Engineering education: coping with the crisis

Government, industry, and academic leaders meet to target solutions to the ominous decline in the academic environment

The economic health of the United States depends increasingly on the fruits of engineering technology. But the educational system that supplies engineers is eroding.

The root of most educational ills appears to be lack of money. Educators say that they need funds to pay higher faculty salaries so they can attract and keep quality professors and turn out quality graduates. They also need better equipment in research facilities and teaching laboratories and larger support staffs to help those faculty members do their jobs. And they need to improve the academic environment and stipends for graduate students to help them resist the temptation to take a high-paying job in industry after receiving a bachelor's degree instead of studying for a Ph.D. degree.

The money must come from somewhere—tuition increases, state government funding, national Government funding, endowments, or industry. And it must be used to build a strong foundation for the educational system, not just to lend a short-term helping hand. There may also be obstacles in the way of building that foundation that will have to be leveled.

If nothing is done, the educational system that supplies engineers will continue to erode, and engineering leaders have come to feel that this erosion could lead to socioeconomic distortion and even disaster.

The view from the average engineering dean's office is alarming: declining quantity and quality of instructors and doctoral students, deteriorating physical plants, and plummeting faculty morale. At corporate headquarters, the scene is relatively calm today but industry employment recruiters are worried about the future. They believe it will become increasingly difficult to hire essential engineers. And the Federal Government, unable to hold its engineers in the face of private competition, fears that the result may be an enfeebled national technological base, with not only economic but also defense implications for the nation.

To contribute to the search for solutions, Spectrum—with the encouragement of the National Science Foundation director, John B. Slaughter—convened a blue-ribbon group of industry, academic, and Government leaders in a closed, all-day roundtable discussion [see "The Panelists," right]. Each participant not only described the problems but also proposed ways to begin solving them and began to assign responsibilities for implementing the solutions. The panel tried to avoid philosophical discussions of the appropriateness of today's curriculum and the nature of university education. Instead it went straight to the basic practical problem: U.S. universities, with today's budgets, are not producing the quantity and quality of engineers that industry needs.

Co-moderator of the session with this writer was Stephen Perry, Associate Editor.

The panelists

The members of Spectrum's roundtable panel were as follows:

John B. Slaughter, director of the National Science Foundation.

George A. Keyworth, the Presidential science advisor.

William J. Perry, former under secretary for research and engineering in the Department of Defense and chairman of a committee of electronics industry leaders coordinated by the American Electronics Association.

Paul E. Gray, president of the Massachusetts Institute of Technology, Cambridge.

John C. Hancock, dean of engineering at Purdue University, West Lafayette, Ind.

Herbert H. Woodson, chairman of the electrical engineering department at the University of Texas at Austin.

Edward E. David, president of Exxon Research and Engineering, Florham Park, N.J.

Jerrier A. Haddad, vice president of the IBM Corp., Armonk, N.Y.

Seth H. Washburn, vice president of personnel and public relations for Bell Laboratories, Murray Hill, N.J.
I. The problems

Less than an hour after the discussion began, the panelists had agreed that the unattractiveness of the academic career is causing most current problems in engineering education. All the other problems—including the loss of faculty to industry, the shortage of Ph.D. holders, and the declining proportion of U.S. citizens among graduate students—stem from that, the participants said.

The panel focused on low faculty salaries as a major factor making academic careers so unappealing. Mr. Haddad said that though the salaries for full professors were not bad compared with what those engineers would be paid in industry, assistant and associate professors received salaries of from 25 to 30 percent less. And instructors, he said, receive about 40 percent less than they would be paid at an entry-level job in industry.

Mr. Haddad pointed to tenure as another factor in the unattractiveness of the academic career path. "The new holder of a bachelor's degree," he said, "looks at an academic career as a possibility and says, 'My God, I have to take a 40-percent pay cut and work like hell for six years after spending four years studying for a Ph.D., and then somebody votes with black and white balls to decide whether I keep my job.' It is not attractive."

Dr. Hancock said that the real issue was the academic environment—heavy teaching loads and poor laboratory facilities. This poor environment lowers faculty morale and causes a decline in graduate students. The students see their professors' plight and are discouraged from pursuing academic careers, he claimed. In addition, the panel noted that current faculty members are being drawn into industry. "In my previous life at Los Alamos," Dr. Keyworth said, "we attracted a large number of Nobel-caliber scientists from top universities. They were fed up with the academic life—fed up with large classes, crummy equipment, the whole environment."

But, Mr. Haddad said, "There's no sense wringing our hands and saying that industry is sucking these guys out. That's just the way it is. In a free-market economy that is what is going to happen."

Industry faces a Ph.D. shortage

Many industrialists are finding that they cannot get Ph.D.s when they need them, according to Dr. Keyworth. He related this problem to the deterioration of academic life.

"Most students who go after a Ph.D. do so because it ensures the possibility of pursuing an academic career," he said, "so if they see an academic career as unattractive, at least half the motivation for a Ph.D. disappears."

But perhaps part of this problem is industry's fault, the panelists suggested. Dr. David of Exxon complained about the irrelevance of the doctorate to many industrial jobs. He said that if it were more relevant, salaries would be higher for Ph.D.s.

Dr. Hancock of Purdue did not agree that the Ph.D. was irrelevant, but he did agree that industry was not signaling to students that they needed it. Rather, he said, students get the impression that they need only a B.S., and perhaps an M.B.A. later, as they work their way into management.

Dr. David said, however, that there was a need in industry for advanced-degree holders "who understand how to design in an overall systems context, as opposed to designing a box or a piece." Engineers graduating at the B.S. level do not have that broad view, he said.

Graduate study is too expensive

The high cost of graduate study is another problem, Dr. David claimed. As an example he mentioned that the Rose-Hulman Institute of Technology, Terre Haute, Ind., one of the many smaller, less prestigious institutions that nevertheless provide industry with a steady supply of engineers, was having trouble aiding its students, who are drawn from fairly low-income rural areas. He said the same problem existed at the graduate level.

"This problem is important," Dr. David continued, "because some of the very best engineers have come from low-income backgrounds in the past, and I think they will again if they are given the opportunity."

Engineering has an image problem

The panelists expected the shortage of engineers to worsen in the future [see "Yes, there is an engineering shortage," p. 68] and suggested that one culprit might be the public perception of the profession. This image—created by horror stories of boom and bust cycles, newspaper articles about engineering Ph.D.s driving taxicabs, and the like—gives the impression of constant fluctuation between surplus and shortage, according to Dr. Gray of the Massachusetts Institute of Technology.

In fact, he added, there are very few professions where one can find a pattern of greater stability in the long run than in engineering.

Reacting to this, Dr. David emphasized that some companies hoard engineers, laying them off when there is a drop in business. This policy does not generate confidence of future employment.
among engineers, he noted.

Dr. Gray agreed that engineering practices are partly to blame for the field’s tarnished image. “We tend to promote career patterns,” he said, “in which people work at engineering for a relatively short time—10, 15, or 20 years—then are regarded as unsuccessful unless they migrate out of engineering into management or a nontechnical career. The only role models that young people have of engineers in mid-career, at age 45 to 50, are, by and large, academic role models. You don’t find very many folks in engineering at those ages in the industrial sector—the sector for which we are preparing most people.”

Mr. Haddad took a different stand, noting that some students studied engineering to prepare themselves for other careers. “I think we should be very careful not to decry that, but in fact to encourage it,” he said. “If engineering graduates did not go into law or medicine, business, the biological sciences, and so on, we would be a much poorer society.”

Dr. Slaughter agreed, observing that one of Japan’s strengths was the large number of engineers in senior Government positions.

And Dr. Hancock, speaking from his Purdue experience, said he saw more and more students pursuing an engineering curriculum without any intention of practicing engineering.

Dr. Gray pointed to problems at the precollege level, including a growing demographic problem. The number of college-age people has peaked and will decline by about 25 percent during the next 15 years, he said, and this decline in the source of undergraduates “is bound to put pressure on engineering enrollments simply because there will be fewer youngsters in college.

“The second factor, and probably the more important one,” he added, “is that the teaching of science and mathematics at the secondary-school level is a national scandal. There are fewer and fewer youngsters graduating from high school with anything that you would recognize as adequate preparation in the sciences or mathematics.”

Dr. Keyworth concurred, saying that precollege science courses did not convey that science could be challenging and fun, that scientific and engineering careers offered more than “just a job.” He attributed the problem to a decline in the quality of high-school science teachers, and Dr. Hancock agreed, noting that talented people did not go into high-school science teaching because the rewards were poor.

**Quality of engineering graduates questioned**

The panel had become deeply embroiled in discussions about the quantity of prospective engineers, when Dr. David of Exxon cautioned the group not to forget the quality of engineers graduating from colleges. A domino effect was feared.

“There are people being placed on university faculties today that 10 years ago we would never have considered,” Dr. Hancock said, “and they are going to get tenure because the shortage is going to continue.” Substandard teachers turn out substandard engineering graduates, he pointed out.

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**II. The solutions**

After reaching a consensus on the basic problems to be solved in engineering education, the panelists began the more difficult task of coming up with workable solutions.

**Raising faculty salaries**

One obvious way to make academic careers more attractive, it was suggested, is to raise faculty salaries. Dr. Gray of MIT said that universities would have to make engineering faculty salaries higher on the average than those in other academic disciplines. He said that universities had learned to live with the fact that there is little or no parity between medical and law school faculty salaries and those in other academic disciplines; now they must live with the same differential in engineering salaries.

“We are in a buyer’s market for faculty in essentially all of the humanities and social sciences,” he said. But “we are in a seller’s market in engineering,” he added.

“We have to be able to increase engineering faculty salaries,” Dr. Gray went on, “and be prepared to do that in the face of all the economic pressures universities are facing and also in the face of increasingly bitter complaints from faculty elsewhere that ‘this is not fair; you are raising those folks’ salaries faster than mine.’”

Dr. Woodson, discussing his recent experience under an ad-
administration at the University of Texas sympathetic to the needs of the engineering school, said that the engineering college "got a little increment last January—very quietly—that nobody else got," and "that didn't cause any real problems." He conceded that there were "some disgruntled faculty in the other colleges" but said it was not a "serious problem."

Finding the dollars

Once the universities accept the need to pay engineering faculty members more, where will the money come from?

Dr. Gray said that the extra salary dollars should come from the same place all salaries come from—endowments and tuition—because the salary differential has to be permanent.

"You can't do it by looking to some industrial consortium or individual company or some other entity to give you a helping hand for a few years," he said, "because when the helping hand goes away, you are back in the soup. You have to build it into your operating cost base, wherever your operating money comes from."

Yes, there is an engineering shortage, most panelists say

Ever since the traumatic layoffs in the aerospace industry in the early 1970s, many engineers have viewed predictions of engineering shortages as cynical attempts by industry to flood the market and keep engineers down. The majority of Spectrum's panelists recognized that there was controversy on this issue. Among the group, only Seth H. Washburn, vice president of personnel and public relations for Bell Laboratories, questioned the seriousness of the engineering shortage. He said, "I think that if there were a true shortage, this would be reflected in starting salaries."

"That will be," responded William J. Perry, chairman of a committee of electronics industry leaders coordinated by the American Electronics Association.

Mr. Washburn recalled hearing the same sentiments 10 years ago. "In fact," he said, "I think I am right in saying that starting salaries on average have gone up about with the Consumer Price Index. If there is a real shortage today, I think it is inescapable that real starting salaries will go up correspondingly. The shortage today is principally in quality rather than quantity."

According to Dr. Perry, "They are going up. I think your statistics are in error because of their aggregate nature. If you go to the computer science field, where the shortage is greatest, you'll see average starting salaries of $30,000 to $35,000."

Expressing the view of the majority of the panelists, National Science Foundation director John B. Slaughter said, "We do have current personnel shortages at almost every degree level and in nearly every specialty of engineering and the computer professions, as well as in certain professions of the physical and biological sciences—geology, for example."

"The enrollment in the engineering schools has been increasing very rapidly since 1973. The figure we hear now is that throughout the nation, somewhere in the neighborhood of 500,000 students are in our engineering schools. If the increase in enrollment continues, one would think that perhaps the shortages could be relieved by the end of the decade. But the problems I have mentioned—faculty and equipment—operate against that."

"And even though we have greatly increasing numbers of undergraduates, the number of engineering Ph.D.s has been decreasing since about 1972. So the shortages are likely to continue and even to worsen."

John C. Hancock, dean of engineering at Purdue University, observed that "engineering is a growth field. It has been a growth field for the last two decades."

Dr. Perry cited a study by the American Electronics Association supporting this statement: "The AEC went to companies in the electronics industry and about 700 companies, representing about $80 billion a year in annual sales, responded—about one third of the electronics industry."

"The aggregate demand for electronics engineers and computer scientists turned out in their projection data is 15-percent-a-year compounded growth. You compare that with the supply. It is not close to that."

"In particular, that aggregate number for electronics engineers and computer scientists over five years comes to over 200,000 new jobs in those two fields. You compare that with the graduates in electrical engineering and computer science of about 15,000 a year, and you get some measure of how far we are off the mark. It is about a 3-to-1 disparity."

"To the extent that this demand estimate is in error, my guess is it is in error on the conservative side. This does not take into account any estimate of people retiring out of the system—both people leaving the engineering professions and going into management and those just quitting—and that aggravates the problem more. These figures represent the companies' conservative estimates that they use for planning investments and tend to err on the light side—and they really knock your eyes out."

"I think a substantial case can be made that there is a potentially serious impact on the national security when you think of the extent to which defense and energy and our economy depend on technical input."

"As far as the Government defense laboratories are concerned, most of them are sitting on open requisitions for engineers that they are just not able to fill—or, to the extent they do fill them, there is a fairly substantial lack of quality. Government laboratories in general don't have the same appeal or drawing power as industry."

Dr. Hancock said his experience confirmed Dr. Perry's projections: "The vigor of recruiting at the undergraduate level is unlike that at any other time since I have been in academia. My general feeling is that these data are accurate. Whether or not it is 15 percent or 10 percent I don't know, but it puts tremendous stress on the system."

"In the last three years the number of employers coming to Purdue looking for B.S. graduates has gone up 53 percent. Our class has not increased by 53 percent. The number of employers looking for master's students has gone up 67 percent, and our class has remained about the same. The number of employers looking for Ph.D.s has more than doubled in the last three years and our Ph.D. class has dwindled."

—T.S.P.
Gray: The teaching of science and mathematics at the secondary-school level is a national scandal.

Hancock: If we go down the tubes, industry is going to pay the price.

Slaughter: We have current personnel shortages at almost every degree level and in nearly every specialty of engineering and the computer professions.

Haddad: There's no sense wringing our hands and saying that industry is sucking these guys out. That's just the way it is.

Universities are audited and must prove that the money is being used to fulfill the research contracts. It can't just be used to raise salaries, he said.

"Again," Dr. Keyworth continued, "you have as one element of the grant the individual salaries and overhead, and those are always negotiable. What happens if at the beginning of the grant the faculty salary costs X instead of the 0.7X that it cost the year before? I don't think there are any fundamental laws that prevent anything."

Dr. Perry, the former DOD under secretary for research and engineering, had a different thought. The American Electronics Association, he interposed, is planning to promote the establishment of many new chairs of instruction in universities by granting annual stipends to augment existing salaries.

Other panelists suggested that some universities might object to this form of payment. In those cases, Dr. Perry said, the stipends could be earmarked for research assistants and travel expenses.

In addition, Dr. Perry said, his association might urge its member companies to hire beginning instructors at universities as part-time consultants. "Most of the professors with 10 to 15 years of tenure have all the consultancies they want," he said, "but entry-level instructors don't. If we can package something so the university can offer the instructor a job with a guaranteed consultancy, that would go a long way toward dealing with the faculty issue."

A better life for academic faculty

Salaries are not the only thing that must be improved to make academia attractive, the panel suggested. Dr. Gray brought up the matter of the quality of academic life.

"Quality-of-life issues," he said, "relate to the problem, which is tied to the question of facilities and equipment; the Government grant system, which over the last 10 years has become more bureaucratic, more fragmented, and more difficult to deal with; teaching loads; and growing burdens of peripheral obligations or required unproductive activities that contribute little to a professor's main task."

In Dr. Gray's opinion, the facilities and equipment segment of this problem could be ameliorated. "We clearly need more capital funds invested in laboratory equipment," he said, "and that is an area where I think both Government and industry have specific roles to play."

Augmenting university faculty

The use of adjunct faculty members was suggested as a way to help relieve faculty shortages. The American Electronics Association, Dr. Perry said, intends to try to increase the use of
visiting professors from industry. But Dr. Woodson saw a problem: a knowledgeable person in industry, someone a university would really like to have, would probably be so committed to the company that he would be reluctant to leave.

A possible solution, Mr. Haddad said, is for universities to create intensive short courses. "Now," he explained, "the guy can take four weeks off and come back, and, having organized his job well, he will still find his desk and his job. When he leaves for a year, he's done."

Helping graduate students

On the universities' need to attract more graduate students, the panel did not view the problem as 100-percent financial. Dr. David indicated that the schools were overlooking the idealism of young students; he believed they would continue their education if they could be convinced that three to five years of graduate school would broaden them and make them better qualified for careers.

Dr. Gray said, "You have to get graduate students up above the poverty level if you expect to attract more of the best students." He suggested that industry and Government could help solve this problem. Perhaps, he said, fellowships could be established, bearing the names of companies supporting them.

Dr. Hancock said that the NSF should recognize that support for top Ph.D. candidates must go beyond the current NSF grants. Dr. Slaughter replied that this would create a Catch-22 situation in which increased stipends to individual students would decrease the total grants. He suggested the Odeg a source of funds and said the Office of Naval Research was in the process of studying the feasibility of individual grants in the $12,000 to $15,000 range.

"That begins to get in a range that makes more sense than what we have been doing," Dr. Slaughter said.

The panelists also explored the expansion of cooperative programs, under which a student shares his time between study at a university and a job in industry. But though the representatives of industry on the panel appeared willing to back a large increase in co-op program participation by graduate students, the response from academia was mixed.

"I think a five- or ten-fold increase could be sold to industry," Dr. Perry said, but some universities are reluctant to expand their co-op programs, he noted. Dr. Gray suggested the reason.

"We have long held the view that graduate education ought to occur on a residential basis," he said, "so that the graduate students are rubbing shoulders daily with the faculty and undergraduates and research staff."

"We are the only nation in the world which combines graduate education and research. In all of the other nations research occurs where there are no teaching responsibilities and no young people. Young people lose because the educational environment is not as invigorating as it could be, and the quality of research does not benefit from the continuous injections of new ideas and the creative impulse from young people."

Dr. Keyworth agreed that the synergism in American graduate education makes the American Ph.D. program generally more successful than those in other countries.

Meeting the increased demand

Once the current problems are solved, the group agreed, the number or size of engineering programs must expand. Dr. Perry noted that he was studying how to increase the throughput of bachelor of science candidates in electrical engineering by 50 percent over the next five years. It is going to be expensive, he said.

Dr. Gray put the capital cost per graduate at approximately $300,000 to $400,000. "If we are going to make any substantial increase in capacity and size, those costs are going to have to be met in some way," he said.

The resistance of university administrators to disproportionate increases in engineering enrollment was touched on. Dr. Gray said that MIT has doubled its engineering enrollment in the last seven years and is not going to contribute to any more capacity increases. And Dr. Woodson said that the University of Texas would resist engineering capacity increases on the grounds that it does not want a university made up entirely of engineers. But Dr. Perry said that the American Electronics Association planned to try to funnel its financial support to universities that committed themselves to increasing engineering capacity.

Will they? "There are those who expect the bubble to burst as it has in the past," Dr. Woodson noted.

"We understand that reluctance very well," Dr. Perry responded, "but we will try to put our money where our mouth is."

Where the responsibility lies

The panelists agreed that Government, industry, and academia must share the responsibility for solving engineering education's problems. But which sector should take the initiative?

"Part of the problem," Dr. Hancock said, "is an industry problem, because the university is a servicing agent to industry. If we go down the tubes, industry is going to pay the price."

Mr. Haddad countered: "The facts are that if there is a structural problem in academia, industry is not going to fix it. Industry will help fix it, Government will help fix it, but academia is going to have to fix it. We don't set the relationships in industry between what universities pay an assistant professor and an associate professor; the university sets the relationship. It sets the relationship as to what an engineering professor is paid—the relationship between overhead and salaries, and so forth. You run your institutions; industry does not. Therefore any structural problem is academia's problem. We may suffer in the end if you don't do your job properly, but let's not say it's industry's problem, because that's tantamount to saying that industry had better
Other areas of concern: from minorities to secondary education

Spectrum's panelists touched on many areas related to engineering education that could stand improvement, including opportunities for minorities, secondary education, and educational productivity.

Seth H. Washburn of Bell Laboratories said that more women are studying engineering, with the percentage steadily increasing over the last 10 years. But members of minority groups are not doing as well, he went on. Though their entry into engineering matched the increase for women in the early 1970s, he noted, it has leveled off for most degree levels, and the number of minority Ph.D. graduates appears to be declining.

On the quality of science and mathematics teachers in high schools, the group found a serious problem and said the cause was largely one of financial compensation.

John B. Slaughter, director of the National Science Foundation, asked, "Isn't part of the problem the fact that it is not attractive to people in institutions of higher learning to prepare themselves to be math and science teachers on the high-school level? I often say that if it weren't for football coaches, you wouldn't have math teachers."

Herbert H. Woodson, chairman of the electrical engineering department at the University of Texas, agreed that high-school salaries were the first shortcoming that needed to be remedied, but Jerriee A. Haddad, vice president of IBM, added that education schools that prepared high-school teachers were also lacking.

Some panelists suggested increasing the productivity of the engineering schools by modernizing teaching methods. Dr. Slaughter commented that he was disturbed by the fact that when he visited his alma mater he found students still being taught the way he was taught.

Mr. Haddad disagreed that this needs changing; he favored the traditional method of teaching. "I think," he said, "you learn a lot being at the knee of somebody who knows a lot more than you; that education is more than merely the transfer of knowledge. I would hate to see a lot more mechanization. I have a feeling that just as it takes nine months to make a baby, it takes so much manpower to make an education." —T.S.P.

Washburn: (I see) an incipient tragedy in identification, education, and utilization of black young people.

"You file into a room," he said, "a guy goes to the blackboard with a piece of chalk and lectures the class, and it's almost as though nothing has happened since I went to school. Is there any way to improve that situation?"

Mr. Haddad disagreed that this needs changing; he favored the traditional method of teaching. "I think," he said, "you learn a lot being at the knee of somebody who knows a lot more than you; that education is more than merely the transfer of knowledge. I would hate to see a lot more mechanization. I have a feeling that just as it takes nine months to make a baby, it takes so much manpower to make an education." —T.S.P.

come in and fix your institution for you, and that we are not going to do."

Mr. Haddad said that the initiative must come from academia, though industry would help. He suggested that representatives of educational institutions go to chief executive officers in industry and present a rational request; then "the CEO will get his people to determine what the problem is and whether or not he can and should help," Mr. Haddad added.

Nevertheless industry is currently taking the initiative. Some panelists gave examples. Dr. Perry said that the American Electronics Association planned to lobby in state legislatures to increase both the size of engineering programs and faculty salaries in state engineering schools. And the association recently set up a foundation to improve engineering education, asking its 1700 member companies to contribute the equivalent of 2 percent of their R&D budgets, or an expected total of $30 million to $50 million.

Dr. David told of Exxon's plans, which include direct action to improve engineering faculty salaries and work conditions and increased fellowship opportunities to attract able students to teaching careers in engineering.

"It seems to me," he said, "if we were successful in doing something about each of these areas, we wouldn't have solved the whole problem, but we would have gone a long way toward getting the wheels rolling in the right direction."

He suggested that by efforts through such groups as the Business Council, the Business Higher Education Forum, the Chamber of Commerce, and the Business Round Table companies could be convinced to take on the parts of the education problem that are linked to their futures.

"What would be required here," Dr. David said, "is some lobbying with these high-level business organizations." He estimated the total cost to industry of solving most of the salary problem for graduate faculty at $50 million.

Dr. David suggested that a group like the Council for Chemical Research be created to coordinate a program. The council works like this: companies contribute to the council a certain amount of money for each chemist or chemical engineer they employ. The council distributes money to universities, depending on how many graduates they produce in chemistry or chemical engineering.

As a second and larger part of the program, Dr. David said, member companies put a certain percentage of their gross earnings into various programs at universities, making a statement to the council as to where the money was put and what it was for. "That gives you the diversity and the lack of bureaucracy which is attractive to many industries," he said.

Mr. Haddad suggested that a quasi-governmental institution be set up to funnel money from industry to universities and tax credits be given for industrial contributions to the institution. But he said that that is probably "a long time coming."

A plan taking shape

The discussion covered in this article went a long way toward identifying causes of the present crisis in engineering education and suggesting actions that could be taken, but a realistic plan of implementation is needed. To foster the development of such a plan, George A. Keyworth, the Presidential science advisor, and Spectrum are convening members of industry, education, and government in Washington, D.C., this month and asking them to lay out a program and assign responsibilities. A report of the November discussion will appear in a future issue of Spectrum. —T.S.P.