Science and Technology: The Basis for Global Competitiveness

Keynote Address

Joel Goldhar

Joel Goldhar

What is the potential role for technology in business strategy and competitiveness? Are American businesses positioned to take advantage of increased opportunities to acquire new technology from a wide range of sources and reduce their traditional reluctance to utilize that technology as a basis for the way they do business?

A cynic would have to ask: does U.S. industry have a strategy for success that takes *any* kind of technology into account? My answer in general is, no. Most firms do not have any strategy beyond a set of financial objectives. As a result, we're not competitive in a lot of business areas. We spend a lot of our time focused on the financial restructuring of various businesses through such cost-cutting measures as closing down central R&D facilities, selling assets, reducing product variety, and a number of other steps that are widely discussed these days. Overall, we have a balance. At least for now, we appear to be successful in some areas: aircraft, defense technology, biotechnology. On the other hand, there are too many areas in which we are not competitive. In addition to our problems in global markets, we can't compete within the U.S. against products made by foreign suppliers.

These comments, of course, don't apply to people scanning this volume, because the fact that you're reading this speaks well for your company's desire to utilize the best available technology. But on the whole, the million or so managers and companies that *could* benefit by reading this, but chose not to, don't care about the availability of technology, nor do they think very much about how to utilize technology to make a difference in their competitiveness.

We all know the problems: declining productivity, declining market share in everything from ball bearings to machine tools to shoes and textiles, aging factories, a general short-term financial numbers emphasis, a lack of long-term investment, and a general lack of interest in innovation.

I want to address that lack of willingness to invest in innovation because I want to dispel some misconceptions. Businesses that choose not to innovate don't do it because they're dumb. They do it because, in fact, they're very smart, given their understanding of the constraints of traditional manufacturing technology and the economics of innovation in a very uncertain world. Among the motivations that drive them is the relationship of their salaries to stock price as a measure of shareholder value. Shareholder value is the new buzz word at other business schools besides my own, but it is defined these days much more by the interest and values of short-term stock traders and manipulators than by the long-term investors. There are lots of conflicts going on, making it smart for many businesses to not invest in high-risk, uncertain new technology, no matter how good, if they can't easily see how to make that technology profitable.

And yet, we're enmeshed in a world of new technology, new materials, new production processes, new information technology, new understanding of biology and of the most fundamental meaning of matter, energy, and space. We know much more about the technology and behavior of products in use. It doesn't cost us very much to add intelligence to everything from cameras to household appliances to my penultimate favorite product, the microchip-controlled toaster. As it turns out, three months after Hammacher Schlemmer advertised "The World's Only" microchip-controlled toaster at $42.95, a knockoff appeared, priced at $24.95. What amazed me the most was that both the original and the knockoff came from British firms. That tells you something about how much of a fundamental change we're seeing in the world marketplace. We now have a much greater scientific basis for product functionality. For example, we can design running shoes based on the biomechanics of the body.

In effect, the old "industrial policy" arguments about sunrise versus sunset industries were really a set of political red herrings. There doesn't really need to be any such thing as a sunset industry or a sunset business. What we do have, however, is a lot of sunset management thinking. In fact, there are no business sectors that need to be designated as cash cows for diminishment over time.

Think about the range of technologies we have available: new materials, new intelligence, new functionality and design techniques, and manufacturing technologies that allow us to add variety, customization, and multiple functionality to old products. There isn't any product that can't be dematured along the product life cycle, changed from a commodity product to an engineered product through the use of new information and new capabilities developed through science and engineering.

My ultimate favorite product, so far, is the computer-controlled running shoe. I used to joke about a product like this five or six years ago in speeches. About a year ago, I got a long-distance call from someone who had heard me talk, and he said, "You know that computer-controlled running shoe you were talking about? Go get *Runner's World* for March 1987 and look at the inside front cover. Puma's done it." Indeed, the ad showed a running shoe with a pressure transducer, a small memory chip, and connectors to a PC's serial port. You specify whether you want the software Apple or IBM compatible. As soon as you finish your run, you immediately take your shoes to your computer, plug them in, and you get a plot of how well you did compared to how you've done in the past.

Imagine the change in that business: from sneakers to running shoes. We're talking about the kind of "non-shoes" that your mother never let you wear to school, but made you carry to gym class because, if you wore your gym shoes all day long, you would have broken arches. Today, you can't buy baby shoes anymore; kids start out in a pair of Reeboks. (The challenge, of course, is how to bronze a pair of Reeboks.) Did you ever think you'd pay $50 to $130 for a pair of non-shoes for a 12-year-old? Or that you would be buying a sneaker which has 35 precision parts and is designed on a computer with the mold cut on an automated computer-integrated manufacturing cell in widths as well as lengths, with corrections for overpronation and underpronation, otherwise known as clubfoot and pigeon-toed? Or that you would buy that shoe, not at J.C. Penney, but at a specialty store where a technician would not ask your shoe size, but would interview you about your lifestyle in order to find the correct shoe for you? Not only that, you can also get that shoe in puce, mauve, "Miami Vice" pink, or today's hot new color for the kids: white. It's wonderful. What goes around does come around. That is what marketing is all about. It's what

business is all about as it takes advantage of technology. But none of this is possible without significant transfers of technology from medical science, from information science and technology, from materials science and basic physics. Who knows, perhaps the same chip that is now controlling the TEVATRON will also control the next generation of running shoe.

If we sometimes feel that we are 4-bit chips running to keep up in a 32-bit world, that's exactly correct. A Booz, Allen, Hamilton Consulting Company report compared product innovation in the 1980s to a similar study of innovations in 1968 in terms of the mortality curve of new ideas from the time they leave the lab until they finally reach the customer. In 1968, it took 40 to 50 new ideas to get two successful products. By the early 1980s, we were talking about eight ideas out of the lab for every two new products. That appears to represent a tremendous improvement in the efficiency of research and development, and the efficiency of innovation.

If we're that good, then why ain't we rich? The same report reveals the answer: 90% of the new products range from cost-reducing products to simple line extensions, that is, taking well understood capabilities in one market and moving them to another. This is what we teach in MBA programs and marketing courses: Take a small step; old products to new markets, new products to old markets. The big jump, new products to new markets, is very high risk and you'll never make any money. We've got a lot of history to prove that. As a result, less than 10% of all the new products developed are really new-business generating products like the videotape recorder, or soybean-based artificial bacon, products that make a difference, products that start new businesses.

This data gives us a sense of why we are in trouble. We're good at innovation by an efficiency measure, but we're not getting a lot of major new products. The big change in the globalization of business isn't the globalization of the markets. It's the switch from a situation where a foreign competitor's product is probably a knockoff, to a situation in which the newest, furthest out, most innovative product designs and functionalities are coming in from overseas competitors. That's a real world-turned-upside-down development for traditional American industrialists, and they aren't responding to it very well.

Why are we in trouble? We're in trouble because we learned how to play the game by the old rules and the old economics, and we became good at it. Indi-

vidual managers and entrepreneurs made a lot of money. They did this either by starting companies or becoming highly paid senior managers by doing the right things in an environment of essentially limited competition based on traditional mechanical manufacturing technology and human brain, paper archive, physical movement kinds of information systems. This leads to products with mostly domestic markets, relatively long life cycles, and fairly leisurely rates of technological change. You can see that behavior best if you think about the traditional product life-cycle diagram.

Everybody's been exposed to the product life-cycle concept somewhere, whether you've had a marketing course or not. This is an idea that drives much of our business thinking. It's always a time plot versus cumulative units sold. Have you ever seen one that's got real numbers on it? You never will, because we don't know, at the time we're playing with the model, what those numbers are going to be. But it makes a big difference if stages 1, 2, and 3 are three months, three years, three decades, or the reverse - three decades, three years, three months. Or, as is beginning to come about, more like three years, three months, three months. We're seeing a tremendous shortening of product life cycles, and we know that there's a relationship between rate of innovation and the length of product life cycle.

In the first stage, there's still a lot of product innovation going on: engineering change orders, feedback from the early customers, and so on. At this point we want a very flexible production process, one that is labor intensive, involving the smartest segment of our labor force. Sometimes it's our engineers putting together the first few prototypes and beta test components because, after all, they're the only ones who know what they've left off the blueprints in the first place. At some point we freeze the product design. Everybody does that by some system; the one I favor is to disconnect the phone line to the engineering group. You have to freeze the design, otherwise you can't start production-process innovation in an effort to figure out how to make the product in high quantity at a reasonable cost. At this point, we start to migrate from labor intensive to capital intensive kinds of technologies, initially to get enough product out the door to capture a large market share. Then, when it becomes a mature product (we know it's mature when we begin to see competitors), we switch to cost-reducing technologies. We look for yield improvements, and we squeeze

labor out and allow the process to become more and more dedicated by tooling for a narrower and narrower range of product designs. At the final stage, we have a very efficient factory - good at doing one particular product design - just about at the point in the product life cycle when that product is ready to die and customers are looking for something else.

By doing what we've been taught to do, both in mechanical engineering and in manufacturing management, the "good" production-process technology and innovation in effect becomes a *barrier* to the next round of new product innovation. That is because we're going to obsolete that production technology before it has paid off. We're going to have an embarrassingly empty physical plant and that's not good if you intend to be a manager in that business for very much longer. Everybody's got horror stories of that happening - nice new plant, old product, disaster.

The fact is, this situation doesn't happen nearly as often as you'd think from my comments because, again, we're not all that dumb, even in manufacturing. Right about in the middle of this process, when we start to talk about heavy investments to squeeze labor out, somebody says wait a minute. We can go to Sri Lanka for $.25 an hour instead of $9.50 an hour, and we won't have to make the choice to migrate from labor-intensive to capital-intensive technologies, so that our exit barriers will stay very low. The third stage of the product life cycle is that of low prices, a commodity product, and low-cost manufacturing. They are too low to give us any real profits, but they entail high exit costs for leaving because of those technology-based, capital-intensive physical facilities. The flexibility of a labor-intensive plant is not flexibility of multiple product designs. It is the ability to close the plant and leave without having an embarrassing residue left over, particularly if that plant is 5000 miles away.

So we decide to outsource. We go overseas for our manufacturing. This is the "hollowing out of the American corporation." That hollowing out is not dumb, as various articles in the business press have implied, it's smart. Some companies have gotten so smart that right at the beginning they look at this process, and if they cannot assure themselves of a third stage long enough to recoup an appropriate return on investment in the kind of technology they know they need in order to be cost competitive with low labor-cost countries, they don't start the innovation in the first place. They buy it from someone else, of-

ten a foreign competitor. They put their own label on it and move it through their own distribution system. Again, more hollowing out as we lose more basic technical skills in design and production.

We can see ancillary anecdotal evidence of this in the reduced number of new products and in the reduced demand for engineers. I haven't heard anybody from a U.S. company scream about an engineering shortage in about two years. We see the continued closing down of central R&D facilities in companies ranging from food products to traditional automobile components to high-technology electronics. These companies think they're going to buy cheap technology from the universities. They have a real shock coming. Either they aren't going to get it at all, or it will be too late, or it's going to be very expensive, because we're not dumb in the universities either. The companies that are closing down central R&D labs are going to look back fondly at the days when they controlled their low-cost technology development.

It's these kinds of tradeoffs that have forced us to constantly pit innovation against productivity. In most companies, productivity has always won out, because we know how to *measure* productivity improvements. We know how to reward people for productivity improvements. Our accounting systems, which in turn drive our stock prices, are based on evaluations of productivity in easy-to-measure areas like labor costs. We don't know how to measure the value of a new product or a new process which is going to pay off three, four, five years in the future. We continue to see this kind of behavior in U.S. industry, behavior that is driven by doing the right thing within the constraints of traditional mechanical engineering-based manufacturing technology and human brain, paper archive-based information systems.

However, we're also seeing a lot of changes. First of all, the marketplace today and over the last five years has been radically different from the marketplace in which most of today's generation of senior managers grew up. The biggest change is the truncation of the product life cycle. Not every product has the six-month life span of a video game, but within the culture of a business, it looks as if product life cycles are settling down to somewhere around a third of what they were as little as five years ago, whether we're talking about running shoes or automobiles or cameras. We begin to see the tremendous trun-

cation of the product life-cycle in all fields of science and technology. That must drive us to doing things differently!

In addition, we've got more product designs, more customized products, higher technology products, many more competitors, and a marketplace that is fragmented, but global in scope. An even greater change is in the available production-process technology. We are essentially seeing the information revolution as it is applied to all aspects of design, manufacturing, and distribution, and to relationships between vendors and their customers. That revolution is fundamentally changing the economics of how we do things and the strategies that we need to employ. We've got computer-aided design and computer-aided engineering capabilities. We've got robots that are getting smarter and smarter, and cheaper and cheaper. Never mind the horror stories you hear about the difficulties of using them. What's interesting is that the real successes don't get talked about very much.

You may have seen a small article six months ago noting that Kellogg of Battle Creek has stopped giving plant tours. Why? It's not that it was too expensive. It's because their unique technological capability - the ability to weld together corn and rice into a single breakfast chip - is so sensitive that they're afraid a competitor who sees even the outside of the technology will figure out how to do it. Once that happens, Kellogg will have lost the up-front value and the lead time in the marketplace derived from a unique new product. That product's uniqueness arises from the fact that it can't be copied, *because the competitive advantage is not in the design of the product, but in the capabilities of the production process and the technology* that Kellogg developed. That's a good model for the strategic direction we're taking in many U.S. businesses today. We're moving toward much more of a service orientation in traditional manufacturing businesses. The 48-hour turn-around ASIC-chip factory for custom designs is as much a service business as is a three-star restaurant or anything else you can think of in the traditional economist's version of a service business.

We're seeing the same thing for mechanical parts. Take, for instance, the flexible manufacturing system at the Ingersol Milling Machine Company in Rockford, Illinois. They are a special-machinery manufacturer. Their system is capable of producing 25,000 different piece parts, one at a time. Most of them are made only once, in completely random order. The key to all of this is what

we call CIM, or computer-integrated manufacturing. It's really the application of digital electronics and telecommunications capabilities to all aspects of manufacturing, moving away from the delays that paper and human beings put into a system. This is a *fundamentally different* set of technologies. It not only does the old jobs faster, cheaper, and better, *it also allows us to do new things and create the kinds of businesses that simply weren't possible with traditional manufacturing technology*, no matter how good you were at it, or how cheap your labor was, or how smart your human beings were. This new technology is based on information and machinery that will perform in new ways, tools that are multi-mission and smart, and paperless knowledge work. We're moving away from a manufacturing era when we did long runs of standard products on highly customized manufacturing equipment. We're going to an environment where we do small runs, down to economic order quantities of one at a time and one of a kind. This will be done on standard, off-the-shelf, but flexible and smart production facilities that are tailored to the needs of each particular product's design through the software and local-area networks.

The underlying economic concept is something that is called "economy of scope." In deference to my friends from the University of Chicago, what economy of scope means is that the production function has "ray vector subadditivity." If you're in manufacturing, it means that "economic order quantity equals one." Variety is free on the plant floor. The plant doesn't care whether it runs 12 in a row of the same design or one each of 12 different designs in random order, provided it has the instructions for that design in its memory and the task is within its range of tooling. We're not talking about bed sheets, perfume bottles, and bulldozers out of the same factory. We are talking about ASIC chips, anything you can insert on a 12-in. x 12-in. PC board, anything that you can turn from a 1-in. to 6-in. base shaft, a tremendous variety of capabilities. *What it means from a marketing and business point of view is that there are no longer any exit costs attached to a particular product design.* You no longer have a one-on-one relationship between the "good" factory and a particular product. You can drop a product and the capacity for manufacturing that product is fungible, it can be utilized for something else. So now the rewards to being an innovator go up, because the risks go down. You cannot so easily get "stuck" with high-investment dedicated manufacturing capability.

We all know that the innovation costs at the beginning of the process - getting the prototypes, doing the technology - are small potatoes compared to the high cost of building manufacturing capability and then breaking into the marketplace and doing the advertising. At least on the manufacturing end, we can now eliminate the factory as a barrier to high rates of new product innovation and reduce the risk of being an adopter of new technology from outside sources into your own products and businesses. It's a new kind of manufacturing. While it has no cost penalty for variety, it's a high fixed-cost business. It's more like a chemical plant than the traditional high variable-cost manufacturing system. It doesn't have many people around. If your production drops in a labor-intensive facility, you lay people off. If you're manufacturing with robots, you can stop using them, but they keep on drawing their depreciation. So you must have a high rate of new product innovation. We have to have a lot of new technology, and we have to have low-cost and efficient engineering R&D and technology transfers in order to feed this kind of new factory capability.

To reiterate: If your company chooses to adapt CIM plus flexible automation technology, *the factory is no longer a barrier to aggressive rates of new product innovation.* More importantly, the cost and constraints of the factory are no longer an excuse for not aggressively searching out new sources of technology, new kinds of technology, new ideas to pump into your traditional products. The new factory requires an increased rate of innovation. It demands fast, efficient, creative, low-cost R&D. Manufacturers need to be open to new technology from a much wider range of sources outside their organization. There are a lot of companies that would never dream that there's anything at Fermilab that might be useful to them. That's not true! You see that when you're here. The question is, will you be innovative enough to take advantage of that knowledge early in the game before everybody finds out about it?

This leads business to a set of counter-intuitive strategies based on the abilities of CIM technology (and the availability of new product technology and new science) to accommodate the need for rapid rates of innovation at low cost. The first part of this is to *invest in flexibility*, not only in facilities, but in organization, in people, in their thinking, and in the range of sources of new ideas that you take into account. We need *new marketing tactics*. We need to *deliberately shorten the product life cycle* so that by the time a "clone" or a "copycat" or a

"niche improver" goes into your marketplace, the customer knows it is the old thing. We need to *fragment the marketplace* into slices too thin to support traditional economy-of-scale-based factories. In effect, *obsolete your own products before your competitor does it for you and deny the fat middle to the niche players. Deny the marketplace to anyone that doesn't make the same investment in development of both product and process technology, and the learning process of getting good at utilizing that product and process technology.*

What CIM technology really does is level the playing field so that labor costs don't matter. Then what happens? Then the challenge is to build competitive advantage into your research and development, and into your distribution and linkages with customers. We switch the basis of competition from labor cost and manufacturing capabilities to innovation, creativity, and service - a place where we would hope U.S. industry is going to be better able to compete in world markets. We get to a point where speed becomes the basis of competitiveness rather than cost. Speed- or time-based competition, in the words of my friends at the Boston Consulting Group, is the new competitive philosophy. Rapid development. Rapid manufacturing ramp-up. Rapid processing on the plant floor. Rapid distribution. Rapid acquisition of new technology. Why? Because the faster you do something, the less likely you are to be proven wrong by events not under your control.

The only forecast I'm willing to go on record with is that there will be more and more events not under our control at a faster and faster rate. Speed will be the essence of competition in world markets. The future belongs to the quick, but hopefully not the dead. It belongs to the innovator. Remember the old joke: How do you find the pioneer in the crowd? The pioneer is the guy with his face in the mud and the arrow in his back. Like all jokes, there was a lot of truth in that for a long time. I think we've repealed those kinds of rules in that the rewards to innovation, the rewards to being first with a new technology, are becoming commensurate with the risks attached, and the risks attached are being reduced dramatically.

The keys to the future are, first, a strategic approach to the role of technology in the development of a competitive advantage in global markets. Second, a focus on the use of information technology for integration of all aspects of the business, and between the enterprise and its suppliers and customers. And

finally, the *management of innovation is the most important skill your organization can develop.* We all need to develop the skills of the innovator and the skills of the technology forecaster. Forecasting is very difficult to do, especially when you want to forecast a future that is not a linear extension of the past. The real challenge is to be able to see the implications of change before others do.

As an endpoint, I want to offer you some examples of famous forecasters of the past: Harry M. Warner, head of Warner Brothers Studios and a fine entrepreneur, said, "Who the hell wants to hear actors talk?" Grover Cleveland, one of our more memorable political lights and founder of the earliest antecedents of the Department of Energy, said, "Sensible and responsible women do not want to vote." Robert Milliken said, probably at a meeting much like this, "There is no likelihood man can ever tap the power of the atom." Tris Speaker, for those of you who follow baseball, made the famous comment, "Babe Ruth made a big mistake when he gave up pitching." Lord Kelvin once said, "Heavier-than-air flying machines are impossible." He may turn out to have been right in the long run. And finally, I call to your attention a man who, were it not for this quote, would have lingered in total obscurity and complete forgetfulness, and that's Charles H. Duell, who as director of the U.S. Patent Office in 1899 said, "Everything that can be invented has been invented." It is up to you to see that no one will ever be able to say that American industry has invented everything that it is able to invent.

The Roundtable panel on the stage of Fermilab's Ramsey Auditorium. From the left: Joel Goldhar, Hirsh Cohen, Steven Lazarus, Richard Nicholson, and Lee W. Rivers.