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ABSTRACT

In a discussion of the crisis in graduate education in the sciences and engineering, focus is on factors that threaten American capability to produce world-class science in universities. While finances play a part, the causes are basically structural--the rigidity of university faculties, stemming from a significant expansion in tenured positions, and the scarcity of new faculty positions for younger doctoral scientists and engineers. After a rapid growth in universities, due to the post-war baby boom and a growing affluence, federal support declined from 42 percent in 1967 to 23 percent in 1975. Meanwhile cost inflation eroded the value of the dollar, austerity budgets were implemented, and sciences and engineering felt the squeeze. More recently the federal government has increased its basic research fundings (up about 8 percent in 1972 constant dollars). College enrollment is expected to peak in 1980, with about 7.4 million degree students enrolled in colleges and universities; however students enrolled in sciences and engineering are down 12 percent from 1973. It is suggested that the problem of tenured faculty might be met by a government incentive program for faculty who decide to embark on a second career well before retirement age. Other solutions are grants that would free university money to hire young faculty members or the creation of research institutes funded by industry, with tax incentives. (PHR)

PROPOSED REMARKS OF

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AT

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Demographics, Dollars and Difficulties in Graduate Education

Good afternoon.

I want to thank Dean Zaffarano for his kind invitation to share your hospitality today.

It is my purpose in this talk to discuss some of the broader dimensions of what is sometimes loosely called the crisis in graduate education in the sciences and engineering.

The crisis concerns a number of interacting factors which threaten in the next 10 or 20 years to erode our national capacity to do world-class science in our universities. It is in the universities that 55 percent of all our basic scientific research is performed, and in disciplines like chemistry doctoral candidates contribute to more than half of the research reports.

It is sobering to reflect that most of our fellow Americans would think it odd for us to worry about the vitality of American science. Just last month, American investigators won every Nobel award in the sciences--in physics, chemistry, medicine and economics, to be exact. Still another American won the award in letters. What more compelling testimony could one adduce to the strength of our science and our system of higher education in the sciences.

And yet we know that appearances can deceive. We are part of something which has been labeled the "knowledge industry" and if we are to pursue this metaphor a bit further, then I believe we must acknowledge that our present appearance of good health and prosperity may be supremely deceptive. The dividends we are generating today represent a consumption of capital, and we are plowing back too little to produce future income.

When the Dean invited me to visit Ames, he suggested that an appropriate topic would be the impact of federal funding on graduate education. However, I am taking the liberty of enlarging the area of discussion. As we shall see, while federal funding is a major year-to-year factor in graduate education, for the long pull it is not the only one--nor the most important.

I believe we are dealing with a constellation of factors which together define a problem that is more structural than financial. It is a problem that cannot be solved simply through additional infusions of resources within the existing framework of federal support for graduate and postdoctoral education in the sciences and engineering, even were such an approach to become politically realistic.

Let me list the components of the problem from my own viewpoint. These are dollars, of course, but also demographic trends, the rigidity in university faculties stemming from a significant expansion in tenured positions, and the scarcity of new faculty positions for younger doctoral scientists and engineers.

If we can appreciate the interaction of these elements, and the long-term threat they present to the vitality of our basic research apparatus, then I believe we can begin to develop constructive new approaches to alleviate some of the worst features of our situation.

But first I would like to review some recent history. Surely the outstanding fact has been the explosive growth in science and engineering degrees. Annual awards of bachelor degrees in these fields surged from 121,000 in 1960 to 295,000 in 1975. The award of masters degrees increased from 20,000 to 54,000 annually during the same period, and doctoral awards increased from about 6,000 to more than 18,000.

This rapid growth in the sciences and engineering was part of a vast expansion in college enrollments for degrees of all types, and in turn rested upon demographic factors. The first of the wartime and postwar babies had reached the 18-year cohort by the early 1960s, and this fact plus rising affluence did wondrous things for college enrollments. It is noteworthy that science and engineering degrees held roughly constant at 30 percent of the total of all bachelor and first-professional degrees awarded during the 1960-75 period, while the absolute number of all degrees in these disciplines increased strongly during the period.

As a consequence of this educational commitment to the technical disciplines, our total number of scientists and engineers doubled during the 1950s to 1.2 million, and reached 2.0 million in 1974, including 274,000 at the doctoral level. At a later point I will focus more precisely upon this group for they represent the most highly-trained men and women of their professions.

It is they who must provide the leadership for our scientific community, and because almost 60 percent of our science and engineering doctorals pursue their calling within the higher education system, I deem it particularly appropriate to dwell on their well-being in this forum.

To return to history, however, a second fact to consider is the trajectory of resources available during this period of rapid buildup to support graduate level education in the sciences and engineering, as well as basic research in these disciplines. Focusing on the latter point first, total outlays for basic research in the universities multiplied six-fold in current dollars between 1960 and 1975, when the outlay amounted to about $2.4 billion. The federal share of this support, about 70 percent at the beginning of the period, expanded to a peak of 76 percent in 1968, but thereafter fell back to about 71 percent in 1975--or approximately $1.7 billion.

The picture grows much bleaker when we apply the GNP deflator and look at the numbers in terms of 1972 constant dollars. On this basis, we see that growth in university outlays for basic research essentially stopped dead in 1970, and since then total outlays have tended to contract. It is obvious that the federal government has played a significant role in this development. After peaking at more than $1.5 billion in 1968, the federal contribution to university basic research has declined about 5 percent, resulting in a 1975 level of about $1.4 billion in constant dollars.

The statistics are even more cheerless when we consider the pattern of support for graduate science students. In 1967 the federal government provided 42 percent of the support of full-time graduate students in the sciences by means of such mechanisms as fellowships, traineeships, research assistantships, and training grants. By 1975, the government's contribution had fallen to

23 percent and it was supporting only about 48,000 graduate science students.

Here indeed is a federal impact on graduate education, and on the conduct of basic research as well. I believe we can trace this contraction to the convergence of several factors. There was a sharp reduction in the volume of basic research supported by the Defense Department in the late 1960s which was not entirely offset by increased support from NSF and the Department of Health, Education and Welfare. There was a stubborn cost inflation which eroded the value of current dollar outlays by more than their year-to-year increase, particularly after 1971. There was a series of "austerity" budgets designed to cope with this inflation by reducing aggregate economic demand, and the science and education community found itself particularly vulnerable when it came to passing out the cuts.

But fundamentally, I believe the end of growth in the sixties was inevitable and that it reflected a perception that we had overbuilt our educational plant in the sciences, that we were producing too many scientists and engineers for the available careers in these disciplines, and that continued growth at the heady rate of the earlier 1960s could no longer be justified in terms of national security needs.

So much for the dismal history of our present situation. Now I would like to return to the central line of discussion. We are concerned with the factors shaping the future of graduate education in science and engineering--factors which also threaten the vitality of basic research conducted within our universities. You will recall that these factors include dollars, demographics, rigidity in the composition of faculties, and the scarcity of faculty positions for younger scientists and engineers.

As for the dollar outlook, I am happy to inform you that the federal funding pattern has now turned upward slightly. In the budget request for the 1977 fiscal year, the Administration asked the Congress for $2.5 billion to support all basic research in the sciences and engineering, an increase of 7.4 percent over the previous year, and a small increase in constant dollars. While we have not yet projected the impact of this on basic research spending within the universities, it is noteworthy that the Foundation's portion of total Federal basic research funding has increased from $541 million in the last fiscal year to $612 million in the current year. This is an advance of 13 percent in current dollars, and an advance of about 8 percent in 1972 constant dollars.

Now let us turn to the demographic factor. As we have seen, this was the main driver in the expansive 1960s. What impact will it have in the 1980s? As we track the 18-year cohort--the age of keenest interest to the college deans of admission--we see that we have almost reached the peak in our post-war population. In fact, this will arrive in 1979, when this group will total 4.3 million, about 60 percent greater than in 1960. Thereafter the number of 18-year-olds decreases; by 1990, for example, we anticipate fewer than 3.5 million in this age group. As might be expected, the 23-year cohort--the age of interest to graduate schools--will peak in 1984, then turn downward in the same fashion.

What will this mean for college enrollments? The National Center for Education Statistics of HEW predicts a peak of 7.4 million degree-credit students enrolled in four-year colleges and universities in 1980, about 20 percent of them graduate students. As for the numbers of students pursuing advanced degrees in the sciences and engineering, the National Science Foundation projects a total of about 210,000 by 1985, 15 percent below the peak reached in 1970. Our worst case is in the physical sciences, where enrollment peaked at 41,000 in 1968 and had already declined about 12 percent by 1973. The projected 1985 enrollment for advanced degrees in physical sciences is expected to be about 55 percent below the 1968 peak.

Of course, university faculties are not immune to these demand fluctuations. The Foundation projects a probable faculty level of about 230,000 in the science and engineering disciplines in 1985, about 7 percent below the 1972 level. Again the physical sciences present the worst case--a falloff of about 25 percent over the period.

The point I want to emphasize here is that the demand for the services of science and engineering faculty is essentially fixed by demographic trends, and there is little that government policy or the universities can do to alter this circumstance. To the extent we have any flexibility at all, it is mainly on the supply side of the equation. Here we are concerned with the ways universities and faculties respond to this reduced demand, and the impact of this response on university employment opportunities for younger science and engineering doctorals. What we are seeing is that faculty supply elasticity, such as it is, falls almost entirely on the junior, untenured PhDs.

Three sets of statistics are instructive with respect to current faculty trends. One shows a steady decline of "young doctorals"--those holding doctoral degrees for seven years or less--in science and engineering faculties. Between 1968 and 1975, they dropped from 42 percent to 27 percent of the total on these faculties, and in physics they dropped from 40 percent to 19 percent. The second statistical trend is the substantial increase in the proportion of tenured faculty in the sciences and engineering; by 1974, this had reached an overall average of 70 percent, with physics at 78 percent and chemical engineering at a high of 81 percent. The third, and one I am sure none of us want to dwell on, is the relentless increase in faculty age. We show an increase from 40 to 44 years in the median age of all science and engineering faculty between the years 1969 and 1973.

It is this concentration of tenured science and engineering faculty in the middle years which is causing us increasing concern. In the physical sciences, for example, we find 80 percent of the doctoral faculty was under the age of 50 in 1973, and almost 95 percent were below the age of 60. When we combine this age structure with the anticipated decline in total faculty, we see that we face the prospect of limited attrition of tenured faculty in the years immediately ahead, and limited possibilities for translating this attrition into the appointment of new, young doctorals who must, of course, pick up the torch if we are to maintain a viable basic research capability in our universities. In this situation, one naturally begins to think of options to assure a smoother flow of younger doctorals into faculty positions. One opportunity for this is the mid-career shift for the man or woman who would like to strike out in new directions, but who is many years away from retirement. Such mid-career shifts would free up faculty positions for junior doctorals.

But when we examine the possibilities of mid-career shifts for senior faculty, we immediately run into a major obstacle--the characteristics of the private retirements plans in which most faculty participate. Many of the older plans specify a fixed retirement age, usually 65 or 70, before the benefits are available. Increasingly, the newer plans contain early retirement provisions, but they invariably exact a substantial financial penalty on the faculty member who elects this option, usually about 6 percent for each year of premature retirement. Considering the differential between salary forgone and the reduced pension and social security benefits, we find that faculty retiring at age 62 rather than the usual age 65 incur a financial penalty of as much as 25 percent.

However, we are not really concerned with early retirement <u>per se</u>, because this has little potential for solving our problem. There are simply too few senior doctoral scientists approaching the age of 60 or 62. Even if they were to retire a few years early, this would not open a significant number of vacancies for junior faculty members. This is why we focus on mid-career opportunities for faculty with many productive years ahead of them. It is here that we see that the private retirement arrangements constitute a major barrier to career decisions which many of our senior faculty might otherwise contemplate. To keep the plans viable until a proper retirement age is reached, the contributions to the plan must be continued. But who is to carry this burden? The departing faculty member? The university which has lost the services of the faculty member and which is almost certainly under financial strain? Or the new employer, if in fact there is one?

Here, perhaps, is a possible role for the federal government. One can visualize an incentive program for faculty who decide to embark on a second career well before retirement age. In this program the government might contribute at least a portion of the funds necessary to maintain the individual's retirement plan, and only on condition that the vacated position is made available to a younger scientist or engineer. But how is such a program to be administered?

If open to all, what would prevent the departure of the most valued faculty members--perhaps to other universities where we are also trying to create spaces for younger faculty. On the other hand, if the plan is to be made selective, how can this be made equitable?

I have gone into some detail on this because I want to emphasize that we are dealing with a complex situation which lies well beyond the reach of the federal government--though the government can make a significant contribution. There is little we can do about demographics, of course. As for university-faculty relationships and a host of individual career decisions, these are the very stuff of our academic freedoms. The federal government cannot simply "buy" a solution with dollars, because the solution in the end must be worked out in the universities. However, I am hopeful that the government can play an important role in easing the necessary transition to a more flexible and responsive institutional arrangement, and that in this way we can maintain the continued vitality of our national knowledge base and the crucial basic research capability in our universities.

With this caveat in mind, I would like to suggest one or two additional approaches we might consider for making mid-career shifts more attractive for senior faculty, and in the process freeing up university positions for junior faculty.

We might, for example, institute a program of Senior Research Scientist Grants for outstanding and productive scientists. Such a grant, equivalent to perhaps one-half the individual's regular salary, would permit him or her to devote full time to research projects, while remaining on a university faculty.

A condition of the grant would require that the university use the released salary funds to hire a young faculty member to pick up the teaching load previously carried by the senior scientist. If we were to institute such a program on a pilot basis, the initial awards might range up to $25,000 annually for a five-year period, with the possibility of a one-time renewal for an additional five years.

A second area of interest concerns the basic research needs of our major industries. We have traditionally tended to compartmentalize our approach to basic research in terms of who is performing the work. Yet the commodity remain. the same. Industry is a major consumer of basic research results, and its needs run far beyond those it can be reasonably expected to supply on an in-house basis.

It seems to me that we may profitably consider the needs and strength of university faculties on the one hand, and industrial consumers of basic research on the other, for we may find significant complementarities where a small investment will exert a high degree of leverage in terms of attracting senior faculty into a return to full-time basic research. I have in mind possibilities like the creation of research institutes which enjoy some industry participation but which remain under university auspices. Tax incentives might be helpful in the creation of such institutes, as well as a suggested new Foundation policy to expand support for cooperative basic research projects conducted by joint industry-university groups.

I do not pretend that these approaches will "solve" our fundamental problem of maintaining the strength and creativity of our scientific research at levels to which we have happily become accustomed. Like the laws of physics, demographic trends tend to be rather inflexible. The Nobel Prizes we harvest today are rooted in work typically conducted 15 years or so in the past, and we cannot realistically expect that the lion's share of these coveted awards will continue inevitably and automatically to flow in our direction.

On the other hand, I do not share some of the deeply pessimistic sentiments voiced by a wide cross-section of basic researchers as to the future of basic research in our institutions of higher learning. However, I am most impressed by the concern in the academic community that we are no longer attracting the ablest young people to our disciplines--not because they are "turned off" of these tough disciplines, but because they perceive little opportunity to advance in them even if they master the difficult regimen.

One thing we absolutely must do is think more systematically about science in the 1980s and 1990s--the last two decades of this century. In fact, the Foundation intends to mobilize the scientific community to participate as widely as possible in a searching inquiry of scientific trends and capabilities during this period. We want to consider potential intellectual developments in science during the last two decades of this century, changes within the science establishment affecting its future strength and its needs for public resources, and finally the possibility that economic, social and technological problems may arise which drive future knowledge demands and technical manpower needs in new and unaccustomed directions. We are now studying a number of options for the conduct of this exhaustive study, and I am hopeful that it will eventually provide us with important insights for the handling of the somewhat narrower problem we are discussing today.

At the very minimum, I am confident that this major study will help us avoid the mistakes of the past, so that we will not again be blind-sided by anything as obvious as a demographic trend. And I am confident that we will be able to find solutions to the problem I have discussed today--how to prevent a gap of 10 years or so in the introduction of substantial numbers of young doctoral scientists and engineers into our university faculties. I am also confident that together we will find answers to the broader question of how to devise institutional structures which will enable us to meet the growing need for scientific research in an era of limited university resources.

But more than this, I think we must recognize that science and engineering, and the practitioners of these professions, continue to enjoy a high level of public respect and confidence. It is true that public esteem for all institutions and professions during recent years has declined in absolute terms. But recent surveys by the National Science Board show that relative to others, our own field has either held its own or gained.

I believe we can draw satisfaction from this because a supportive public is crucial to our endeavors. At the same time, it should remind us that public trust is a thing which must be continuously earned, and that all of us have an obligation, both to ourselves and to the public, to find ways to sustain the vitality and creativity of our disciplines.

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