Is U.S. Science and Technology Adrift?

CPST
Commission on Professionals in Science and Technology

Abstract

"STEM" is an acronym for "Science, Technology, Engineering, and Math." During the 20th century, strong demand in the United States for trained STEM professionals fueled significant growth across all of science and its allied fields. New data suggest that this long trend may have ended, at least for the time being. While the U.S. economy's need for growing numbers of skilled technical people may not be over, since 2001 the STEM share of employment in the U.S. has been shrinking. Our scientific and technical workforce is still growing but it has been lagging behind the growth of the U.S. labor force as a whole. This paper assesses the present condition of STEM occupations in the light of these data and recent observations about the status of science in this nation.

In a paper issued by this project in 2006, Lindsay Lowell and Mark Regets noted that between 1950 and 2000, employment in science, technology, engineering and mathematical ("STEM") occupations in the United States grew more than three times as fast as the civilian labor force as a whole.[1] New data from the Current Population Survey (CPS) indicate that this long trend of strong U.S. demand for scientific and technical specialists ended after 2001 and had not resumed by 2006. As a result, updated tabulations of the CPS statistics indicate that the STEM share of total U.S. employment has been shrinking (see Figure 1, below).

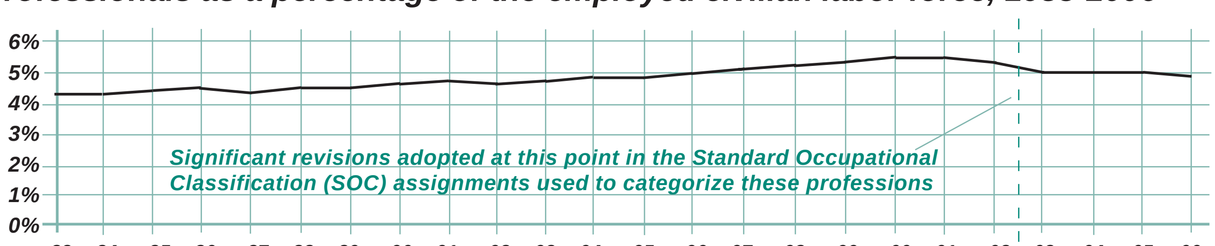
Many factors might help to explain this change in the numbers for the U.S. scientific and technical workforce. One possibility, always present in statistics, is that previously unconsidered factors may explain apparently surprising results, and the new CPS data seem certain to lead to more work as analysts compare them with other sources of workforce data. We carried out one such comparison in a separate white paper published earlier this year, and found rather good agreement between the 2003 CPS results and the Bureau of Labor Statistics' separate 2004 baseline data for its current set of employment projections.[2] We are currently

[1] "A Half-Century Snapshot of the STEM Workforce, 1950 to 2000," STEM Workforce Data Project White Paper No. 1 (Washington, D.C.: Commission on Professionals in Science and Technology, August 2006), p. 3.

[2] See Table 1: Comparable estimates of the overall size of the employed STEM workforce: 2003 results from NSF/SESTAT, annualized 2003 data from the Current Population Survey, and 2004 baseline data from the current version of the BLS industry-occupation matrix, in "Improving Federal Statistics on the Science, Technology, Engineering and Mathematics (STEM) Workforce," STEM Workforce Data Project White Paper No. 2, (Washington, D.C.: Commission on Professionals in Science and Technology, January 2007), p. 5.

Figure 1

STEM professionals as a percentage of the employed civilian labor force, 1983-2006



Year	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Total STEM (millions)	4.4	4.6	4.8	5.0	5.0	5.3	5.4	5.6	5.6	5.6	5.7	6.1	6.1	6.3	6.7	7.0	7.3	7.6	7.6	7.3	7.0	7.1	7.2	7.3
Total ECLF (millions)	100.8	105.0	107.2	109.6	112.4	115.0	117.3	118.8	117.7	118.5	120.3	123.1	124.9	126.7	129.6	131.5	133.5	136.9	136.9	136.5	137.7	139 .3	141.7	144.4
Percent STEM	4.4%	4.4%	4.5%	4.6%	4.4%	4.6%	4.6%	4.7%	4.8%	4.7%	4.8%	4.9%	4.9%	5.0%	5.2%	5.3%	5.4%	5.6%	5.6%	5.3%	5.1%	5.1%	5.1%	5.0%

Sources: STEM Workforce Data Project Archive 1, updated to 2006 with new results from the AAT ("annual average tabulation") series 11 datasets, based on the Current Population Survey and maintained by the Bureau of Labor Statistics at ftp://146.142.4.23/pub/special.requests/lf/. For the complete derivation of the data depicted above, see the data archive for this project at http://www.cpst.org.

planning to test the CPS results for possible changes in the demographic composition of the STEM labor force. We expect that other analysts may take similar steps of their own.

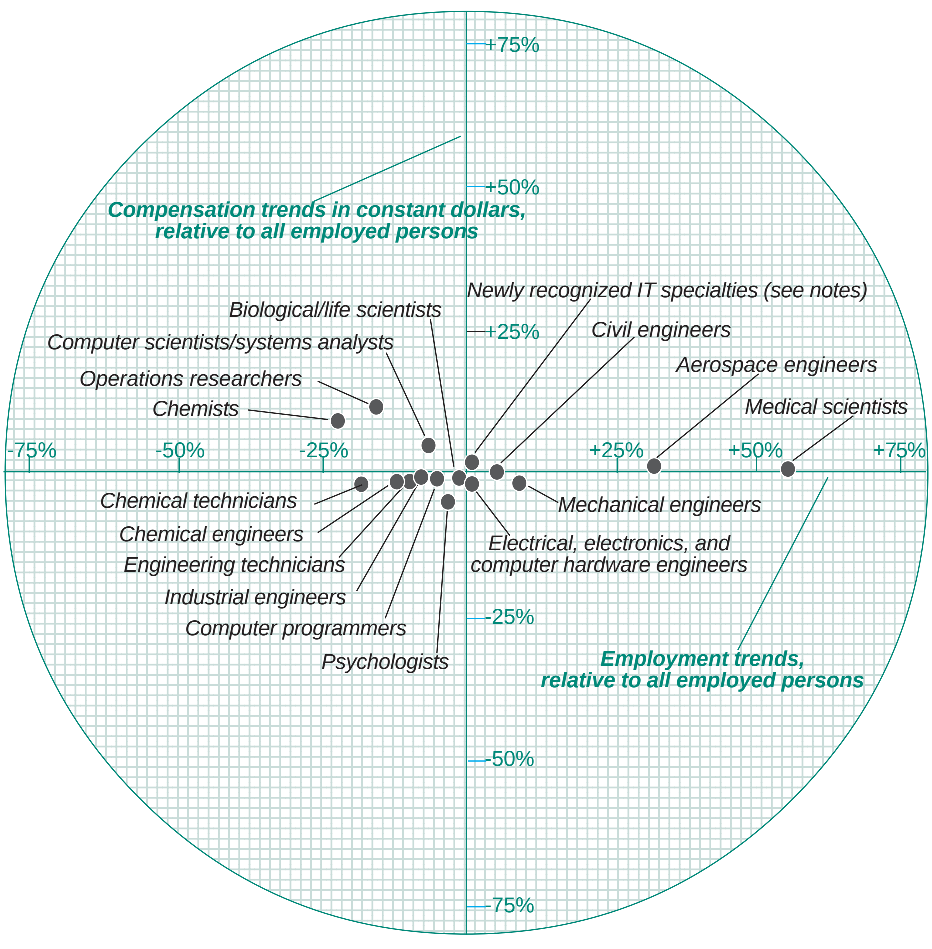
Some possible explanations of changes in data can be ruled out. For example, the statistics include foreign-origin workers on temporary visas. Another likely contributor to reduced rates of growth for domestic STEM jobs, the rise of offshored outsourcing of scientific and technical work, cannot be reliably measured at all. Recent data from the Department of Commerce's Bureau of Economic Analysis on imports from 2001 through 2005 show that payments for foreign computer and information services may have nearly doubled in these five years, while those for imported research, development, and testing services may have nearly tripled,[3] but it is not clear what these figures mean in terms of lost U.S. jobs. There are signs that economists are reviewing their data and methods as events indicate that global markets require global oversight. While multinational business operations are here to stay, offshoring in particular is getting a second look as its limitations become more evident.[4]

Other reasons for weakened growth of STEM jobs could include possible migrations of STEM talent to other professions, including health occupations (which are the largest science-related arena of employment not covered by this project), or to elementary and secondary education, where employment is rising rapidly and understanding of science is in demand. And, of course, many observers of science and its applications believe that young people increasingly favor financial or business careers,[5] even if they possess credentials in STEM subjects.

Looking more closely at trends. Earlier reports in this series include data on two measures of economic demand for an occupational specialty: employment and compensation.[6] Updates of those numbers,

Figure 2

Employment and compensation trends in selected STEM occupations, 2003-2006



Notes: data from the AAT11 and AAT39 series of tabulations, based on the Current Population Survey and maintained by BLS at ftp://146.142.4.23/pub/special.requests/lf/. Median weekly earnings converted to constant 2005 dollars to eliminate influences of inflation. To allow for refinements in federal Standard Occupational Classification (SOC) codes applied to these data after 2002, computer hardware engineers have been added to the electrical and electronics engineering group, and an additional group is included in this chart that combines results for five occupations related to information technology which had not been separately reported in this time series before: computer software engineers, computer support specialists, database administrators, network and systems administrators, and network and data communications analysts. The reported occupations accounted for 82 percent of all STEM employment in 2006.

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3 See Table 1b, "Trade in Services, 1992-2005," from statistics on international economic accounts at http://www.bea.gov/international/intlserv.htm.

4 "You can't just let market forces run roughshod over every social concern," says Colin Bradford of the Brookings Institution, speaking of the ultimate need of civilized governments to protect the welfare of their people (quoted in Peter S. Goodman, "End Nears for Era of Presidential Trade Authority," *The Washington Post,* June 30, 2007, p. D1). See also Alan S. Blinder, "Free Trade's Great, but Offshoring Rattles Me," *The Washington Post,* May 6, 2007, p. B4.

5 Kim Hart, "Graduating With a CP-Yay: Firms Lavish Accounting Majors With Trips, Parties, and Offers," *The Washington Post,* July 6, 2007, p. A1.

6 Gauging demand for technical professionals is a tricky business. For guidance, see Burt Barnow *et al.*, *Skill Mismatches and Worker Shortages: The Problem and Appropriate Responses,* final report to the Office of the Assistant Secretary for Policy, U.S. Department of Labor (Washington: The Urban Institute, 1999).

which are based on merged annual results compiled by the Bureau of Labor Statistics from the monthly Current Population Survey, provide a way to observe trends among some major components of the STEM workforce since the end of the dot-com/telecommunications boom of the 1990s. Figure 2, on page 2, depicts the STEM portion of the U.S. occupational structure during 2003-2006. Figure 3, on page 3, provides comparable data for 1995-2002. All of the information in these exhibits is relative to general trends for the entire labor force: that is, the location of a profession on these diagrams shows whether it is doing better or worse than average. Spreadsheets and other materials archived at this project's website at http://www.cpst.org provide all original source data used to create these charts and document all subsequent manipulations of the numbers.

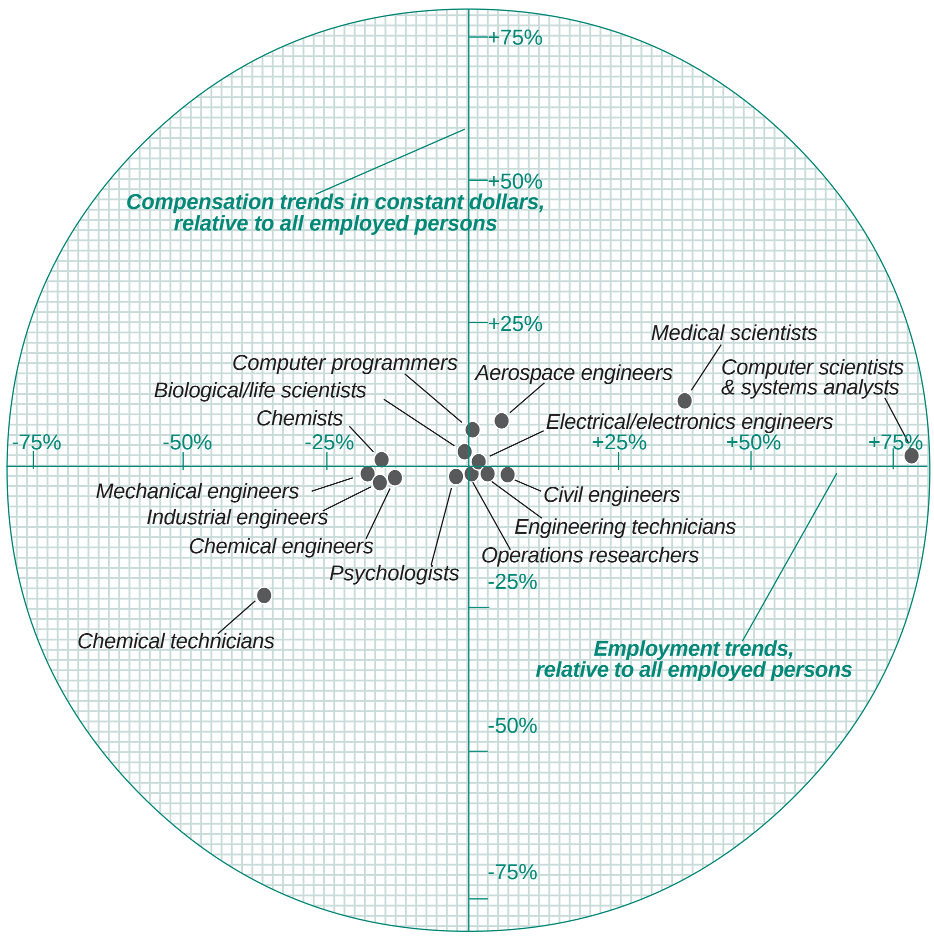
Although these data cover at least 80 percent of all STEM employment, details for many important disciplines are missing because reliable numbers on both employment and compensation are only available for larger occupations. For more details, see reports one and five in this series.

In these charts, the horizontal axis reflects change in an occupation's employment, compared to results for the entire labor force. Occupations on the left side of the graphs are not keeping up with overall growth rates for all employment in the nation, while those on the right have above-average growth. The vertical axis of the graphs reflects change in weekly earnings, measured in constant dollars and expressed, like the changes in employment, in degrees of growth or decline relative to all employed persons. Occupations in the top half of the graphs are doing better than average in improving the actual buying power of their pay scales, while those in the bottom half are not.

Professions at the exact center of these charts match overall national employment and salary trends; they are doing neither better nor worse than most. The top right quarters of the graphs contain occupations that are growing faster than the overall economy and are seeing improvements in real income, while those in the lower left quarters have been declining in both employment and median levels of pay. The other quarters of these charts describe less obvious economic possibilities. The top left regions contain occupations where median pay is improving but which have not grown fast enough to match overall national trends for gains in employment — conditions that may apply when employers anticipate growing future demand and raise salary scales to provide incentives for recruitment. Occupations in the bottom right quarters have better-than-average growth in employment but worse-than-average trends in pay — a set of outcomes that occurs in these data only when relative declines in salaries are small.

Figure 3

Employment and compensation trends in selected STEM occupations, 1995-2002



Notes: data from the AAT11 and AAT39 series of tabulations, based on the Current Population Survey and maintained by BLS at ftp://146.142.4.23/pub/special.requests/lf/. Median weekly earnings converted to constant 2005 dollars to eliminate influences of inflation. Prior to 2003, these tabulations did not include separate details for computer hardware engineers, computer software engineers, computer support specialists, database administrators, network and systems administrators, or network and data communications analysts. The reported occupations accounted for 80 percent of all STEM employment in 2002.

Figure 1 on page 1 of this report says that the STEM share of all U.S. employment has dropped to levels last seen in the mid-1990s, although the absolute size of this workforce has increased by more than one million people. Figures 2 and 3 document how these changes have been distributed among different STEM professions. The great rise in information technology jobs that occurred in the 1990s (and which is reflected in Figure 3) has ended. Growth in IT employment is still a very significant source of added jobs, because this sector has become very large, accounting for more than 42 percent of all STEM employment (however, note that apart from medical scientists, this percentage does not allow for the equally large health sector).

There has been a recovery of growth for mechanical engineers, who did not fare well during the dot-com years. Current trends for some other STEM professions now seem to be following directions that may have been signaled earlier. Employment in industrial engineering has continued to decline, although at lower levels of severity. Within the three professions tied to the chemical industry, employment losses have also continued, although losses in compensation have declined for chemical technicians, and pay scales have improved for chemists.

Two larger STEM-related occupations have done well during the last several years: aerospace engineering, where growing employment reflects rising demand and improved financial incentives during the 1990s, and medical scientists, who are gaining from strong demand for medical specialties in general. During 2003-2006, neither of these two professions has seen much more growth in real income. Expressed in constant dollars to allow for the effects of inflation, median earnings for the entire U.S. labor force have actually declined slightly.

In the graph for 1995-2002, longer time spans apply, so larger effects are possible. As in 2003-2006, many of these fields clustered around the center of the chart, mirroring trends for the economy as a whole. Four occupations — chemists, chemical engineers, industrial engineers, and mechanical engineers — showed declines in employment. Chemical technicians declined in both numbers and pay. Compensation trends were more positive during 1995-2002 for aerospace engineers and medical scientists. As noted above, those improvements may have signaled rises in demand that led to even more employment growth for these two professions during 2003-2006. Information technology, where employment between 1995-2002 rose 75 percent faster than the rate of job growth for the general economy, captured most of the limited attention of media and the public for such trends. What did not get as much attention was the equally impressive containment of compensation scales for the IT workers, which did not rise much above the modest average improvement of about 7.7 percent in real income that applied to all employed persons.

Other disturbing assessments. Additional signs of trouble for the scientific community have become visible. In 2005, the three highest scientific bodies in the nation — the National Academy of Science, the National Academy Engineering and the Institute of Medicine — jointly issued a report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* which found that "the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength."[7]

[7] Washington, D.C.: National Academy Press, 2005, p. 2.

The next year, another report published by the Defense Science Board concluded that our "lead in critical technologies is under threat and that commercial off-the-shelf technology is insufficient to meet U.S. and UK needs in these areas."[8] Further comments on this second report appeared June 3, 2007 in an op-ed column by David Ignatius of *The Washington Post,* titled "The Ideas Engine Needs a Tuneup." Ignatius argued that excessive aversion to risk "could undermine America's dominance of the new technologies that will be crucial to the nation's security in the 21st century,"[9] and he pointed at two possible causes for such concerns: congressional earmarks, which may now account for as much as 40 percent of U.S. military funds for science and technology; and feelings among some practicing scientists that agencies like DARPA (the Defense Advanced Research Project Agency) and the National Institutes of Health have become less willing to support higher-risk, cutting-edge work.

Other recent reports make arguments similar to those in the *Gathering Storm* report,[10] and pressures are building for new improvements

[8] Letter of transmittal, Report of the Joint U.S. Defense Science Board and UK Defence Scientific Advisory Council Task Force on Defense Critical Technologies (Washington, D.C.: Department of Defense, March, 2006).

[9] Page B7.

[10] Examples include two documents from the National Science Board, *The Science and Engineering Workforce: Realizing America's Potential* (Arlington, VA: National Science Foundation, 2006), and *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System* (Arlington, VA: National Science Foundation, draft for public comment revised August 9, 2007). Other organizations arguing for federal action to safeguard the nation's STEM capacities include the Council on Competitiveness and the U.S. Commission on National Security/21st Century.

in science and math education, increased R&D funding, and other additions to the nation's investment in scientific and technical leadership. On August 9, 2007, the President signed the "America Competes Act," authorizing (but not appropriating) a doubling of grants for research in the physical sciences, improvements in education, funds for energy research, and more.[11] However, the White House also indicated that it might not support much in the way of actual appropriations for some of the initiatives in the bill. Many other federal programs have been funded well below their authorized levels of support, and it remains to be seen just how much new money will go to support additional STEM activities.

In addition, it is not clear how plans like these, which are supposed to encourage greater participation in STEM occupations, can overcome the skepticism that is being displayed on the part of both experienced STEM professionals and young persons about prospects for these careers. While observers of trends in the placement of new STEM graduates report that employers are actively recruiting at colleges and universities, opportunities for experienced scientists, engineers, and other kinds of technical professionals are not so easy to find, nor are openings for many recent graduates who don't have access to good college placement services. Some employers seem to have adopted the assumption that technical skill is now merely a commodity to be acquired as needed; in response, the U.S. branch of the Institute of Electrical and Electronics Engineers has been testing a new career management workshop that deals with building survival skills as a contract engineer in an era of "just-in-time employment."[12]

Is U.S. science and technology adrift? Of course it is. Science and its workforce floats in a cultural sea that includes powerful social, economic, and political forces.[13] Most scientific and technical activity is highly decentralized, while other stakeholders present more united fronts, although some segments of the STEM professions, such as large R&D institutions in academia and elsewhere, are considerably better organized than is the whole. It is not surprising, then, that policymaking may not reflect all the concerns and issues that matter in maintaining the general scientific capabilities of the United States. If scientific and technical people wish to increase their influence on policies that affect their own work, this state of affairs will need to change. Such a step would not be easily accomplished. Science values rationality; political and economic values may be more slippery. Moreover, divisions in other parts of the culture — for example, in politics or religion — are present among STEM people as well, and so those in the workforce may seldom be of one mind when faced with choices outside the realm of one's professional skills.

Still, some queasiness might be expected among people in the U.S. STEM workforce, given their diminishing presence in the economy, their frequent replacement with foreign labor located both here and abroad, continuing worries about the brief career life of one's technical training, and demands from many employers for total, 24/7 concentration on immediate results — a point of view that may be reasonable in some business situations but which is not always so reasonable for activities like science, research, and development that may require attention for years before yielding returns, if indeed there is any yield at all. Despite concerns like these, which are not entirely new, the persistence of STEM degree production over the years[14] shows that many Americans believe that as long as the career prospects are reasonable, science or one of its allied applications is what they would like to do. There is no shortage whatever of interested people. What is in short supply are reasons to believe that technical careers will be worth the considerable investment they demand in time and training. To attract more participants, at least two problems need attention. First, at the very time that the nation needs to make STEM careers more attractive, domestic job markets are soft because employers have tapped foreign sources of labor that were not available before. There are signs, however, that access to foreign talent will not be unlimited. Multinational employers will need to compete with increasingly intensive local development agendas, especially in Asia. In addition, a story in the July 3, 2007 issue of *The Wall Street Journal*, "Second Thoughts: Some in Silicon Valley Begin to Sour on India; A Few Bring Jobs Back As Pay of Top Engineers In Bangalore Skyrockets"[15]

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[11] Ben Worthen, "America Competes... on Paper," *The Wall Street Journal Online,* Business Technology Blog, August 9, 2007, at permalink http://blogs.wsj.com/biztech/2007/08/09/america-competeson-paper/.

[12] "Careers in the New Millennium," a project of IEEE-USA's Career & Workforce Policy Committee; first presented 10/2005, most recently 6/2007.

[13] For striking illustrations of the effects of external forces on the early development of science, see Neal Stephenson, *The Baroque Cycle* (a novel in three volumes; New York: Harper Collins, 2003-04). For a useful guide to the unified analysis of cultural problems with interacting social, economic, and political elements, see Alfred Kuhn, *The Logic of Social Systems* (San Francisco: Jossey-Bass, 1974).

[14] See the sixth report in this series.

[15] Pui-Wing Tam and Jackie Range, p. A1.

shows just how quickly the new world markets can adjust to changes in labor conditions.

The second problem is that in the meantime the dangers of drift remain. Although the newly signed "America Competes Act" claims to respond to the *Gathering Storm* report and may provide at least some new support for STEM activities, this legislation does not address the labor market conditions that are acting to discourage participation in U.S. science, and the actual appropriations or other initiatives that might be enabled by the act may not be enough to reverse current trends.

The *Gathering Storm* report is a rare case where all of STEM, including medicine, has spoken with a single voice. The three sponsoring organizations share a single supporting staff operation, the National Research Council, which may have helped to make the report's broad sponsorship feasible. There are few if any other leading STEM organizations at this level of breadth and authority, although there are associations for all engineers, for all scientists, and literally thousands of more specialized societies, interest groups, and less formal networks. Most of these are focused on current technical developments in narrowly defined specialties. Some scientific and technical societies are much less focused on career, workforce, or other nontechnical matters, while others cover those aspects of a STEM career very thoroughly. Compared to other interest groups, including other professions, the general level of workforce organization and oversight across STEM as a whole is almost nonexistent, save for what the National Academies have done. There are STEM policy networks, but it is difficult to name any institution that really speaks for all STEM professionals.

Steps could be taken to improve the outlook for U.S. science and technology. The most obvious move is to address the disconnects in federal STEM policy, which has yet to come to grips with issues like offshoring and the use of "guest workers." The next report in this series will address this theme of responsible, rational science and technology policy in more detail, and in November 2007 we will hold a national conference on the status and prospects of the STEM workforce.

Other kinds of initiatives might also be possible but likely to be much more difficult to execute. One wonders if new kinds of STEM-wide undertakings might help raise the visibility and influence of the scientific and technical professions. Similar kinds of efforts in the past have not always met with success. Yet one also wonders: when will we begin to create 21st century institutions that serve us all more effectively? And would not systems for the public's management of its investments in American scientific capabilities be a good place to begin these kinds of tasks? Science already possesses tools that can be brought to bear on these matters. Putting those tools to work will raise many additional issues that will need further examination. We will release a paper on some of these themes later in 2007.

Meanwhile, what of those people newly introduced to this workforce? One certain point can be made: if the number of members of this cohort of workers is significantly smaller than before, every member of the group will gain lasting bargaining power. If you like science and technology, stay in the sector and ride out this storm.

— R. A. Ellis, October 2007

The author would like to thank other observers of the STEM workforce who gave their time to discuss some of the issues raised in this paper, including Eleanor Babco, retired CPST Executive Director; Alan Franklin, retired from the National Institute of Standards and Technology; Richard Freeman, National Bureau of Economic Research; Richard Heckel, Michigan Technological University; Susan Hill, CPST (visiting researcher from the National Science Foundation); Ron Hira, Rochester Institute of Technology; Vin O'Neill, IEEE-USA; Henry Petroski, Duke University; and Robert Weatherall, retired director of MIT's Office of Career Services.

About the STEM Workforce Data Project

The purpose of the STEM Workforce Data Project is to identify and distribute reliable statistics on scientific, technological, engineering, and mathematical (STEM) workers in the United States. Like the similar IT Workforce Data Project (see http://www.cpst.org for those reports), the STEM project uses the full range of U.S. federal statistical resources as well as other sources of information.

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