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# Manpower in Science and Engineering, Based on a Saturation Model

Wallace R. Brode

Scientists have been advised that science is in a sorry state and is being blamed not only for pollution, pesticides, detergents, smog, wars, and health and social problems, but for the current depression and unemployment as well. To emphasize the sorry state, it is said that young people are turning *away* from science in greater numbers than ever before. One could say, with equal proof to substantiate the statement, that young people are turning *toward* science in greater numbers than ever before.

The facts are that there are more young people today in this nation than ever before, more young people are majoring in science than ever before, and more young people are not majoring in science than ever before. In 1969, a larger number of chemists and physicists than ever before in our history were graduated—both on the B.S. and the Ph.D. level. During the past 15 years, we have doubled the annual number of chemists and chemical engineers graduated (*1–3*).

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## Approaching Ceilings in Scientific and Technological Manpower

A decade ago, as a member of the Scientific Manpower Commission, I wrote on the approaching ceilings in our scientific and technical manpower supply (*4*). It has become increasingly evident from the many studies of choices college students make in careers and major fields, as well as from measures of their general academic abilities and qualifications, that only a limited portion of the college-age population (18–22) has the motivation and ability to complete a scientific or engineering course (*5*, *6*). Since 1960, the percentage of 22-year-olds graduating in science and engineering has been essentially constant at approximately 3.8 percent of the college-age population. Prior to the end of the 1950's, this apparent ceiling was being gradually approached, as the percent of the 22-year-olds graduating from college increased.

In the first half of this century, the percent of 22-year-olds that graduated from college rose from 2 to 15 percent (*4*, *7*). While this percentage of graduates is still rising [18 percent in 1960 and 21 percent last year (Fig. 1)], the rate of expansion is slowing down in science and engineering. In addition, there is ample evidence that the growing number of college students and graduates is concentrated largely in the social studies and, in general, involves those who have neither the motivation nor the ability required for science and technology (Fig. 2).

## Career Selection in Science and Engineering

To establish the concept of saturation in the production of scientists (in terms of percent of 22-year-olds), we will need to analyze briefly career selection principles, educational processes, and demographic data. When saturation is reached, supply obviously becomes a constant percentage, and demand should be adjusted to match it.

Selection principles in education involve a youth's deciding what areas he is interested in or motivated toward, and his ability to comprehend and apply the knowledge he has absorbed. In early high school, nearly half of our students profess an interest in a career in science or engineering, even though aptitude and intelligence tests may not always support their choice. The high school curriculum is, however, broad enough and general enough to allow students to change their minds often. Nearly half of the freshmen in college also indicate an interest in science and engineering, but they are not always the same students who, as freshmen in high school, were interested in science. These college freshmen, however, are generally supported in their choice by aptitude and intelligence tests. In college, about 80 percent of our students make at least one change in their selection of a major, and half of those who choose science and engineering move to the humanities and social studies (*5*, *9*).

Students in science and engineering account for about 20 percent of college graduates, but this percentage has been dropping since the early 1900's.

As an aside, one should note that the proportion of students in science is not a good indication of the number of students in science, since the proportion may drop even though the number increases. It is the percent of 22-year-olds in the sciences that concerns us, and for nearly a decade about 4 percent (3.8 percent at present) of all 22-year-olds have been science and engineering graduates. Great efforts to increase this percentage were not effective, even in a period when jobs were plentiful and salaries were attractive. Increased interest in areas other than the natural sciences, especially in the social studies in recent years, has been the main cause for the apparent drop in the proportion of students in science. Yet, the number of students in science is increasing at a much greater rate, especially on the graduate level, than the population of the nation as a whole (Figs. 3 and 4).

Nearly half of the graduates in science and engineering do not practice professionally, but move to areas of administration, business, law, medicine, journalism, theology, social studies, and homemaking. The net increase in the professional pool each year is about 2 percent of all 22-year-olds. This increase must balance attenuation by retirement, transfer, or death and provide the necessary growth of the professional pool. Last year, the 2 percent who remained in science and engineering amounted to about 60,000 people. A third of the students who graduated in chemistry last year and who went on to graduate school did not major in chemistry. Some went into other sciences such as physics, metallurgy, mathematics, and engineering. Others went to medicine or elementary teaching, and a fair number went into law, journalism, social studies, and theology (*1–4, 7*).

Some people plot manpower data on a linear scale, to indicate phenomenal growth; others plot on a logarithmic scale, to show steady growth. It is preferable here to record the percent of a given age group on a logarithmic scale, in order to correct for changes in the base size (annual number of those receiving the appropriate degree or reaching an appropriate level, thereby indicating comparative rates of production. When this latter procedure is used, one notes a saturation or leveling off in elementary school education, essentially a saturation in high school, and a saturation in certain fields at the college level (Figs. 1 and 2). This saturation is particularly evident in science, where for many years a firm and high-level academic and curricular base has been required.

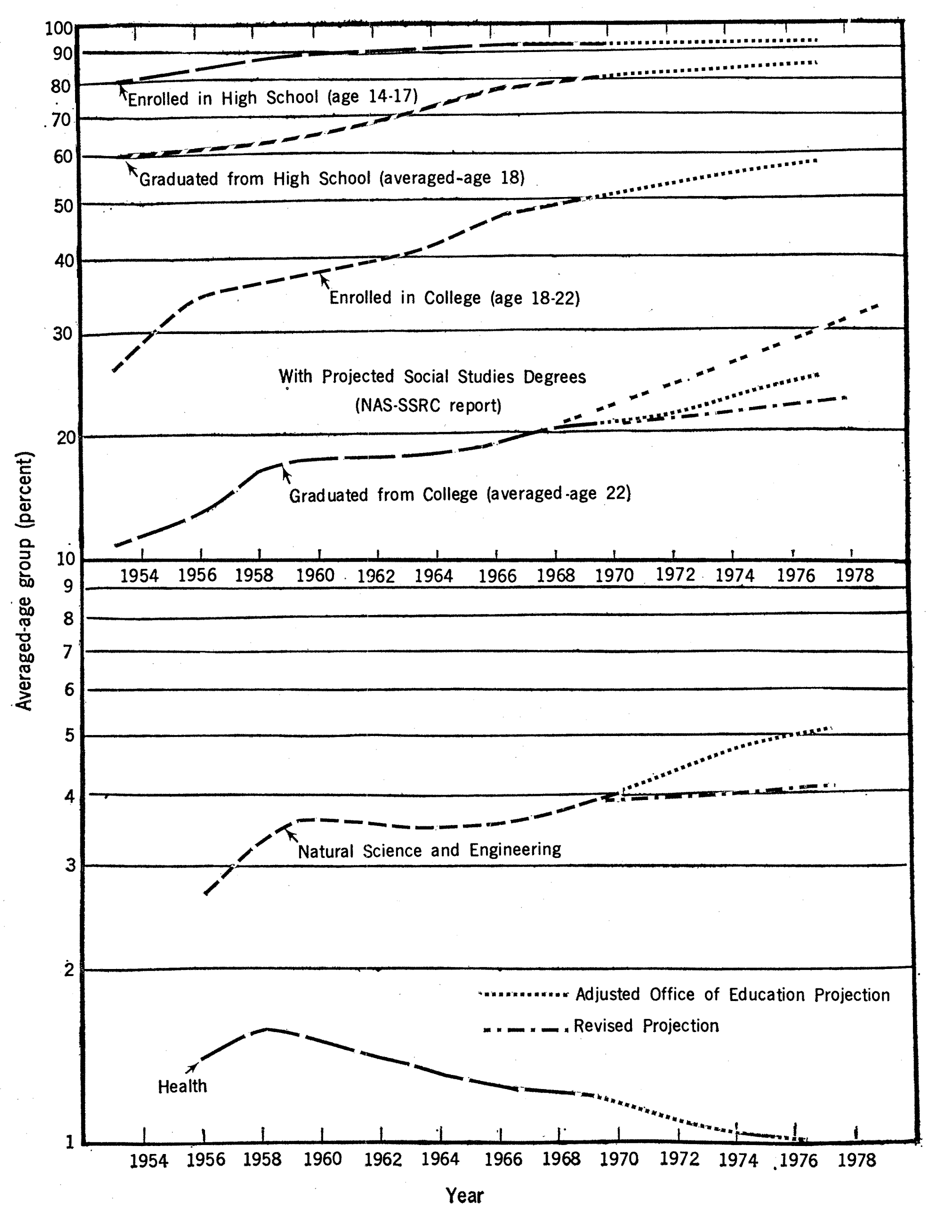


Fig. 1. Percent of averaged-age groups attaining given educational levels (*1–3*). [The term "averaged age" indicates a weighted average derived from the size of a given age group, with the distribution of ages within each graduating class (*1, 2*). Since about 50 percent of the graduates with a B.S. are 22 years old, 12 percent 21 years old, 20 percent 23 years old, and 10 percent 24 years old, an average size is obtained with age 22 predominating, thereby obscuring most of the sharp changes in the age curve (*3*).] Note that high school attendance (93 percent) and high school graduation (80 percent) for 1970 are approaching saturation. The percent enrolled in college is rising, due in part to open admissions. The percent graduating from college shows some evidence of approaching saturation, although recent projections by the National Academy of Sciences–Social Science Research Council (NAS–SSRC, double dash) (*8*) indicate that social studies degrees may rise from 14 percent of all B.S. degrees in 1957, to 20 percent of all B.S. degrees in 1967, and 33 percent of all B.S. degrees by 1977.

## The Changing Size of the College-Age Population

When the annual size of a given age group is relatively constant from year to year, the number of graduates produced can reasonably be used to measure the efficiency of education or to measure changes in the rate at which graduates are produced. This was essentially the case from 1925 to 1960 (Fig. 5, F–F). However, in 1955 the number of 22-year-olds began to rise rapidly. From 1955 to 1983, the number of 22-year-olds will rise from 2.1 million to 4.3 million, a growth of over 100 percent in about 30 years, or about 3 percent per year (Fig. 5, G–G). With an increase of only 3 percent per year, probably no given science student will feel the slightly greater number in the class behind him or the slightly smaller number in the class ahead of him. In other parts of the university system, the increase may be felt much more, due to open admissions and rapid expansion of the social studies. But in science and engineering, the percent of college-age population remains fairly constant at nearly 4 percent.

The growth rate of the college-age population at 3 percent per year is about twice as great as the projected annual growth rate of the total population—and we still have nearly 15 years of growth ahead of us. This growth, with its corresponding increase in the number of scientists and engineers, leads to the inevitable and disturbing prospect that we may produce an excess of scientists and engineers. Between 1968 and 1970, we appear to have moved from a deficit to a surplus of scientists and engineers. The surplus of scientists and engineers in the future will not be great, probably not more than 10 percent of the supply by 1983. But in a game of musical chairs in employment, any excess causes considerable displacement, especially among those entering the game. In spite of an apparent surplus, we should encourage qualified students to major in science and engineering. There should be no mass exodus nor movement to other types of employment; rather, we must provide employment opportunities, and the graduates who are concerned about continuing their career in science or engineering should retain their abilities in their professional area.

After 1983 the excess of scientists and engineers will taper off, and by 1987 to the end of this century we are going to have a real shortage of scientists and engineers (Fig. 5, H–H). If, by 1990, the scientist has maintained and improved his technical abilities, he can just about write his own ticket. This shortage in the 1990's and 2000's will be due to the fact that for the past decade the birthrate of this nation has, as a result of population planning, depressions, abortions, pills, and other factors, been dropping at as great a rate as the college-age population has been rising. For the past 4 years, the birthrate in this nation has been lower than at any other time since 1776 (*14*). Between 1983 and 1992, the number of 22-year-olds will decline by 20 percent.

The number of babies born last year is almost exactly the same as the number of 22-year-olds last June (Fig. 5, x–x). This means that, in about a quarter of a century, we are going to have essentially the same number of 22-year-olds from which to draw our scientists and engineers as we have today. If it is true, and it has been for the past decade, that we are recruiting from the annual population of 22-year-olds about all of the students who have the ability and motivation to be scientists or engineers (Figs. 2 and 3), then we may expect to produce about as many scientists and engineers in 1992 as we are producing today. There are, however, two factors that must be recognized. One is that, every year from 1970 until 1992, about 4 million new citizens will be added to the nation's labor force. While some of the labor force will be lost through death and retirement, the net growth over the next 22 years will be between 40 and 50 million. It is quite reasonable to expect that a population growth of about 20 percent will require some 20 percent expansion in the services of technologists. The second factor to consider is that these predictions are all based on the supposition that the nation is not going to expand its scientific and technological way of life in this quarter century. Such a supposition is obviously erroneous, in view of the rate of expansion during the present century. Both of these factors will contribute to an even greater demand for scientists and engineers in the future (Fig. 6).

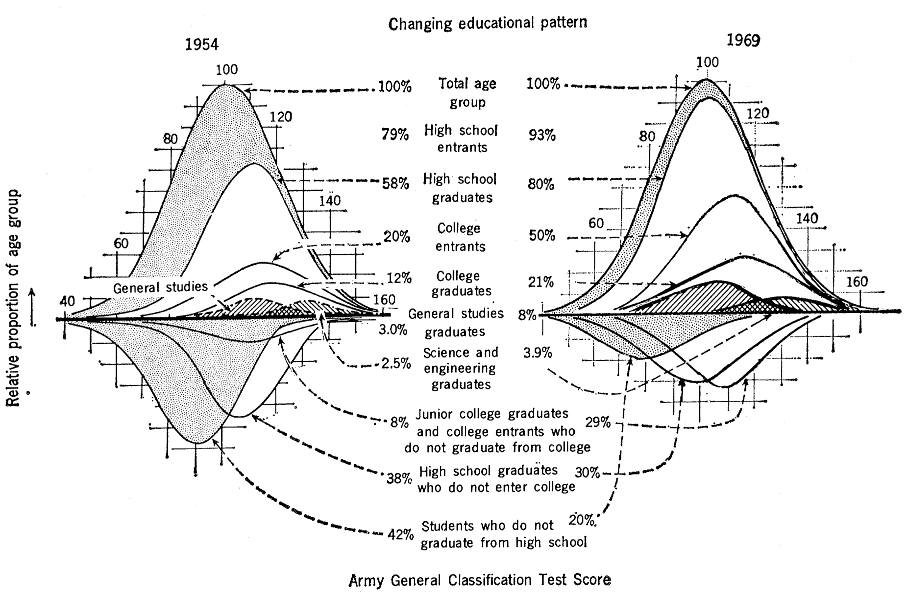


Fig. 2. The changing educational pattern between 1954 and 1969. The mean scores on ability tests, based on an average score of 100, have dropped as the percentage of the college-age population entering and graduating from college has increased (*5, 6, 9*). Since science and engineering attract most of their students from the top 25 percent, as do many of the humanities, it would appear that most of this upper-level group can be identified with definite areas of interest. It would also appear that in 1969 there are few uncommitted students available, unless science and engineering were to reduce qualifications or standards to include those who appear, on the basis of best scores, to lack ability. It has been well established that IQ and entrance tests are excellent criteria for selecting capable students in science and engineering, although there are many who, with some justification, would claim that such tests do not identify those individuals with ability in or who would succeed in art, physical education, elementary teaching, music, homemaking, or social studies. If all applicants are to be admitted to and graduated from college, it may be well to separate by institutions, type of degrees, and curricula such subjects as science, engineering, medicine, and law, as compared with social studies, education, and business areas. This figure demonstrates the approaching ceiling or saturation of that small portion of the population with the motivation and ability required for science and engineering. Data are derived from Wolfle (*9*), and are extrapolated to educational statistics available from the U.S. Office of Education and the National Science Foundation (*1, 10*).

## A Holding Pattern for Today's Surplus

A "holding pattern" to preserve an excess of technologists for this nation is obviously necessary. We should establish, through private, federal, and state funding, technical programs in such areas as health, environmental improvement, pollution eradication, education, postdoctoral studies, updating courses, and basic research, in order to retain trained scientists and engineers and to expand their capability. In the period from 1970 to 1980, these workers will produce much of value and importance to the nation. In the decades after 1980, these scientists in the holding pattern would be prepared to fill important and much needed demands in industry, government, and education.

Today the supply not only exceeds the demand, but is expanding at a greater rate than the demand. Perhaps the most disadvantaged of all are the new graduates, who have gone through or beyond college, even to postdoctoral training. They go out into the cold cruel world, only to find no jobs available, or else below the level of their training and ability. Training scientists and engineers takes a long time. The number of scientists and engineers produced in a given year appears to be controlled by the birthrate some 22 to 30 years earlier. The American philosophy of education advocates a free choice of professional or nonprofessional education and employment, based on ability. We have at times instituted bypass valves, such as the draft, which have seriously altered our pipeline system, but under normal conditions everyone is encouraged to seek his highest possible level of attainment (with the possible exception of such areas as medicine and plumbing, in which professional or trade limitations bar all but a few).

It must be obvious that we are recruiting essentially all of the college-age individuals who are able and motivated to be scientists and engineers. The process of producing scientists and engineers requires essentially a quarter of a century. We cannot easily control this supply except by birth control or stopping the interest in science at the source (and we have yet to identify or develop methods of removing science genes). We have artificial stimulants or depressants, such as economic depressions (when the number of marriages and births drop) and wars (when there is a boom in marriages and babies). But this is a poor and rather extreme method of controlling supply, and it reduces or increases all academic communities proportionally. The most logical method would seem to be controlling the demand, since demand can be regulated with much greater ease and can be exercised selectively on academic areas.

Chemistry and physics, because of their well-established curricula and the continuous updating and improving of their courses, have long led the natural sciences in their professional training programs. Not only do they provide a logical basis for advanced work in other fiields, but, in their well-planned programs toward the doctorate and in their postdoctoral training, they are also leaders and models for other areas. It is therefore natural that chemistry and physics should be among the first sciences to reach the level of saturation with regard to the percentage of the college-age population that selects these areas as a major. This saturation in chemistry, at a little more than 0.4 percent of the college-age population, has held for well over a decade. The percentages of students in other sciences are not yet that stabilized, but some of the variation may be due to shifts among areas; for example, interest in computer studies may cause shifts from engineering to mathematics. Within the past decade, the natural sciences and engineering have maintained a nearly constant level of students, at about 3.8 percent of the college-age population (Figs. 1 and 3).

The possibility that college degrees in some areas may follow open-admission policies, with open admission to courses, no fixed curricula, no grades, and open graduation, is a major reason for separate consideration of science and engineering. It is hoped that science and engineering as professional areas of training will continue to require admission examinations, give grades in

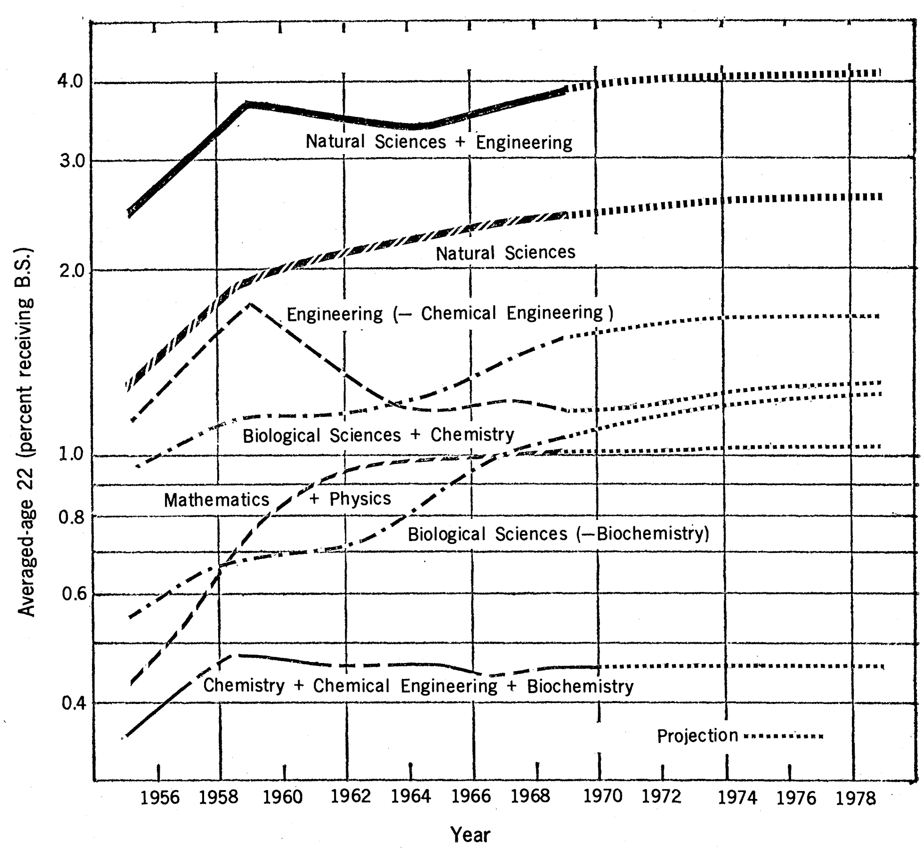


Fig. 3. Distribution of graduates with a B.S. in natural science and engineering, as a percent of all 22-year-olds. Note that chemical engineering and biochemistry have been combined with chemistry to provide a single chemical area. The biosciences are shown without biochemistry, and mathematics and physics have been combined into a single group. Note the saturation or ceiling in such major areas as the chemical sciences and the total of all science and engineering. Long-range projections would show an expected ceiling of 0.47 percent of the 22-year-olds in the chemical sciences, 1.05 percent in mathematics and the physical sciences (not including chemistry), and 4.0 percent in all of science and engineering (*1*, *2*).

courses, require specific courses in sequence, and require specific examinations and grade levels prior to conferred degrees. The U.S. Office of Education *(1–3)* (Fig. 1) predicts a rise in science and engineering graduates to about 5 percent within a decade, but there is evidence of possible saturation (Fig. 3), which would lead to the 4 percent prediction.

The health sciences (Fig. 1) (*1*), if plotted on actual or absolute numbers would indicate a modest growth in the two decades from 1958 to 1978, but when recorded as a percent of the age group indicate a continuous drop, due to restrictions of admission to a nearly constant number in a time of rapid growth of the age group.

## Ratio of B.S.'s to Ph.D.'s as a Measure of an Area's Development

In areas that are developing and that have no full-fledged graduate program, it is to be expected that few B.S. graduates go on to graduate work. It is also to be expected that the percent going on to advanced work would rise rapidly as advanced courses are improved and an acceptable program is developed. This certainly has been the case in engineering (Figs. 3 and 4). In the past two decades, the ratio of B.S.'s to Ph.D.'s has gone from about 80 B.S.'s to 1 Ph.D. in 1958, to about 8 B.S.'s to 1 Ph.D., projected for 1978. On the other hand, in the areas of chemistry and physics, which show a near saturation on the B.S. level and have had well-developed Ph.D. programs for a long time, the ratio is approaching an equilibrium, with 3 or 4 B.S.'s per Ph.D. There should be no single optimum ratio of B.S.'s to Ph.D's; rather, each area should have an optimum that is dependent on subject matter and job requirements. Astronomy might well be expected to have a larger ratio of Ph.D. workers to B.S. workers than might civil engineering. It is expected that B.S. degrees in all advancing and developing areas of science and engineering should be approaching a ceiling in the percent of the age group, if they have not already reached it. At a later time, the ratio of Ph.D. degrees to B.S. degrees should reach an appropriate ceiling.

By comparison, however, I should note that recent projections in the social studies (*1–3, 8, 10*) indicate not only a rather high ratio (about 18 B.S.'s to 1 Ph.D.), but an expected higher shift in the next 15 years (to about 35 B.S.'s to 1 Ph.D.). This shift is in the opposite direction from what we have termed development, but it may indicate the different character of the subject matter, degree, and job requirements. If so, it would seem that short-term training can produce the required degree of professional competence, as compared with the more rigorous and longer training required of the scientist and engineer. It seems reasonable to confine the proposal and program in this article to those subjects that have a reasonable pattern of approaching ceilings, projected shortages, and educational and professional treatment similar to that of science and engineering.

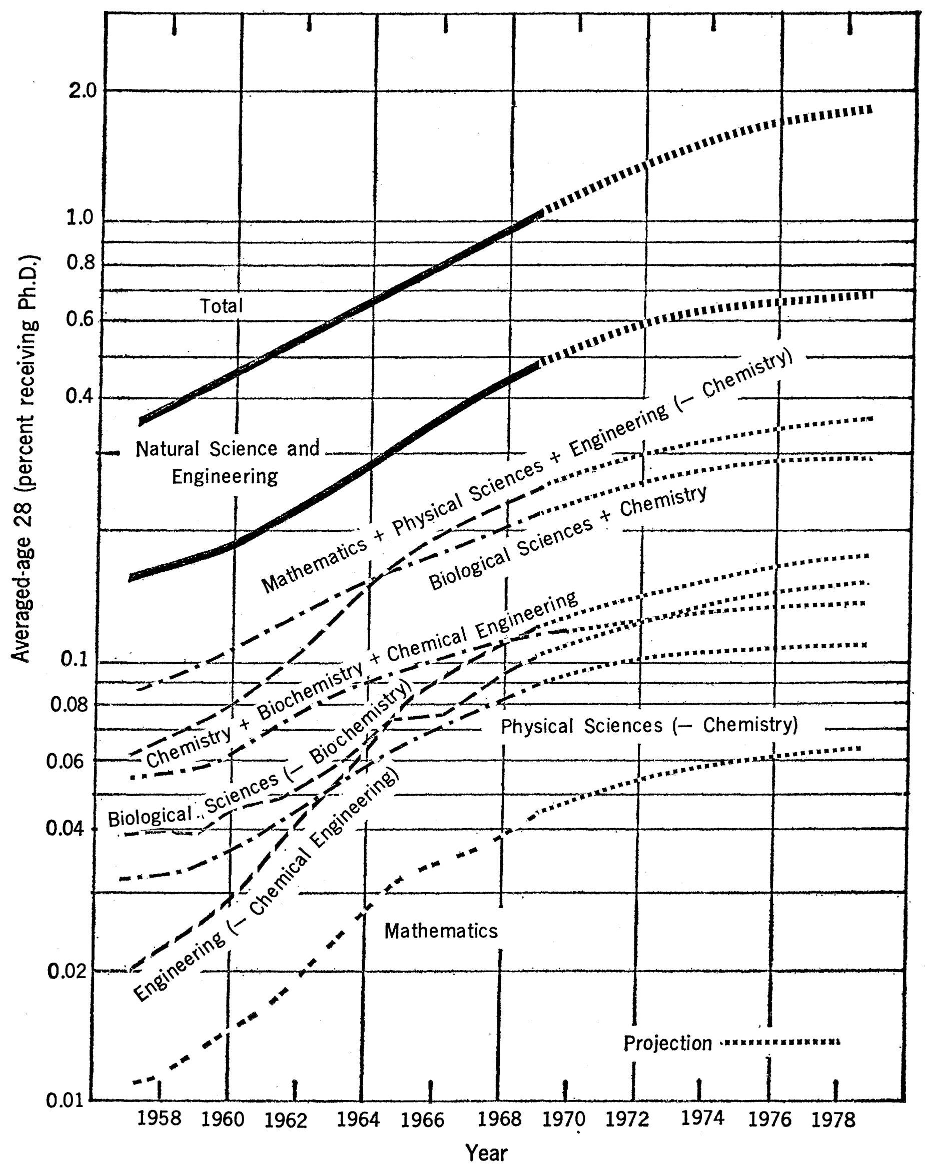


Fig. 4. Percent of averaged-age 28 group obtaining Ph.D. degrees, and analysis by subject areas in science and engineering (*1–3*). Well-established curricula such as chemistry and physics show a marked tendency to level off at a constant percentage, while developing areas such as graduate work in engineering start at low values and show a much greater growth rate. A combination of factors, as determined from B.S. degrees in Fig. 3 and data on the same technical areas in Fig. 4, enables one to characterize the level and rate of development of a subject area and its apparent capability to sustain graduate work on the Ph.D. level. These factors include the proportion of B.S. students who go on for a Ph.D., the rate at which this proportion changes, and the approach of a ceiling at both the B.S. and Ph.D. levels (*1, 2*).

## The Prospect of a Shortage of Scientists and Engineers

In the long run, in our total economy, it will be the exceptional situation in which the supply of scientists and engineers exceeds the demand, since the population is expected to stabilize and thus set the limits of the supply. At the present moment, however, we are in the anomalous situation where the supply of scientists and engineers exceeds the demand (Fig. 6). For these reasons, it is essential that we create a holding pattern, or active ready reserve, to effectively retain and use competent and trained workers in such areas as public service, technology, and basic science. In the present situation, the surplus of scientists and engineers will probably be less than 10 percent of the total scientific and engineering manpower, and this surplus will not last for much more than 10 years, maybe less. Judging from the number of births in the past decade, the demand will exceed the supply in the period from 1980 to 1990. It is important, for maintaining our advanced technological position, that these surplus scientists and engineers of the 1970's be available in the latter part of this century and the early part of the 2000's. The holding patterns may well take the form of additional training (postdoctoral studies as well as specialized and broadening courses), special public services, research programs designed to promote public welfare, advanced work in technical and developmental programs, and research to advance proficiency in science.

In their 1967 projections (*11*), the Bureau of the Census used four fertility assumptions to produce projected Series A, B, C, and D. It has recently become apparent (*4*, *7*, *13*) that the D series was closest to current birthrates; hence, Series A and B have been omitted, and a new Series E has been added in Fig. 6. If there is no net immigration, Series E will lead to a zero population growth by about 2037. In the lower graph (Fig. 6), the population of the United States rises from 205 million in 1970 to about 259 million in 1992 (Series D growth). It is reasonable to assume that future demand for scientists and engineers will at least be in proportion to the population. Although many people feel that our technological growth rate will, as it has in most of this century, be greater than the population growth rate, it may be only slightly greater (Fig. 6).

It is difficult to estimate technological growth rate or underemployment, but a rough estimate (made by integrating the "Surplus" area in Fig. 6 and applying a factor of 2 percent, the proportion of 22-year-olds who are professional scientists and engineers) would indicate that there might be an accumulation of about 120,000 unemployed scientists and engineers during the period of 1968 to 1986. To this number must be added unemployment caused by any economic recession or a negative technological growth rate, and from this number must be subtracted those who leave the profession and those who are underemployed. Even with a technological growth rate equivalent to the population growth rate, it would be expected that in this decade of surplus scientists and engineers there would be a loss of about 50,000 if no support measures are taken.

The Manufacturing Chemists Association and the Engineers Joint Council have indicated that they expect the current surplus of scientific and technical personnel to be for a limited period and that they expect shortages again by 1975 (*15*). The U.S. Bureau of Labor Statistics expects that there will be shortages of scientists and engineers before 1980 (*15*). I expect shortages by 1987 and possibly earlier (Fig. 6), depending on our technological growth rate.

### Suggested Cures for the Problems of the Surplus

Some of the currently unemployed scientists, who are personally feeling the effects of a surplus, urge a suspension of registration in science and engineering in colleges, thus essentially turning off the supply until the surplus is absorbed. After a balance is reached, the supply pipeline might be opened at a reduced flow to insure, as in medicine and trade professions, a continuous mild shortage, thereby providing for premium salaries and working conditions. Others have seriously suggested that such research aids as primary publications and abstract journals should be suspended, in order to create more employment by requiring more scientists to spend more time looking up previous publications and repeating unpublished work done by others. Such featherbedding techniques may succeed in employing more scientists and engineers, but this country would most certainly profit by proper publishing and abstracting, and by using the funds that would be paid for this make-work to further

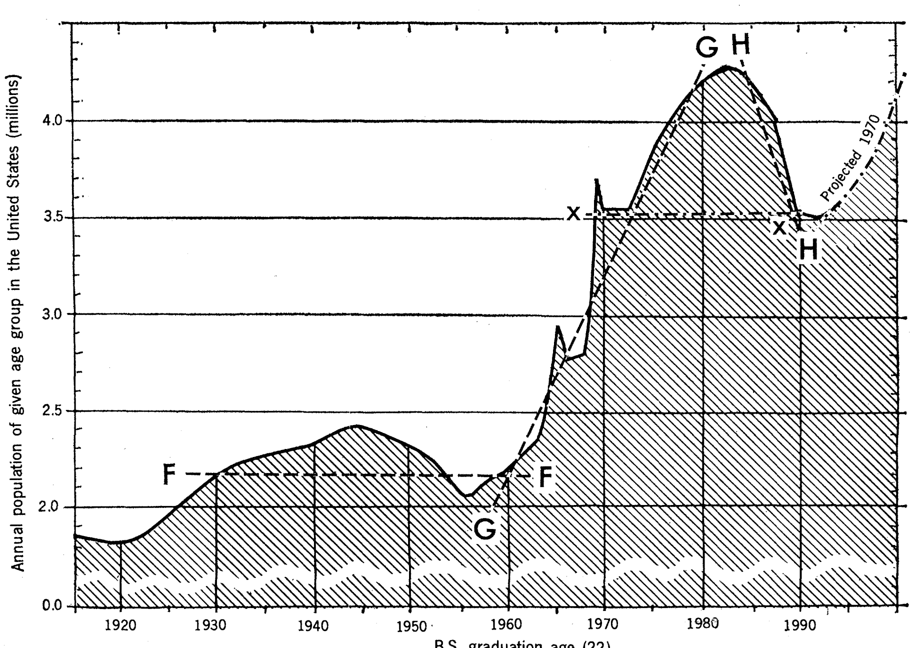


Fig. 5. Annual population of 22-year-olds in the United States. Note the nearly level period from 1925 to 1965 of about 2.2 million per year (F–F); the growth period from 1955 to 1983, from 2.1 million to 4.3 million (G–G); and the drop in size from 1983 to 1992, from 4.3 million to 3.5 million (a 20 percent drop in 10 years) (H–H). Note also that the number of 22-year-olds in 1969 (3.5 million) is essentially the same as the number of 22-year-olds projected for 1991 (x–x). The annual number of 28-year-olds (Ph.D. graduation age) is determined from age values indicated on the bottom line. The data are given as forecast up to 1992 by the Bureau of the Census, since the mortality and immigration rates are not expected to vary very much. Data beyond 1992 are from Series D projections of the Bureau of the Census (Fig. 6) (*1–3*, *11–13*).

our scientific knowledge in new fields.

Some people would rather slow down the production of scientists to a rate that would essentially be only high enough to fill the demand. R. A. Alberty (*16*) has indicated that the level of production for such a balance might require, for a few years, cuts of as much as 50 percent. Such a reduced rate of production of scientists might be reasonable if the future demand and supply could be reasonably matched; yet we know there will be a shortage by 1990, if not earlier, which will last on into the next century. Some planning in advance must be done to meet this situation.

George H. Brown, director of the Bureau of the Census, has taken a somewhat different approach to the shortage in the 1990's and 2000's (*17*). Instead of a holding pattern, he suggested that in the 1990's, when we will be short of senior leaders in the 40 to 50 age bracket, older people postpone their retirement dates or younger people with less experience be promoted more rapidly. Others have suggested that short-term training could be given to prepare persons to fill these shortages. Such short-term or rapid training might be effective in professions that involve general administration or social studies, where no continuity or sequence of courses is necessary. Scientists and engineers are not created on short order, and especially not from random source material. Rather, they are the product of 10 to 20 years of study and application, and they must have the technical ability to begin with.

The problems of a surplus cannot be solved by the inverse of the solution to a deficit. Supply is the result of a long period of training and, to a degree, is a function of the birthrate some 22 to 28 years earlier. It cannot easily be turned on or off at the college level. The deficit of the 1980's, 1990's, and beyond must be met by conserving the 1970's excess for use in the 1980's and 1990's; planned technician training and instrumentation development; a rational system of efficient utilization of scientists and engineers in short supply; a reasonable "brain drain" of competent scientists who cannot be used efficiently in their native countries; and sharing in the abstracting, publications, research, and development of other areas of the world as they reach a developed stage. Today, with only 7 percent of the world's population, we are producing nearly a third of the world's science and technology. It is hoped that, even while continuing to produce at maximum capacity, we will someday supply only about one-fourteenth of the world's science and technology, a figure proportional to our share in the world's population.

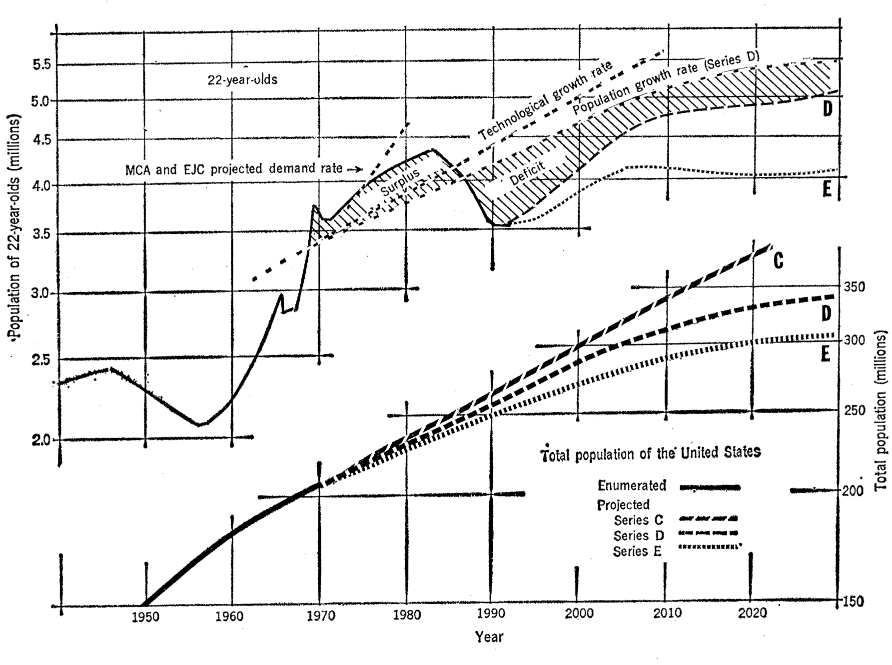


Fig. 6. Projection of surplus and shortage of scientists and engineers from 1970 to 2025. Two separate figures are combined here. Both are recorded on the same log scale so that the rates indicated on one may be applied to the other. The lower portion indicates the total population of the United States (*11–13*). The upper portion of the graph shows the number of 22-year-olds in any given year. The total population (Series D) from the lower portion has been drawn on the upper portion (Population growth rate–Series D), intercepting the annual population at a point (1968) where there was considered to be a balance between supply and demand in employment (Manufacturing Chemists Association, MCA; Engineers Joint Council, EJC).

## Census Projections

The Bureau of the Census projects (in Series B and C) an almost immediate upturn after the low birthrates of the last decade. However, an examination of the 1920's and 1930's would indicate that the rather steep decline in birthrates prior to 1929 was not unlike the decline in the past decade (*14*). A slow recovery, apparent in the early 1930's, followed the drop in births during the Depression. Those who predict a rapid recovery from the current recession, especially with regard to the birthrate, may have information to support such predictions, but history does not indicate a rapid recovery. In all probability, our population will hold close to the Series D rate of growth, but technology may well continue to expand at a higher rate ("Technological growth rate," Fig. 6). It is interesting to note that the Series D projections correspond to the current birthrate and that the Bureau has added a Series E, which provides for zero population growth after 2030.

The distinct possibility of zero population growth in this country by the middle of the next century implies a constant supply of scientists and engineers, in both numbers and percent of a given age group. With an expanding culture and technology, it may well be that in the 1970's we will have, for the last time, a surplus of scientists and engineers. To extend the frontiers of knowledge and retain our leadership in world science, despite a probable shortage of scientists and engineers, we must plan to use this nation's manpower resources in a way that will enable us to devote a reasonable portion of our efforts to pure science and fundamental research.

## A Manpower Employment and Training Act

There should be more than one approach today to solving the unemployment problem. It is, of course, reasonable to provide relief and retraining, to enable those prepared for a specific job to take other kinds of employment. But this employment shift is only desirable when there is little need in the future for many people with the new training, and when the prior training and the retraining do not require a lengthy period or special ability.

On the other hand, when a specialized ability is required, when long and often expensive training programs are involved, and when it appears that such trained personnel will be needed in the future, then we should use a different solution to unemployment. A ready reserve for science and engineering should be established through government support of its existing scientific and technical agencies. Such a ready reserve program should be centered under the direction of such agencies as the National Science Foundation, the National Institutes of Health, and the Environmental Protection Agency. However, the program should not be confused with a retraining program. Retraining should be centered in the Department of Labor and the Office of Education. It should reorient the unemployed and underemployed whose current employment has not required long, specialized training, who are in excess of the current demand, and for whom there is no apparent shortage or increased demand in the near future. If other essential manpower areas can demonstrate ceilings or saturation in supply (assuming admission to the curriculum or training program is open to all with motivation and ability), and if they can demonstrate a potential shortage of professional personnel within a reasonable time in the near future, they should be covered by a conservation action similar to that recommended for scientists and engineers.

The program should encompass several forms of ready reserve: for example, the expert should be employed in programs and projects that interest and concern the public and that utilize his maximum capabilities. Such a program should be able to absorb a major portion of the expected excess of scientists and engineers in the next decade.

However, in this ready reserve and holding plan, programs of great expense and limited return should be avoided. It may also be necessary for some of the excess technical personnel to be temporarily "underemployed"—that is, employed below the level of their training and abilities. For example, competent research and management personnel may be placed in control laboratories, junior colleges, high schools, or other areas that only partially use their abilities. The ready reserve program should provide those who are underemployed with a reasonable subsidy for subscribing to scientific and technical publications, maintaining research and technical contacts, attending meetings at which important technical papers are presented, and taking part in symposia and seminars. The underemployed should be able to take short courses and to engage in brief research conference sessions at universities and at industrial and governmental laboratories—much as ready reserves in the military are kept up-to-date by technical courses and drills and by flight programs.

There is no doubt that the devoted scientist of the future would, in time of economic crisis, prefer reasonable underemployment to deserting science for another profession—if along with the underemployment was the opportunity to maintain his professional contacts and abilities, and to know that there would be reasonable future opportunities in his chosen profession.

A manpower training bill was passed near the close of the last Congress, but it was vetoed by the President, who felt that the bill did not provide a link to future employment opportunities. Congress failed to override the presidential veto by only eight votes. Similar bills have been introduced in both the Senate and the House in the present session of Congress. It is hoped that this Congress will pass a revised manpower employment and training bill, one which would consider the nation's *future* needs in science and engineering employment, as well as the immediate problems.

An acute surplus of scientists and engineers in the 1940's was avoided because of the increased technological and manpower requirements of World War II. Wars are, however, a poor and inefficient method of absorbing and utilizing surplus technical manpower. It would be far better, both from a fiscal and a technological viewpoint, to support a program designed to maintain the productivity of highly trained experts.

Proper presentation of the short-term need for preserving the technical abilities of those people whose careers require long training periods and who will be in short supply in the near future should enable the Congress to obtain presidential approval for a ready reserve program as part of a revised manpower employment and training act in the current session of Congress.

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