different changes noted above, over 80% of the respondents felt satisfied with the professional challenge, autonomy and independence and opportunity to utilize their physics training that their current positions offered them. The first two of these dimensions they considered of major importance in a job. They were much less satisfied with several organizational dimensions: teaching load, internal politics, administrative responsibilities, number of assistants, and student quality, although they ranked none of these as important aspects of a job. Those working at the top-rated university departments and those in non-academic physics positions tended to be more satisfied with their current jobs than those in lower-rated university departments. (We used the so-called "Roose-Andersen" ratings; K. D. Roose, C. J. Andersen, *A Rating of Graduate Programs*, American Council of Education, 1970.)

Faculty in the lower-rated graduate departments and in colleges, together with those respondents who had left physics, were (for quite different reasons) the ones least satisfied with their employment. The former group was particularly dissatisfied with the strength of their departments, and the research funding, time and assistance available to them. Those who had left physics were mainly dissatisfied with the lack of opportunity to use their physics training and their job security. Yet, even these groups were highly satisfied with the professional challenge their jobs provided, the one aspect all groups considered most central.

While a few respondents had become alienated, for most the transition from the junior faculty position at top physics departments, although not always easy, was accomplished quite well.

Looking back. One quarter of the group

Transition in Physics Doctoral Employment

This article is a condensation of the APS Physics Manpower Panel report entitled "The Transition in Physics Doctoral Employment 1960–1990."

The members of the Physics Manpower Panel are:

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The complete 350-page report is the work of Alpher, Fiske, Grodzins, F. S. Ham (General Electric Corporate R&D), Kahn and Porter. Copies can be obtained from APS, priced at $5.00 for the complete report or $2.00 each for the separately issued sections:

Executive Summary (Fiske)
Mobile Young Faculty (Porter)
Transition—a Follow-up Study of 1973 Postdoctorals (Porter)
A Statistical Study of the PhD Physicist Employed in Industry (Alpher, Fiske, Ham, Kahn)
Supply and Demand for PhD Physicists (Grodzins)

The Review Committee for the work of the APS Physics Manpower Panel consists of:

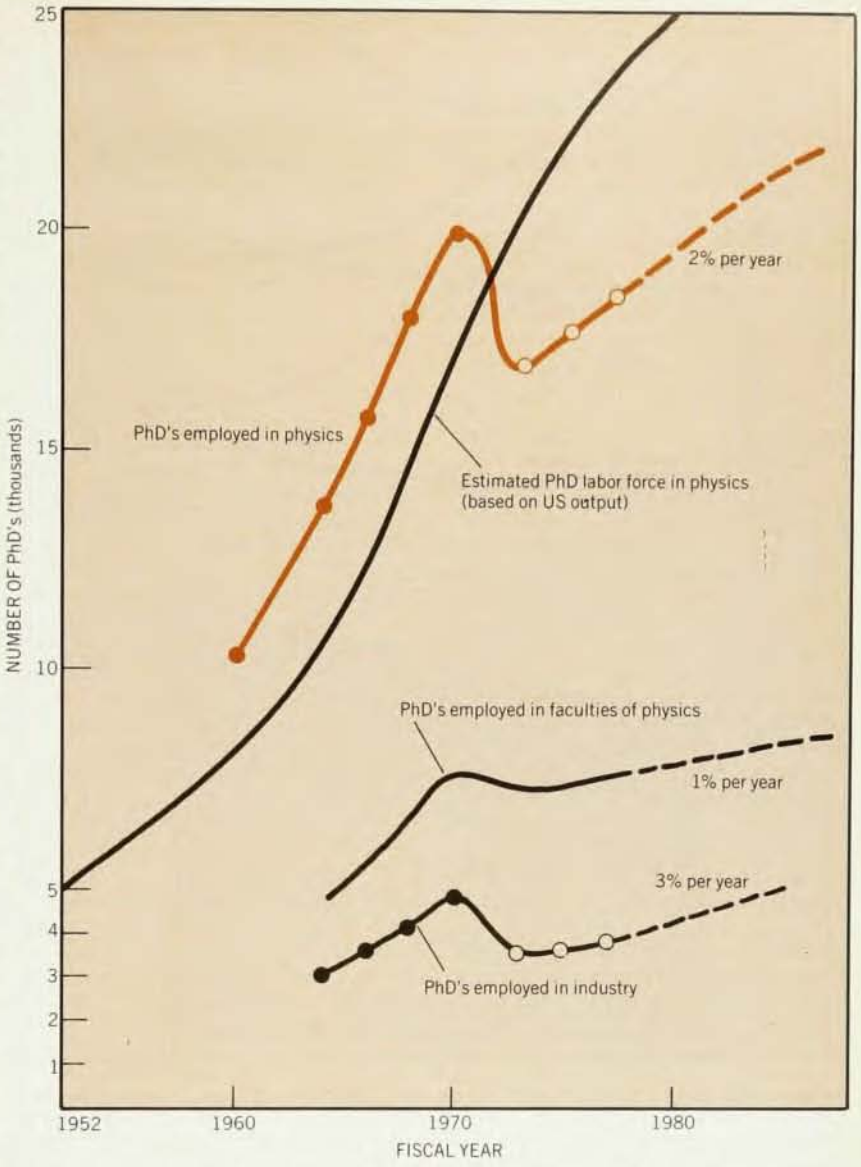
William C. Kelly—Chairman (National Research Council)
Eugen Merzbacher (University of North Carolina)
David Robinson (Carnegie Corporation of New York)

saw some weaknesses in their graduate training, mainly in the areas of experimental and applied preparation. There were fewer negative reactions from the group when their theoretical background and their general physics training were considered, and only a very few would have changed their area of specialization within physics.

While a minority indicated any training deficiencies, nearly half outlined areas of information that would have been of aid to them in graduate school: projections of supply and demand, a fuller explanation of what non-academic positions entailed, a broader knowledge of fields within and closely allied to physics, some knowledge of the "real" academic world of grant applications and tenure decisions, and better counseling and faculty transmission of job market information.

The future. Many in this group had faced hardships and difficult changes. However, most had landed in relatively satisfactory positions and few were planning any further career changes. Would they recommend physics as a field of study for others in the future? 18% said they would not recommend it, 60% said they would, and 22% were more ambivalent, frequently giving qualifications—for example: "if the student were very bright, if he was dedicated to the field and if he understood the limited opportunities which lay ahead particularly in academe and was still determined, then I would recommend physics."

With qualifications, then, the majority would continue to recommend physics. And this trend held true both among earlier and more recent degree holders, among those still employed in their original subfield and those who had changed, among those still working in academe and those now employed in non-academic sectors and even among those who had left physics.



Estimated physics labor force. The colored line indicates PhD's employed as physicists; it exceeds the US PhD output in physics until around 1970 because of the net flow into physics from other fields and from abroad. Solid data points are from an American Science Manpower series; open points are from a National Research Council survey. (See page 52.)

Postdoctoral follow-up study

The postdoctoral position is a familiar and traditional one in the field of physics. In the past decade between 25 and 40 percent of each new crop of physics PhD's have held temporary postdoctoral positions. These positions have provided the new PhD with an opportunity to further his research experience and to delve more deeply into complex problems, temporarily freed from teaching and administrative responsibilities. For a physicist aiming at a faculty or staff position in the top research-oriented universities and federal labs the postdoctoral position has clearly been a traditional, frequently necessary, stage in the development of his career.

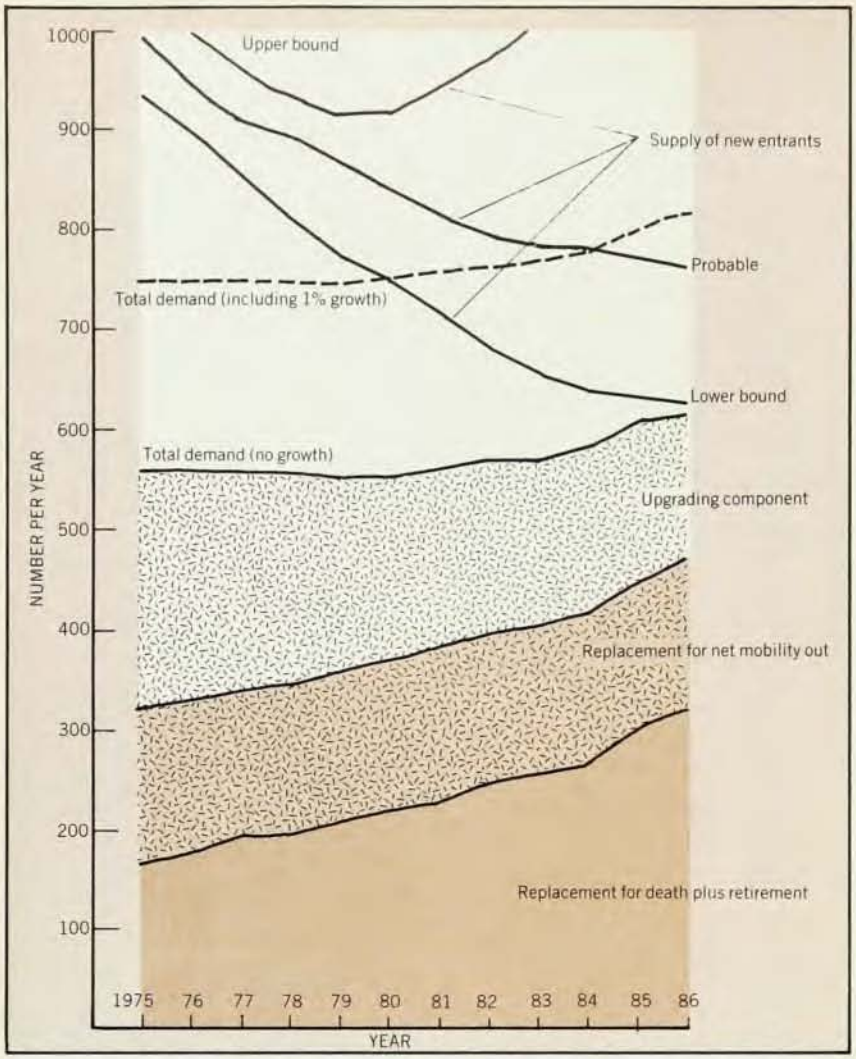
In the changed job market of the 1970's these traditional areas for postdocs' later employment were—and promised to remain—very tight. Yet in 1973 an estimated 2000 physicists and astronomers, including over 40% of the class of 1972, were holding postdoctoral positions. It was suspected that many of these postdocs took these positions because they could not find other suitable employment, and had settled into a temporary holding pattern.

The role of the postdoc in the early 1970's had probably changed in unknown ways; the future of these postdocs posed even more challenging questions. How did these physicists caught in the stream of change proceed with their careers, either within or outside of physics? And how have they been affected?

Such questions led to a follow-up study four years later of the group of physicists who had held postdoctoral positions in 1973. In 1977, a seven-page questionnaire was sent out to over 1400 of these 1973 postdoctorals. The response rate was 61%.

This is a report of instability, transition, and change. Four years is a short period in a career and, particularly when it is at the beginning, change is paramount. However, physicists continue to hold temporary postdoctoral positions in relatively large numbers. This report may provide the new generation with at least an opportunity of examining the experiences, both positive and negative, of their peers who passed through but four years ago.

The postdoctoral position. Following their PhD's from top universities in the early 1970's a large proportion of these postdocs first sought other positions, mainly within the academic structure. They chose to



Supply and demand. The three upper curves show projected supply rates, ranging from an admittedly improbable upper bound to a somewhat pessimistic lower bound, for new entrants into the physics employment market. Demand is illustrated in its three basic components and projected totals for "no growth" and "1% annual growth" assumptions. By the early 1980's the number of positions opening up each year should equal the number of new entrants. (See page 53.)

take the temporary postdoctoral positions both for the traditional reason (expanding their research experience) and the more economically based one of having some physics-related employment until they could secure more permanent positions (what we call the "holding pattern"). A smaller number used the postdoctoral position to move into another research area, occasionally out of physics altogether.

Nearly three-quarters of them took their postdocs in academic institutions, the remainder in FFRDC's and government labs.

For most of these physicists, the postdoctoral position provided research experience and, they felt, enhanced their professional reputation. Those who had taken postdoctoral positions in medical physics and biophysics also found the experience useful in defining their career objectives and changing fields.

Most of the respondents, however, did not consider their postdoctoral positions an asset in obtaining job offers, defining or achieving their career objectives or competing with colleagues. Many felt the postdoctoral position had simply been irrelevant. This was particularly true for those now employed in industry.

In terms of job security, most felt the postdoctoral position had clearly proven to be more of a liability than an asset. The feeling of lack of security was a theme permeating these responses. Postdoctoral positions in the past were stepping stones to secure academic positions; they have not proven to be so for this group.

Careers after the postdoc. For one-half of these physicists, the postdoctoral position described was the only one they took. One-third, however, had held two postdocs; 13% had held three or more. While a sizeable proportion (23%) stayed with their postdoctoral employers, particularly in the FFRDC's, the majority contacted employers directly. Formal mechanisms, such as job placement services, advertisements and so on, were used by only a minority. While tenure-line university positions were of major interest to this group, the search patterns in non-academic areas were fairly broad.

In 1977 one-quarter of these physicists were still in postdoctoral positions or holding non-tenure-track academic positions. Another quarter had found apparently tenure-track positions; the remaining half were in non-academic employment, primarily the FFRDC's and industry. This distribution was a major departure from the heavy academic dominance of their postdoctoral positions.

In terms of subfield, elementary particles, solid-state physics and nuclear physics experienced heavy declines between the postdoctoral position and current employment. Astronomy appeared rather stable, while employment in optics and medical physics both approximately doubled during the transition between postdoctoral position and current employment.

It is estimated that between ten and fifteen percent of this postdoctoral group has left physics—four years after their 1973 postdoctoral position.

Job satisfaction. Three-quarters or more of the respondents were satisfied on their current jobs with their freedom to publish, the congeniality of work relations, voice in selection of research problems and professional challenge. Less than half were satisfied with the internal politics, deadline pressures, and lack of job security. The latter was of particular concern to them. Overall the most satisfied group appeared to be those working in the FFRDC's, the least satisfied those employed in industry.

However, job satisfaction was not a simple single dimension. In areas related to individual choice (freedom to publish, voice in research-problem selection and autonomy and independence) those employed in the colleges and lower-rated universities appeared the most satisfied with their employment; those employed in industry the least. When it came to research facilities, funding and time for research, physicists working in both those spheres appeared equally deprived, in strong contrast to those working in the FFRDC's, government installations and the upper-rated Roose–Andersen departments.

Those working in industry were quite satisfied with their salaries, fringe benefits and job security. In contrast, less than half of those employed in academe were satisfied in these areas.

Despite such tradeoffs and the fact that no matter where these postdocs were now employed they were likely to encounter professional challenge and to use their physics training, it must be noted that

those now employed in industry and to some extent those employed in colleges and the lower-rated universities are not finding as much satisfaction as their colleagues. Part of these groups' dissatisfaction appears related to their lowered research involvement. After spending several years beyond the PhD concentrating heavily on research, they have had to make abrupt changes. Many are still in the midst of transition and finding it difficult.

Looking back at their graduate training, a majority felt their graduate courses had prepared them well for their future employment, although a substantial proportion, particularly of those now working in industry, wished they had developed a better grasp of the applied aspects of physics when they were in graduate school.

Their reaction to counseling and faculty attitudes was less positive. Nearly two-thirds felt that their graduate schools had not provided adequate counseling, half felt their advisers were not well-informed on the physics job market and over 40% felt their advisers had disparaged nonacademic employment.

If they had it to do over again most would still go into physics; 30%, however, would have chosen other areas, medicine and engineering predominating. Looking ahead, less than half would recommend physics as a career to others, primarily due to the insecurity they experienced and the tight job market they foresaw. These will be matters of continuing concern to the physics community.

The PhD physicist in industry

The life of physicists employed in industry is poorly known with any generality, and certainly much less known than that of their counterparts in academe. A solid body of data concerning industrial physicists has been needed, describing what they do, what their careers have been and what they think of their lot. This information is especially needed now in graduate physics departments, since the industrial sector offers probably the largest potential for future employment of new physics PhD's.

It was the purpose of this study to develop a base of selected data concerning the PhD physicist in industry, and to present such insights from these data as suggested themselves for consideration, particularly by graduate students making initial career decisions, and by physics faculty who develop physics curricula and provide career guidance for students.

We sent questionnaires to some 3400 PhD physicists in US industry; the 53% overall response included 1642 usable returns. The 25 questions sought out the attitudes and events that led the respondents to their present positions, asked what their career histories have been and what they now do, what ambience, rewards, constraints and so on they find in industry, and finally various demographic data.

A supplementary graduate-student questionnaire asking four of the same attitudinal questions was sent to every physics department in the AIP Graduate Program Book listing more than 30 full-time PhD graduate students in 1977–78. It was important to do this in order to sense the extent to which views had changed, if at all, between the graduate days of the industrial respondents—a median of 15 years ago—and the present day. There were 787 usable returns from the 3000 questionnaires sent out.

Why and how to industry. The first eight questions addressed the circumstances surrounding the path to employment in industry, including attitudes recollected from student days (and in comparison. those presently held), initial career objectives, options available, finding the first job, and so on.

About two-thirds of the respondents had had industry as a career goal. This was not a career choice looked on with great favor by faculty. In fact, 51% of the faculty were remembered as considering it undesirable, only 12% as desirable. Moreover, the faculty was of little help in locating a job in industry. By far the most successful means were direct contacts between the individual and his prospective employers or their campus recruiters.

As a fraction of jobs offered, industrial offers have steadily risen, offers from Government laboratories have steadily fallen, and those from other types of institutions have remained about the same.

Of the 1642 respondents, half were employed in just three states—California (22%), New York (15%) and New Jersey (13%). Fifty were self-employed; the remainder were distributed among 385 different employers. The seven companies who employed 40 or more respondents accounted for 32% of the total responses. At the other extreme was but a single respondent from each of 252 different firms.

What do they do? This section of six questions sought data showing how physicists perceive their activities.

Their activities can be sorted, after a fashion, by how they spend half or more of their time. In this sense, 12% of respondents are in basic research, 42% in applied R&D and 29% in management. Those in basic research average only 17% of their time in applied R&D and trivial amounts elsewhere; those in applied R&D spend only 6% of their time in basic work, and 10% in management. Those in management do little else, applied R&D heading their list at 15% of their time. Fifty-one percent of respondents spent more than 40% of their time with one to three colleagues, and 19% with a large team. Basic research is almost entirely an individual effort; very little such research is done by a large team in industry.

Solid-state physics was the leading subfield of primary use in present positions, and was also the leading dissertation subfield. Optics, electronics and electromagnetism, however, which rank among the five most important subfields in industry, together accounted for only 9% of thesis specialties.

Only 50% of all respondents considered their physics background essential in their daily activities, but virtually all the rest found it useful. A surprising 38% of those in management regarded their physics experience as essential to what they do.

In general, the areas where training appears weak, particularly in view of the needs perceived on the job, include interdisciplinary training, engineering, writing and oral skills as indicated in the figure on page 45.

Respondents rated a list of 18 present job attributes. Their responses indicated job satisfaction overall to be high, with 60–80% "very satisfactory" or "satisfactory" contrasted with 10–20% "unsatisfactory or very unsatisfactory" on most of the 18 items. Most cited of the desirable aspects were "salary" and "professional challenge," while the leading undesirable aspects were "internal politics" and "management." The Table on page 52 gives more detail of these ratings.

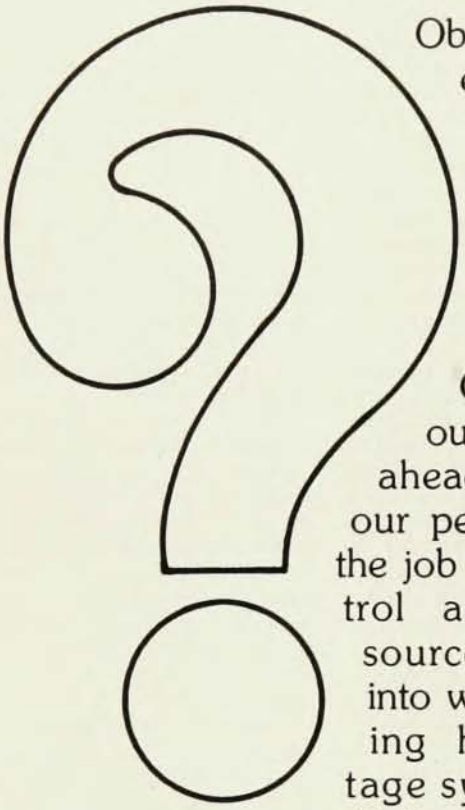
What is it like? These final ten questions touched on a potpourri of activities and relationships involving industrial physicists in ways perhaps different from those affecting their colleagues elsewhere; namely, their rewards, constraints, publications, professional and academic interactions.

Perceptions of the job market

Year left Junior-faculty position	GOOD	TIGHT	N
1963–65	73%	0%	37
1966–67	45%	21%	38
1968–70	12%	62%	68
1971–76	2%	85%	96

From a survey of physicists leaving junior faculty positions.
Column headed "N" shows the number of respondents in each category.

In order to provide answers one must first understand the question.



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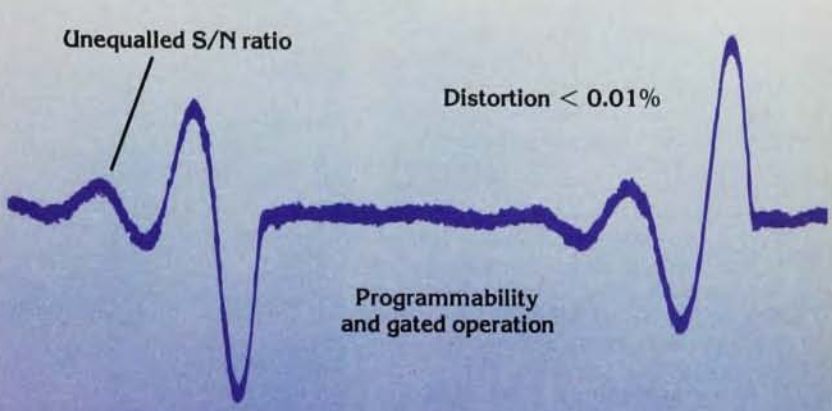

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In the familiar area of publications, it was found that the average respondent published slightly more than one publication per year in professional journals and conference reports, nearly two company technical reports per year, and produced a patent every four years.

There is a strongly bimodal distribution of interaction with the professional community, as measured by travel to professional society meetings and other laboratories. Perhaps a third of the respondents reported few if any such trips, while a third averaged three or more trips per year each to meetings and other laboratories. Professional involvement appears to be very much more a matter of personal inclination than of institutional setting or work activity, and is a common thing for physicists in industrial life.

In contrast with a popular image, respondents reported themselves as typically "very little" constrained in speaking out, either within their company or publicly, about a variety of issues, political, social, economic and so on. In fact, they saw themselves as little different from their academic colleagues in this regard.

Comments were invited at a number of places through the questionnaire, and the concluding question was an open-ended invitation for comments. All told, there were nearly 3000 responses, some quite lengthy. Here are two whose themes recurred often:

"Physics is a superb vehicle for training people how to think. Unfortunately, however, physicists are regarded as specialists, and many of those specialties do not command a high value in the market place. The point must be made that physicists (especially successfully trained ones) are generalists who can move in effectively to exploit new fields or to bring new approaches to old ones."

"It would be most helpful if emerging PhD's could have some appreciation of industry as a meaningful institution of society which provides a vehicle for problem-solving, and also have an equally important appreciation of their training as a tool rather than an end in itself. The goal of R&D in industry is to maintain the long-term profitability of the company. Physicists who wish to work in industry must appreciate this fact."

Views of industrial work

Most Desirable	Total Frequency of Citation	Most Undesirable	Total Frequency of Citation
① Salary	419	① Internal politics	276
② Professional challenge	339	② Management	185
③ Opportunity to see own results used	321	③ No free choice of problems	171
④ Broad range of activities and problems	250	④ No job security	169
⑤ Relevant research	244	⑤ Little time for research	119
⑥ Research facilities	241	⑥ No research funds available	82
⑦ High quality of associates	197	⑦ High-pressure atmosphere	80
⑧ Availability of research funding	156	⑧ Publishing limited	76
⑨ Autonomy and independence	123	⑨ Administrative routine	75
⑩ Good advancement	105	⑩ Short-term projects	70

These are the ten "most desirable" and the ten "most undesirable" aspects according to a survey of 3400 PhD physicists in industry.

Supply and demand 1960–1990

The manpower crisis in physics has about run its course. The decade-long decline in PhD production is nearly over, and employment for physics PhD's is picking up again in industry and to some measure in academia as well.

The figure on page 47 summarizes the overall situation. The line in the figure starting in 1952 shows the estimated doctoral labor force in physics based on the PhD output of physicists. The number of doctorates actually employed as physicists, shown by the colored line, exceeded the US PhD output throughout the 1960's; there was a net flow of more than 3000 PhD's into physics from other fields and from abroad. The situation changed dramatically around 1970 as the number of long-term physics openings vanished. The older physicists who were looking for positions found few available, and large numbers left the field; the younger physicists embarked on alternative careers rather than face uncertain prospects following temporary appointments. For about ten years, graduate schools produced too many physicists for the available jobs; during the decade, about 10 000 doctorates trained in physics left the field to work mainly in allied areas of science and engineering. In 1980, the physics labor force will be about the same size as it was in 1970. The industrial physicist was especially hard hit, as many research laboratories shrank or closed, but the recovery of that sector has been strong in recent years.

Every field in the physical sciences and in engineering has had severe manpower problems during the 1970's, but physics has suffered more than any other. The growth of employment has been less, the outward mobility has been greater, the number of young people entering the physics community has been comparatively smaller, and the physics community has been aging more rapidly.

The PhD output has now diminished in response to the marketplace factors, and the support for physics research has begun to increase. But the need for physics faculties, determined primarily by the need to teach physics, is not soon again to have growth rates like those in the decades past. For the foreseeable future the demand for physicists will be closely coupled to funding by government sources and by the needs of industrial research and development laboratories.

Methodology. What then does the future hold, quantitatively, for physics jobs and job seekers? In this paper we forecast into the 1980's by simply extrapolating separately identified components of supply and demand. The supply component consists of those new PhD's who expect to enter the physics labor force plus those who are attracted into physics from other countries and from other fields. The demand for physicists is a sum of the replacement needs for those who die, retire, move out of a field or emigrate, the growth or reduction in the size of the field itself, and the upgrading components in which PhD's are utilized in physics positions hitherto filled with non-PhD's or with non-physicists.

No feedback loops are included, for it is our view that such models are now of limited predictive value. One reason is that the time delays in the feedback loops

primarily involve the supply side of the equation and are considerably longer than the time span between unpredictable changes in the funding of research and development in the physical sciences. Another reason is that the imbalances between supply and demand not only influence future supply but also have a direct influence on the mobility and upgrading components of demand, neither of which are well enough understood for such refinements as feedback loops.

Supply. The number of new entrants into the physics labor force is determined by the number of US PhD's awarded per year corrected for the exodus out of the country, out of physics, and by the mobility into physics by foreign PhD's and by those not trained in physics. Of these the principal component is the PhD production from US universities, which reached its peak at about 1700 per year in the early 1970's and is now down to 60% of that value. To extrapolate these trends, use is made of the extensive data available on enrollments and degrees. Several different projection algorithms give similar values. The upper bound in the figure on page 48, which assumes a five-percent growth rate in baccalaureate production and a six-percent per year growth in the fraction of those baccalaureates who go on to take a PhD, is considered improbable.

Immigration and mobility data are derived from National Research Council data. We conclude that about 77% of the PhD production of physicists from the United States will enter the US physics labor force.

Demand. There are three basic components to the demand for PhD physicists: the replacement of those who die or retire and those who move from permanent positions into non-physics employment, the upgrading components in which non-PhD's who leave a position are replaced by PhD's, and the growth of the field.

From the known age distributions and mortality tables, it appears that combined death and retirement, now about 1%, will climb to about 1.6% by 1985. Increase of the mean retirement age beyond 65 will delay that date correspondingly. NRC data suggest that the number leaving "permanent" positions to work in non-physics activities is about 1–1.5% also.

Upgrading is one of the most important demand components. From college teacher to research-support personnel, from salesmen of high-priced instrumentation to administrators of technology, there is an ever-growing need for the more intensively trained. In the early 1960's, two-thirds of the jobs in physics were done by non-PhD's; now, two-thirds are done by PhD's. To estimate the upgrading component, we take the number of physics positions occupied by non-PhD's, 5900, multiplied by the job turnover rate, estimated to be 8% per year, and assume that 50% of these positions are filled by PhD's. Further assuming that there is no growth in the non-PhD labor force, we conclude that the available number of upgraded positions will diminish by about 4% per year.

Growth. There is a growing number of non-faculty research positions in academia, as well as a continual influx of physics PhD's into faculty positions in other sciences (especially the earth sciences) and into engineering where they continue to identify themselves as physicists. The non-faculty group has been growing by 50 to 75 positions per year for the past four years; the non-physics faculty group increased by some 500 positions from 1973 to 1977. Industry has been expanding its employment of physicists by several percent per year in recent years, and a recent survey of those industries that employ most of the physicists found that they expect their growth to continue at 3% per year through 1985. In the present projections a net growth of 200 positions per year (1%) has been assumed, which is roughly half of the growth rate of recent years.

Projection. The various components of the projections through 1986 are given in the figure on page 48. We conclude that the physics community, taken as a whole, has passed through its gravest hour. The job market is beginning to look healthier for new entrants into the field, primarily because there are relatively fewer of them. By the early 1980's the number of positions in traditional physics should be about equal to the number of new entrants into the field. But there will continue to be imbalances between many components of supply and demand throughout the 1980's. For example, theoretical physicists, who make up about one-third of the graduating PhD's but only about one-sixth of the non-academic labor force, will continue to find a very tight job market for their services. On the other hand, the number of PhD's per year in nuclear physics has dropped so precipitously (to 40% of its peak) that the ratio of supply to demand for experimentalists in this field is now about unity. Considerable anecdotal evidence indicates that there is at present a shortage of experimental nuclear physicists.

Throughout the 1980's the number of openings per year in academic institutions will continue to be far below the number seeking such positions. The probability that a PhD in physics will find a career in one of the doctoral-granting physics departments in the country has dropped from 30–40% in the early 1960's to around 10% now; the expectation is that this probability will rise slowly but will remain below 15% throughout the 1980's.

Promise for the future

More than by any other consideration the work detailed in this report has been motivated by concern for the problems faced by young and embryonic physicists. What do they face in the decade ahead? Can they count on a career in the profession they aspire to? What will their lives be like? The report can be reassuring to them in its affirmation of the diversity of options open to them, well beyond their academic experience, but it can also be unsettling in its statements of uncertainty.

It is well to remember that, except for one brief glimpse of Camelot, physicists have perennially faced uncertainty, even if not penury. In the euphoria of the 1950's and 1960's it seemed natural and right that society should support physicists in doing what they wanted to do; society would be well repaid by good things out of science, or at least by a sense of having supported worthwhile activities, like symphony orchestras or the arts. However, young physicists—adults, not children—came to believe that because they were bright and had spent dedicated years seeking the Truth, society was bound to continue supporting their quest. The revelation that society was bound to do no such thing came as shock and disillusionment, and the past decade has been a time of trauma for many of them.

What should be encouraging to all, and especially to the young generation now just peering into physics, is that as a whole these people didn't make out too poorly. Many are not where they had wanted to be, many are not doing at all what they had hoped to do, but a preponderant majority have found it not all that bad. They have interesting lives doing interesting things, perhaps not the physics they had envisioned or not even physics at all, but activities nevertheless intellectually challenging and fulfilling well beyond their fears during their days of despair. It is that very diversity of activities and of careers into which young physicists have leaped or fallen or been pushed in the 1970's that offers the brightest promise for the future, a promise innate in our profession.

What the new PhD's do depends, of course, on the drums they hear and who is calling. For some years ahead that call will come only feebly from the academic model they know best, but the experience of recent years (and we hope, this report) attests to the demand for the versatility of young physicists able and willing to put their hands and minds to whatever baffling problems arise. It remains for the physics community to demonstrate to the physics student that physicists outside academic halls can have challenging and fulfilling lives, and to convince yet more employers that a physicist can indeed do anything.

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