



THE REAL GLOBAL TECHNOLOGY CHALLENGE

BY LEONARD LYNN AND HAROLD SALZMAN

At one of the renowned Indian Institutes of Technology, we recently asked a class of 80 engineering and science undergraduates how many wanted to go to the United States for graduate school or a job. A decade ago nearly everyone in the classroom would have a hand in the air. Now, not a single hand was raised. “Why go to the U.S.,” they asked, “when all the opportunity is in India?”

In China when we visited software, telecommunications, and heavy-equipment companies owned by U.S. multinational corporations, we met managers born and raised in Asia but with U.S. engineering degrees. They had expected to spend their entire working lives in the United States. So why had they gone back to China? Because these days not only were the new career opportunities there as good as those in the U.S., but the technology-development projects were even more challenging.

Clearly the U.S. is no longer the universally preferred home for the global technology elite. Increasing numbers of scientists and engineers who were educated and have built successful careers here are returning to China, India, and other countries. Many in the younger generation never come here in the first place.

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Noting these trends, the policy and technology communities are sounding the alarm about an impending U.S. fall from scientific and technological dominance. Compounding the loss of international talent, they say, is the declining appeal of science and engineering for American students, even as the tide of engineers and scientists trained in China and India rises. Recent policy reports and popular press stories claim that each of these countries is graduating around 600,000 engineers a year, compared to about 100,000 in the United States.

Leading policy groups fear that this combination of a decline in science and engineering prowess and the rising strength of China and India will leave the United States a much-diminished technology power, one that will have to concede leadership to the emerging economies. The American Electronics Association warns that “the United States can no longer take its technological dominance for granted;” the National Academy of Sciences fears that the “scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength;” the Business Roundtable exhorts us to “not disregard our history” of scientific and technological superiority, “nor forget who we are;” and the Council on Competitiveness foresees “a fall from leadership [that will] threaten the security of the nation and the prosperity of its citizens.”

THE NUMBERS GAME

Well, *should* the U.S. worry if China and India each graduates about five times as many engineers as we do? First of all, there is good reason to doubt the numbers. Only a few thousand new engineers are coming out of the Indian Institutes of Technology (IIT) or the premier Chinese universities each year. Many others are graduating from universities with poor or marginal facilities where students have little exposure to innovative engineering and science. And frankly, the numbers being reported seem to overestimate actual graduation rates by a factor of four or five.

But let’s not quibble. Surely, even if India and China only graduate two or three times as many engineers as we do, as no doubt they will over the next decade, shouldn’t we think through the

ramifications of this fact? Well, yes. But perhaps we should first ask what all these engineers in China and India *do* after they graduate. Those of us with long memories may recall that when the U.S.S.R. launched the first satellite in 1957, policy observers warned that that nation was graduating far more engineers than we were. The feared corollary of Russian domination of space was military domination on earth. Later, in the 1980s, when Japanese businesses seemed unstoppable in every industry from steelmaking to consumer electron-

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ics, critics complained that the brightest Japanese went into engineering while the brightest Americans got M.B.A.’s and law degrees. The inevitable consequence seemed to be that we would soon fall under Japanese economic domination. U.S. education and industry did rise to the international challenge, but not by cajoling twice as many of our young people to major in engineering. It turned out that the key to military and economic success based on technology was not the *number* of engineers but how they were educated and used.

Let’s go back to our class at the elite Indian Institutes of Technology. When we asked the students about their career

aspirations, part of the research we conducted for a study funded by the National Science Foundation and the Kauffman Foundation, two-thirds said they had no intention of going into a science or engineering career. The opportunity they saw in India was in starting a new business or rising through the management ranks of a multinational (and rising more quickly at the Indian office than they would in the firm’s U.S. or European office). But, we asked, why spend four years in a grueling engineering or science curriculum if they wanted to go into business? “Branding” was the reply. Two-thirds of U.S. science and engineering students abandon a strictly scientific or engineering career path upon graduation, and Indian students seem to be planning similar career trajectories and strategies for success.

In our view the key question is not how many engineers graduate in a country; rather, it is how they are educated, how many are used in the development of innovative technology, how they are used, and how well they are supported by a country’s innovation policy.

So the U.S. economy is not threatened by the increase in the numbers of scientists and engineers in China and India. Nevertheless, our research in the U.S., Europe, China, and India does find plenty for us to be worried about, as well as pointing to what kinds of public policy could address those concerns. Unfortunately, the spurious data on numbers of engineers are a distraction that may cause us to devote our resources to the solution of false problems, while neglecting those that are real. That neglect is due in part to our failure to appreciate how the world is changing and how the role of the United States in the new global economy will have to change if we are to continue to prosper.

“SEA TURTLES” AND THE END OF U.S. TECHNOLOGICAL HEGEMONY

All the best opportunities for science and technology were located in the United States as recently as five or six years ago. We had the best universities, the best technical facilities, and the companies that offered the most exciting technical careers. We offered the best opportunities for entrepreneurs using advanced technology to start new companies. Indian engineering students

competed desperately for opportunities to attend U.S. universities and to make careers here after graduation. Chinese nationals with good jobs at major firms here never would have dreamt of going back to China. Silicon Valley and its ilk were the engines of the American innovation system, powered by a unique elixir of intellectual and financial fuel, and coupled with the opportunity and openness inherent in the United States culture and economy. A key ingredient was our ability to attract some of the most dynamic technological entrepreneurs from India, China, and other countries.

Clearly this is no longer the case.

China has welcomed nearly 200,000 returning scientists, engineers, managers, entrepreneurs, and other Western-educated Chinese in recent years, according to a count by the Chinese Ministry of Education. Known as *hai gui*, sea turtles returning home, they are representative of a shift in the high-skill migration tide away from the West and toward emerging and transitional economies around the globe. Perhaps even more significant is that with the return and retention of scientists and engineers, venture capital, multinational collaborators, and other components necessary to build global enterprises follow this tide. Many successful Indian and Chinese entrepreneurs are moving their existing companies to their countries of birth. We were also surprised to discover how many small technology firms in India have recently been founded by expatriate Indians returning after 20-, 30-, or even 40-year careers at large firms in the U.S.

An American has to ask: What causes someone in a secure, well-paid position—with long-time residency and often citizenship in the world's richest country—to begin anew with a risky venture in a country with a spotty infrastructure and some of the world's worst pockets of poverty? The answer, in brief, is the promise—which used to be uniquely American—of opportunity.

In Guangzhou we interviewed a 35-year-old entrepreneur from Taiwan and toured one of his plants, a facility producing zinc and brass components for U.S. and European multinationals, components that are used in a variety of products ranging from plumbing fixtures to communications equipment. A dozen years ago he had gone to the U.S. to get an M.B.A., and he had planned to make

his career here as well. But when he graduated in the late 1990s, his father called him back to take over the family business and expand it into mainland China. The firm had 150 employees then. Now it has more than 5,000 at several sites in China. A U.S. engineer who first visited the plant in Guangzhou six or seven years ago told us that at that time the plant was using 1920s technology. Now, he tells us, it is more advanced than any comparable facility in the U.S.

And if the U.S. is less and less regarded as the “land of technological opportunity” for bright technologists and entrepreneurs from China and India, China and India are increasingly seen as the lands of technological opportunity by multinational corporations, both American and foreign. Multinationals from the U.S., Europe, Taiwan, Singapore, Japan, and Korea increasingly

try, although nearly all are in California, not Detroit. So while we do not believe that the rise of global competitors will make the U.S. a science and engineering rust belt, this country *is* facing a difficult transition as the opportunities, challenges, and companies are changing.

THE UNITED STATES’ “TECHNOLOGY PROBLEM”

We need to understand both the economies and the sentiments beyond our borders in order to develop policy that will support the future economic and technological health of the United States. Unfortunately, U.S. policymakers have not fully grasped that need. Their talk of a “science and engineering gap” based on numbers of engineers misses the point.

Policies that have been proposed to shore up the U.S. technological position in the world include investing more in basic research; revamping the visa system to re-establish our attractiveness to the smartest foreign students, scientists, and engineers; improving the pre-university education in science and math; and enticing more young Americans to major in science and engineering. While we certainly favor doing a better job of increasing our store of knowledge through research and our human capital by attracting the best and brightest from around the world, we do not believe these approaches fully address the major challenge now facing the United States.

Nor does merely increasing the quantity and quality of American science and math education. Just as comparing the numbers of engineering graduates in the United States to those in China and India is misleading, so too is attributing our newly vulnerable position to a collapse of the U.S. education system based on the low international ranking of our students’ senior-year science and math scores. While our schools can always do better and are woefully inadequate in serving certain groups and areas in the nation, a science and math deficit is not the major driver of our technology problem. When only a third of qualified four-year college graduates in science and engineering continue in those fields, we should turn our attention to market demand.

Why produce more types of workers that firms have no intention of hiring? When we asked U.S. engineers and engineering managers what careers they wanted for their children, none

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populate the new technology parks of China and India.

Meanwhile, back home in the United States “foreign” firms like Toyota, Honda, Hyundai, and BMW are now hiring American autoworkers. And the U.S. has become the center of design, with every leading auto manufacturer in the world establishing a design center in this coun-

mentioned engineering. And it was not because they hadn't had a great ride in their careers, but rather it was because they thought the ride was over for the next generation. The U.S. technology problem, we would argue, is that the technology needs of the growth markets—for both consumer products and capital goods that require new types of technology or innovation (ranging from low-cost laptops to more efficient heating technology to less-polluting manufacturing technology)—are not being met by U.S. engineering or science or the current direction of public policy. This is the crux of the *real* science and engineering gap in the U.S.

SCIENCE AND ENGINEERING JOBS HAVE CHANGED

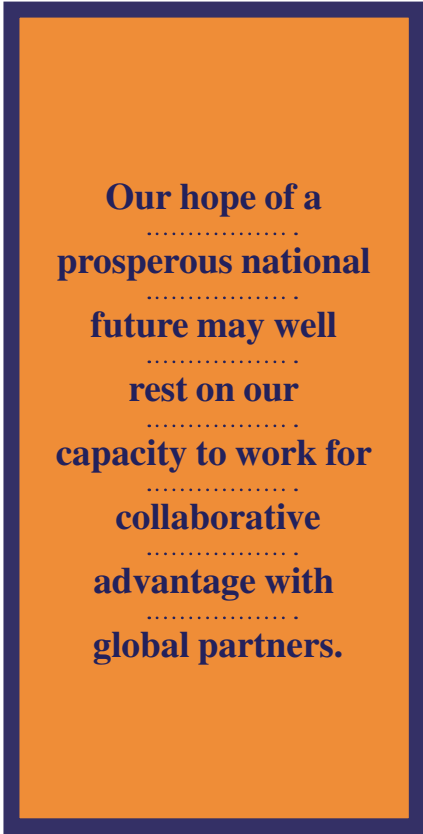
Today's engineering or science firm looks little like one of just a decade ago, when nearly all software development was done by teams in the United States or Europe. Now, as one U.S. manager explained from the half-vacant offices of his IT company, the jobs of programmers and even systems analysts are being done abroad. His and other companies currently are hiring only experienced project managers. Among the IT firms we've studied, the latest projects will have only 10 to 20 percent of the work done in the U.S. or Europe. The rest will be done in India and soon China.

Shortages of certain types of engineers in the United States may occasionally be a factor in the decision of U.S. firms to offshore their technology development, but more common reasons are 1) to serve customers in the fastest-growing markets, 2) to take advantage of lower wages for professionals (although this is declining in importance), and 3) to increase the capacity and deployment of their science and technology workforce. Some offshoring has taken place because the substance of engineering work has changed and, in some cases, technology innovation is different from what it was just a few years ago.

In office software, for example, innovation now comes from improvement in the process, not the functionality of the product. Standard office-suite products such as word processing, spreadsheets, and presentation slides have been relatively static in the past few years (with the addition of a new feature or two to sell new products). In the past eight years, perhaps the most

important productivity innovation in office software has been the reduction of failures, namely fewer system crashes. Now, the most critical need for software innovation is to increase user productivity by addressing the problems of ever-new bugs, security threats, and difficulty in supporting and maintaining software—much of which depends on building *better* products rather than new products. This, in turn, depends on improving the process of development software.

But while important to users, improvements for stability and maintainability are



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hardly the stuff of pioneering discovery and invention or great IPO potential. One only needs to talk to the current crop of computer engineers and entrepreneurs in the U.S. or Europe to gauge their lack of interest in devoting their careers to developing more secure, stable, and maintainable versions of existing software. These improvements are increasingly the result of innovation in the methods and process of software development, of using structured methods and systems. The current wave of software development is flowing to the locus of *process innovation*, which is offshore. Under the aegis of low-cost and legacy work, Indian software firms have been focused on work that addresses

the real needs of industry and, at least for the moment, there are many bright science and engineering graduates in India and China who are anxious to work on these problems for a good salary. Ramping up the number of our young people majoring in software engineering will not recreate the IT heyday of the past decade.

So, will these trends continue until all technology development has left the United States? Of course not. Indeed, we believe there will be some reversal. There is substantial evidence that a lot of the offshoring of technical work has taken place because of a kind of "bandwagon" effect. A perception exists that major savings can be made by offshoring, so Wall Street analysts ask CEOs about their offshoring policies. Thus, pressures to outsource are driven down into organizations from the top levels. Engineering managers are allowed to expand their headcount of employees, but not in the United States. Naturally, they go global.

But this strategy may not be cost effective. Our interviews at multinationals suggest, for example, that the strategy of having teams on both sides of the globe is often based on a mythical 24-hour workday. The coordination problems working across time zones can cost as much as outsourcing saves in salary costs. With actual total cost savings (not just salary differences) estimated at 15 percent—among other things, offshore productivity is about three-fifths of onshore productivity in our estimates—the benefit can be small if cost is the only reason for going offshore. Sending a team manager to visit his or her team in India can easily cost \$10,000 to \$15,000 a trip, and for strategic operations, frequent trips are a necessity.

Moreover, salaries for qualified engineers and engineering managers in India and China are rising fast. One multinational manager in Shanghai commented that he has trouble keeping good engineers for more than a year, and to attract qualified replacements, he must pay significantly more. There is also an emerging shortage of Chinese and Indian engineering managers who can work effectively within multinationals.

China, Russia, and other Eastern Bloc economies once tried to out-compete the West by setting ever-higher quotas for the production of steel and other products. The result was scrap yards piled high with steel and other products

that were neither needed nor usable. We should expect the same kind of result if we concentrate on setting quotas for the production of engineers. Our educational institutions should instead focus on educating the *types* of technologists and innovators that the markets will demand, through gaining better understanding of changing job requirements and employer needs, rather than relying on their long-standing curricula and programs. And in their role of promoting the U.S. public good, policymakers can play a pivotal role in guiding human-resource investment, with the aim not to restore national technological hegemony but rather to ensure us a rewarding place in the newly developing global technology system.

TECHNO-NATIONALISM VERSUS COLLABORATIVE ADVANTAGE

Globalism is permeating the U.S. economy at every level. The Chinese and Indian economies are growing faster than the typical 3.5 percent annual growth rate in the U.S. and other “advanced economies,” and their markets are much larger than ours. This means that the emerging economies are not only producing producers of technology—they are also producing consumers. Already, U.S.-based firms have made their top priorities developing products for the emerging economies. If those products also sell in the U.S., all the better—but the needs of the American market will no longer be the sole driver of the technologies of the future.

As a mature market, the bulk of U.S. consumption can be satisfied with older products and technology. Not so in the emerging economies. Heating technology developed for the U.S. market and U.S. energy prices will gain little market share in China. With relatively low energy costs and well-established technologies, the U.S. market has less demand for new low-cost and highly efficient technologies than do the emerging markets. Similarly, the SUVs and large automobiles developed for maximum profitability in the United States market may find a niche among the wealthy and status-conscious in the emerging economies, but they are unlikely to meet the far greater demand from the expanding middle classes in those countries.

In some cases, technological and scientific priorities will suggest that work should be done elsewhere. For example,

a pharmaceutical firm we visited in Europe centers its research on infectious diseases in India. That’s where they can find top scientists who are highly motivated to work on this problem, and that’s where scientists have the most experience with it. But U.S. scientists can collaborate with their Indian counterparts to extend the resulting knowledge to other parts of the world. It is challenges like these that are the stuff of pioneering discoveries and IPO potential. Clearly, an understanding that local science leads to global science is already re-orienting corporate strategies.

So what sort of engineers and engineering managers will we need in this new environment? When we examine actual hiring practices of firms, we find that although they are looking for technical competence, they want much more than that. An engineering manager at a major multinational we visited was trying to decide between two candidates to lead an engineering team. One had a stellar academic record and work history while the other had a strong but not exceptional record. Who was hired? The second candidate—because he wanted to travel, felt comfortable in the company of different types of people, and spoke a second language. This firm, like most of the 25 multinationals we visited, needs managers who have not just sufficient understanding of the technology but also excellent skills in developing and managing globally collaborative project teams.

A new class of engineers and engineering managers is emerging who will pioneer the new engineering and science framework necessary for global innovation. These people are not only engineers or managers or marketers; they also have a combination of skills, knowledge, and education that go beyond traditional engineering and science training. They have mixed allegiances to the various countries of their birth, education, citizenship, and residence. They manage their multiple identities while working comfortably across organizational, cultural, and disciplinary boundaries and dealing with the special situations of emerging economies. They have the linguistic ability to conduct negotiations in local languages and the cultural sensitivity to work in a variety of environments. There are not nearly enough of them. And hardly any of them were born in the

United States, although most were educated here.

There are a small but growing number of initiatives to broaden science and engineering education to include academic work designed to develop the broad, multidisciplinary skills and knowledge necessary to produce global innovation. Our system allows considerable local experimentation, and these experiments should be strongly supported. It is the openness and breadth of the American education system that provide a comparative advantage over highly technical programs in other countries.

U.S. innovation policy could help in this effort. It could support more exchange and study-abroad opportunities for our engineering students. It could encourage and support the development of new curricula at engineering schools and promote a broad, rather than a narrowly technical, education for engineers. It could exploit the U.S.’s advantage in having a growing proportion of its college population made up of ethnic and racial minorities.

An important first step, however, is for policymakers to stop talking in terms of threats and competition, which is likely to alienate those with whom we need to work and to prevent us from seeing opportunities for collaboration. Anachronistic, zero-sum nationalist policies are ill-suited for the global economy. Worse, they encourage other countries to compete with us and to look for non-U.S. partners instead of cooperating with us for mutual gain.

The theory of comparative advantage postulates that countries gain when they concentrate on what they do best and trade that expertise to others. In collaborative advantage, mutual gain comes from the strength of interdependencies. Other countries may have comparative advantage in the sheer number of engineers they can devote to problems, in their motivation to develop certain technologies, or because of different approaches to engineering. Our hope of a prosperous national future may well rest on our capacity to work for collaborative advantage with global partners.

Rather than compete with other countries on the numbers, we need to educate the kinds of engineers and scientists who can to work with them to our mutual advantage. We should focus on crafting policies that support the development and work of this new breed. □