Summary

American schools, colleges, and universities have the capacity to provide enough scientists and engineers to meet the Nation's needs. Historically, students and institutions have satisfied changing market needs, as evidenced by the response of engineering enrollments to the semiconductor industry boom of the late 1970s. However, many researchers, employers, and policy makers are concerned that future supply will be inadequate. In the early 1990s, the Nation will experience a decline in the number of college-age students, although some increase can be expected before the turn of the century. More important, fewer students, particularly those white males who have been the mainstay of science, seem to be interested in science and engineering careers. Women's interest in science and engineering, after rising for a long time, seems to have plateaued. Non-Asian minorities, traditionally poorly represented in science and engineering, will form a steadily increasing proportion of American schoolchildren.

Despite these changes, OTA concludes that shortages of scientists and engineers are not inevitable; the labor market will continue to adjust, albeit with transitory and perhaps costly shortages and surpluses. The Federal Government may need to play a more active role. Rather than trying to direct market responses, policy can aim to prepare a cadre of versatile scientists and engineers for research and teaching careers, invest in an educational system that creates a reservoir of flexible talent for the work force, and ensure opportunities for the participation of all groups in science and engineering.

The Federal Government has had both direct and indirect effects on the education of scientists and engineers, but it is only one of many actors in the system. The Federal role in science and engineering education is most significant at the graduate level, more diffuse at the undergraduate level, and small in elementary and secondary education.

Federal investment in science and engineering education and training is undertaken for many reasons; there is no single objective or mission. One class of investments is in direct support of graduate students and production capacity at blue-chip universities. Other investments are made in newer, developing colleges and universities with growth potential, and in undergraduate and precollege education. Federal support is spread across different types of institutions and students, partly because of the uncertainty of payoffs, and partly to ensure equality of access and geographical balance. Both short- and long-term investments are necessary in a marketplace where demographics, economics, and technology constantly change the criteria for success in education for the work force.

The educational process from grade school to graduate school is 20 years long. This means there are many possible Federal options for enriching the future supply of scientists and engineers. It is difficult, however, to distinguish which would have the most impact. At each level of the educational system, there are many choices for action. Few measures guarantee predictable effects in the relatively short term; most are more speculative and longer-term possibilities. Just as there are no imminent crises in replenishing the science and engineering work force, there are no quick fixes.

This assessment:

- examines the forces associated with elementary and secondary education that shape the talent pool;
- traces pathways to undergraduate and graduate education in science and engineering; and
- presents a discussion of policy areas for possible congressional action, developed under two strategies labeled "retention" and "recruitment."

Two Federal management issues are also identified. These are leadership and coordination among Federal agencies, and evaluation of trends and outcomes to define future policy actions that will improve the reach and content of science and engineering education. The overarching policy issue is whether the Federal Government allows the market for scientists and engineers to take its course or attempts to intervene more boldly.

The two broad strategies of retention and recruitment complement each other and would operate best in tandem (see table). The retention strategy is designed to invigorate the current science and engineering work force by reducing attrition of undergraduate and graduate students. Such short-term retention programs could increase output of scientists and engineers within a few years. In contrast,

Policy Options To Improve Science and Engineering Education

Recruitment-Enlarge the Pool

- Elementary *and secondary teaching:* encourage and reward teachers; expand support for preservice and inservice training.
- *School opportunities:* reproduce science-intensive schools; adjust course-taking and curricula; review tracking; and revise testing.
- Intervention *programs:* increase interest in and readiness for science and engineering majors; transfer the lessons from successful programs; encourage sponsorship from all sources.
- *Informal education:* increase support of science centers, TV, fairs, and camps.
- *Opportunities for women:* enforce Title IX of the Education Amendments of 1972 and provide special support and intervention.
- Opportunities *for minorities:* enforce civil rights legislation and provide special support and intervention.

Retention—Keep Students in the Pool

- *Graduate training support:* "buy" Ph.D.s with fellowships and traineeships; these people are most likely to join the research work force.
- *Academic R&D spending:* bolster demand and support research assistants, especially through the mission agencies.
- *foreign students:* adjust immigration policy to ease entry and retention.
- *Undergraduate environments:* support institutions that reward teaching and provide role models, such as research colleges and universities, and historically Black institutions.
- *Hands-on experience:* encourage undergraduate research apprenticeships and cooperative education that impart career skills.
- *Targeted support for undergraduates:* I ink need- or merit-based aid to college major.

Strengthen Federal Science and Engineering Education Efforts

- *National Science Foundation* as */cad science education agency:* underscore responsibility through the Science and Engineering Education Directorate for elementary through undergraduate science programs.
- *Federal interagency coordination and data collection*— raise the visibility of science education and the transfer of information between agencies and to educational communities.

recruitment is a long-term strategy to enlarge the base of potential scientists and engineers by recruiting more and different students into science and engineering. Such a strategy entails working with schools and colleges, along with children, teachers, and staff, to renovate elementary and secondary mathematics and science education.

If the Nation wants more scientists and engineers relatively quickly, then retaining college and graduate students in science and engineering is the most useful policy strategy. Many able students leave science during college, after earning baccalaureate degrees, and during graduate school. Only about 30 percent of baccalaureate science and engineering graduates enter full-time graduate study, and nearly half of science and engineering doctoral candidates never earn Ph.D.s. Some loss is inevitable (and, indeed, beneficial to other fields), but those who leave unwillingly and prematurely are a rich resource that could be tapped. Because attrition rates are so high and the population of research scientists and engineers is relatively small, slight improvements in retention could increase significantly the number of scientists and engineers in the work force. Federal policies could work at all levels to retain more of these able, interested students in the pool.

Many factors affect students' career choice and persistence in science and engineering: interest and aptitude; perceptions about careers gleaned from university faculty, peers, and jobs; and anticipated earnings and other, nonmonetary rewards. Students considering academic careers must also weigh the burden of undertaking and financing graduate training. The Federal Government affects these career decisions through targeted support of students, universities, and research, and through its pervasive influence on the American economy and research agenda. The extent and form of Federal support for students, particularly graduate students, affects the attractiveness of further study. Federal research and development (R&D) support and national missions (e.g., in health, space, defense) shape

students' perceptions of the job market for scientists and engineers, as well as the environments in which students are educated.

Many of the policies discussed in this report involve established mechanisms that could be expanded effectively. There are prepared college graduates and graduate students who, with the proven incentives of fellowships and R&D-supported jobs, could be attracted to science and engineering.

The basic goal of recruitment is to expand and improve the talent pool. The years to do this are elementary school through the first years of college. A particularly critical time is 6th through 12th grade, when course-taking becomes more specialized and career plans are formed. Policies to expand the mathematics and science talent pool differ from those to accelerate or improve the education of a small, science-oriented population. Students who take early, enthusiastic likings to science and mathematics can be served differently from those whose interests are still developing.

For all students, the content and quality of their elementary and secondary education determine their academic preparation for college, their likelihood of graduating from college, and their ability to derive the greatest benefit from a college education. Better high school graduates mean better college graduates, and ultimately better scientists and engineers. Increased participation for those students outside the traditional stereotype of college-bound science or engineering majors, such as many minorities and women, must begin with early changes in their preparation, awareness, and interest. They must first be prepared for and drawn into college and science majors before they can respond to graduate and R&D programs. The continuing low proportion of these groups in science and engineering indicates that the current educational system and career incentives must be made to work better. The end of expansion and transition to a steady state of enrollments and research funding will require universities, employers, and the Federal Government to adjust their models and mechanisms of science and engineering recruitment.

There are two demonstrably successful ways to recruit young people to science and engineering: offer special science and mathematics educational enrichment programs tailored to selected students, and give all students good, enthusiastic teaching. An area of lively innovation is informal education—science museums, television programs, camps, and other experiences outside the formal school system.

In the near term, policies can only be implemented with existing teachers, schools, textbooks, and equipment, in a system with multiple educational objectives. In the longer term, substantial improvements in recruitment might come through full-scale revision of elementary and secondary curricula, tracking, testing, and course structure. Such sweeping change should be undertaken with all students and all purposes of education in mind (not just science and engineering), and will be hard to achieve given the scale of American education and the inertia of the existing system.

The health of the U.S. economy, technological changes, and shifting government priorities, none of which can be projected with any useful degree of accuracy, all affect future demand for scientists and engineers. The demand has increased since World War II, and most analysts expect that growth to continue; but growth will vary significantly from field to field. The complexity of analyzing changes in demand for the relatively small science and engineering work force confounds forecasts, especially at the level of individual fields. Federal actions, because of their pervasive effects on the economy and on the size and location of R&D activities, have strong effects, both direct and indirect, on the demand.

Although comprising only 4 percent of American workers, scientists and engineers have specialized skills that are vital to the national welfare: they widen human understanding by doing basic research and by teaching, they develop and apply new technologies of every kind, and they keep the national physical infrastructure and manufacturing base running smoothly. Others trained as scientists and engineers, but not actively employed in research or product development, also contribute to our national well-being in other occupations. Historically, the demand for scientists and engineers has been rising. The Nation is well advised, therefore, to seek an adequate supply of people prepared for science and engineering careers.