Fermilab Industrial Affiliates Roundtable on

The Science-Technology Spiral and the Pace of Progress

Fermilab

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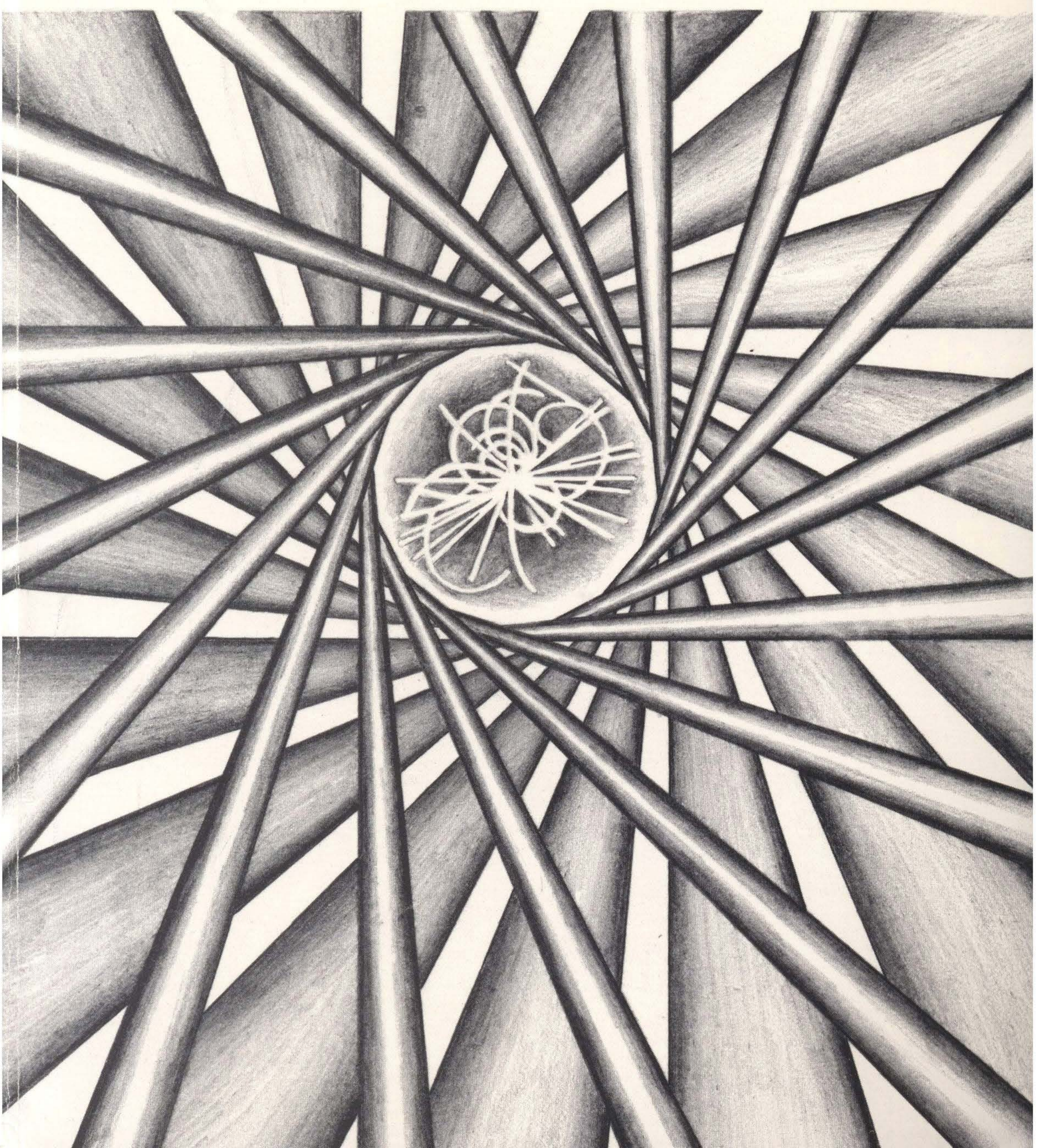

Fermilab Industrial Affiliates
Eighth Annual Meeting, May 26-27, 1988

Roundtable on
The Science-Technology Spiral
and the Pace of Progress

Sponsored by Fermilab
And the Fermilab Industrial Affiliates

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Fermi National Accelerator Laboratory
Batavia, Illinois

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Leon M. Lederman
Director
Fermi National Accelerator Laboratory

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For almost a decade we have held a meeting of the Fermilab Industrial Affiliates as spring bursts over Fermilab and the Fox Valley. Central to that annual night is a Roundtable on a weighty issue. This year was no different. Our subject was "The Science-Technology Spiral and the Pace of Progress." Numbered among our speakers and Roundtable participants were some who are among the greatest spinners in that spiral.

Few doubt that science and technology drive progress. The problem is that hardly anybody, particularly out in lay-land, understands that there *is* a spiral of technology and science. Fewer still know what to do about it.

Not too long ago we were all witness to the spectacle of 13 presidential candidates dashing around the country, talking about farm policy, trade deficits, jobs, economic competitiveness, national defense, and so on. Now these are *weighty* issues and each *may* influence some fraction of our population. . . but not one of the candidates talked about *science* which is *sure* to influence the lives of *all* of us and the lives of our kid brothers and sisters and of our children.

Why did this happen? Are the Iowa farmers or the Michigan auto workers or the Chicago Commercial Club members too ignorant or too stupid to understand issues related to the ozone layer or acid rain or robotics or microelectronics? Or could it be that the 13 candidates themselves and their political advisors and speech writers are uncomfortable with science and technology? And if they are, as I believe, uncomfortable, why is this? After all, each of them spent at least four years in college - more often than not, a fine college. In college they learned about history - economics - literature and, of course, much else that is a part of life and culture. In history they learned about Napoleon and the Kings of England - but did they learn about Michael Faraday? Here is a quiz: Who changed our lives more? Let me give you a hint. Faraday did more to change our lives than Napoleon and all the kings of England put together. His scientific insight gave us electricity - motors whose quiet hum powers our civilization, generators that convert falling water or fossil fuels to electrical power to warm us in winter, to turn night into day, relieve us of the drudgery of physical labor, extend our life span, run our factories and hi-fi sets and even our toothbrushes.

In economics we learn about market forces, productivity, the service economy, and all that good stuff, but the ingredients which generate technology and the relationship of pure research to technology are rarely taught. Could it be that the social-science scholars that embellish our academies are uncomfortable with science?

In literature we read and interpret Shakespeare, Saul Bellow, Baudelaire, Tolstoy, and Thomas Wolfe, but we rarely study Newton's *Principia*, one of the most significant books in the history of civilization and, with help, at least as readable as Baudelaire. Could it be that our humanist professors are also uncomfortable with science?

Now, why is this important? It is very important because in the real world out there, the very fabric of human existence will undergo unimaginable and mind-boggling changes over the next 50 years - changes that will be significant over the next decade and even be detectable in the next two or three years. The primary motive force for these changes is science and technology based upon science. What are the contributions to these changes? There is the good news part and the bad news part.

The ecological problems that we've already mentioned represent the serious global effects of industrialization: ozone, greenhouse effect, acid rain, disappearing forests, oil spills. There are shortages: fossil fuels, minerals, nickel and chromium, high-grade iron ore. There are new diseases such as AIDS and Legionnaire's. There is an exploding population - 5 billion people, headed for 8 billion in the not-so-distant future.

These are heavyweight, depressing issues, so let's look at the plus side, which includes the continuing enhancement of the quality of life in transportation, communication, health care, longevity, entertainment, and at least the potential for the spread of the benefits of technology to the non-industrialized 70% of our fellow residents of Planet Earth. At a deeper level, the implications of an increasingly incisive understanding of how our Universe was created is bound to have a profound effect upon our cultural, philosophical, and theological scholarship.

Science illiteracy threatens our entire democratic system. Important national decisions requiring some scientific knowledge are being made increasingly on the basis of ignorance, misunderstanding, and, so we read, even perhaps astrology!!

As business people, engineers, and scientists concerned with the technical world, we have to encourage the uninitiated to make an effort to include science in the essential continuing education that is part of their lives. They should seek out the lay-audience science books (e.g., Hawkings' *A Brief History of Time*), magazines, and TV programs that are increasingly trying to reach out to the intelligent lay audience. These resources give some an appreciation of the nature of science, its powers and its limitations. Serious journals (e.g., *Issues in Science and Technology*, *Bulletin of the Atomic Scientists*, etc.), will discuss the relationship of this intellectual activity to the driving force of our industrial society and indeed the driving force for hope in the third world. There is an additional reward. The intelligent citizen's efforts to learn science informally are often rewarded with surprising joy at the discovery of aesthetic splendor contained in scientific insight.

So, for the sake of yourself, your fellow humans, the planet, your children and theirs, my plea to you is to campaign mightily in every way, so that all citizens can share the profit and possible pleasure of science. By all means, don't short change the survival factors in a continuing lifelong effort to make your fellow citizens comfortable with this thing called Science.

We hope you find these notes from our Roundtable interesting. If you are a businessman interested in the science and technology at Fermilab, join the Fermilab Industrial Affiliates. All you need to do is pick up the phone and call me at (312) 840-3211 or Dick Carrigan at (312) 840-3333.

Participants

Hirsh Cohen is consultant to the Director of Research at the IBM T. J. Watson Research Center. He has also spearheaded the recent Energy Research Advisory Board study that reviewed technology transfer at Department of Energy laboratories. Cohen, a mathematician, has served in many key research roles at IBM.

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Leon M. Lederman is the Director of Fermilab. An experimental physicist, he has been involved in a long series of experiments ranging from the observation of parity violation in muon decay to the discovery of the upsilon at Fermilab. He is a 1988 Nobel Laureate in Physics for his part in the discovery, in 1962, of the muon neutrino. Lederman established the Fermilab Industrial Affiliates in 1980.

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U.S. Industrial R&D: The Good News and the Bad News

Donald Frey
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Illinois Governor's Commission on Science and Technology
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U.S. Industrial R&D: The Good News and the Bad News

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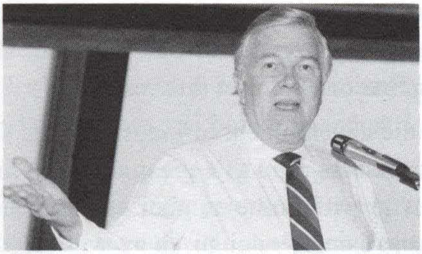

Donald Frey

What is the state of industrial R&D in this country? It is a good news/bad news story. There are a lot of things going on, and change is occurring very rapidly. Some people are very aware of the situation, but others are woefully ignorant. With apologies, I'd like to first review the history of industrial R&D. This is not academic or government R&D, but R&D in the private sector. These are presumably profit-making, shareholder-owned industrial companies. Industrial R&D is undergoing quite a revolution right now - some bad, some good. These changes are relevant, in a societal sense, to the fundamental purposes of the Fermilab Industrial Affiliates members, which is why it is important to consider the subject here.

Industrial R&D began in this country around the turn of the century. The first significant, recognizable, organized, serious, budgeted research center was probably at the General Electric Company (GE). GE established a laboratory from the legacy of Charles Steinmetz, who had created some of the fundamental technology at that time in the electrical generating business. At the turn of the century, a laboratory was based upon a very simple principle, one that is no longer relevant in the real world. This simple principle, which was followed by other companies such as DuPont and Bell Labs, was this: Given the then state of applied science, a company at that time was justified in assuming that they could derive a proprietary, competitive edge in the marketplace from the work done in their R&D laboratory. It was true for the General Electric Company, it was true at Bell Labs, and it was true at DuPont. As I shall explain in a moment, it's not true today.

There was a paradigm at that time (I call it a sequential or linear paradigm), which said, "I will derive, in the R&D laboratory, scientific knowledge that is proprietary to my company because I did it. Then I will obtain a competitive edge, scale it up, develop the processes that go with it (if that is relevant), and take it to the marketplace." In other words, the model is a linear, stepwise process from the R&D lab to commercial success. Some of you may be old enough to remember Coolidge and his pioneering development of ductile tungsten for the filaments in electric light bulbs, which then became a core business for GE and which, to this day, is still very good science. As a result of that research, GE owned the incandescent light business in the first one-third of this century.

During World War I, there was a blip in the development of industrial labs because in the conduct of that war, research work was used to a great extent to further the war effort. There was a steady, slow growth in the number of companies that had industrial R&D laboratories, and surprisingly enough, there was almost no blip during the Great Depression of the 1930s. But the great kicker for industrial research came as a result of the Vandevar-Bush report of 1945, called *Science, the Endless Frontier*, which was published by the National Research Council of its time at the behest of President Franklin D. Roosevelt. Roosevelt asked for a report which would treat science as an effective peacetime economic driver, as it had been in the Second World War. (I remember it personally very well, because I was just out of the army and I read it. I decided at that point to become an "academic," and I went on for the doctorate.) The assumption was this: Any country that wanted to become a continuing economic power in the world had to have an ongoing, R&D-based, basic scientific tradition. This was a further extension, at the national level, of the linear paradigm of old. Much of the subsequent science-funding apparatus of the federal government occurred as a result of the Vandevar-Bush report. It was also assumed by industrialists, who were not yet in the game, that the same paradigm applied to them. As a result, the industrial-research laboratories enjoyed a huge increase in budgets, numbers of people, and numbers of locations in the 1950s and 1960s. Any company that wanted to present itself to the investor world as being worth its salt had an industrial-research laboratory of some sort. As a result, today we have a history of the linear paradigm, which incidentally still prevails as the federal government's paradigm. The assumption is that any country that invests its resources to some degree in R&D will assure its economic success.

In the early 1980s, some clouds appeared on the horizon. First of all, the so-called thinkers, both industrialists and governmental officials, were puzzled by the phenomenon of Japan. Here was a country that had become a major economic power in the world, and it had no R&D history, no R&D tradition, and certainly, up until quite recently, no particular support infrastructure that related to what we would consider to be industrial or governmental R&D. The recession of the early 1980s was caused mostly by the high cost of the dollar, but also by the increasing incursion of the Japanese into well-known markets, such as automobiles and television sets and video-tape players. These Japanese successes continued to impress and bother us industrialists.

Something else began to present itself, and it wasn't comfortable information. There began to appear scholarly studies pointing out that the R&D labs were infrequent sources of innovation for industrial companies (keeping in mind that, speaking as an industrialist, the end game of R&D is innovation in the marketplace that makes a return on capital invested). Not frequent, *in*frequent. As a matter of fact, some of the scholarly studies by Professor Souder of the University of Pittsburgh discovered that successful industrial innovation came most frequently from a *salesman*. Hardly reassuring to R&D experts, but let's face it, that's a studied academic conclusion, and that was a problem.

We also became painfully aware that science had grown up throughout the world, and in contrast to the early days of industrial research, is now the universal good. Science is best described as a kind of pool. Any given company can dip out of the pool what they want. Industrialists became aware of the fact that the real difference between companies is their relative success in dipping into that science pool and taking out what is relevant, be it current science or Newtonian science, and innovating technologically.

Here is the bad news: In recent years, the net result of all of this has been a succession of major reductions, closings, and decentralizations of industrial R&D labs. Painful as it is, that is what is happening. Any number of big companies have announced reductions in budgetary allocations for centralized, serious R&D, or even its absolute abolishment. A not untypical example, to bring things full circle, is the General Electric Company, which closed up the RCA Sarnoff Laboratory and gave it to SRI for a dollar and some subsidy for a period of time. Just as those scholarly studies had pointed out, commercial success in the marketplace has too infrequently resulted from serious expenditures at the R&D level by industrial companies. To repeat, that's the bad news. It's going on every day. I happen to serve on quite a number of public-company boards and to my dismay, four straight annual meetings in a row at four different companies have dissolved the central R&D laboratories. These are large companies which are known for their R&D.

What are the drivers here? First of all, the most common failure, from an industrialist's point of view, is that R&D is too far from the marketplace. Take the case of Eastman Kodak, which is renowned throughout the world for its central research laboratories. For many years, Eastman Kodak managed to miss the video age, the magnetic-tape age, electronic cameras. They managed to miss the whole bloody thing for whatever reason (that's a separate debate). As a result, they got themselves into deep trouble in their traditional markets. The heavy breathers in the company missed all these new markets. Shame on the management and shame on the R&D labs. I think Kodak split their central R&D lab into something like 27 entities and dispersed them to the operating divisions.

The disciplines of the marketplace are iron disciplines: Will the customer buy a product for a given price, and can you make a profit on your invested capital? In too many cases, the R&D lab has drifted off and become too far removed from the marketplace. Whether the R&D personnel like it or not, they had better talk to a salesman. That's a milder version of what I mentioned earlier. The salesman may not be very well educated from an R&D point of view. He probably doesn't have a doctor's degree. But the salesman has one characteristic that is absolutely vital for industrial innovation and commercialization: He talks to real customers who spend real money. And the real customer doesn't give a damn about academic degrees or the origin of something that the salesman is trying to sell. The customer has to pay real money, which he had to work hard to get, for what that company is trying to sell him, and the customer wants his money's worth. That product had better work and be of value from the point of view of the customer, not from the point of view of the purveyor. That gap between R&D and the customer is a serious problem and what's happened, as a reaction, is that companies are taking the R&D functions and moving them toward the operating side of the company. That's called decentralization.

The next thing that has happened is that, inevitably, as you decentralize R&D towards the operating ends of the company, it becomes more D than R, and the D becomes, by its very nature, shorter and shorter term. And that brings me to my last external influence. Short-term behavior in America today - underline America - is driven to a great degree by what I'll call the "Wall Street Syndrome": quarter-to-quarter results. It takes a brave chief executive officer of a company to increase his investment in some sort of innovative activity when that activity reduces his quarter-to-quarter earnings report and puts him at risk to the raider, the merger and acquisition takeover group, or some form of recapitalization. I am sure you can recognize this process; all you have to do is pick up tonight's paper and an example will be in there. That short-term behavior of the capital structure of America is absolutely and totally antithetical for long-term investments. A number of different academics, including my good friend James Bryan Quinn of Dartmouth, have gone to great ends to point out that the average length of time between the initiation of an innovative idea and the commercial success of that innovation (success being defined as the return of the cost of capital at the then market rate of the capital invested) is seven years. The average tenure of chief executives these days is five years. You can figure it out: The mismatch is devastating. The average Wall Street player is looking from quarter to quarter, or three months.

One of the great ironies, which I have observed many times, is that the stock market today, mainly common stock, which is still the principle capitalization of private industry, is controlled by institutions. Forty per cent of the national equity market is owned by institutions. The little old lady from Dubuque is long gone. The performance of those institutions is measured in terms of return on their portfolio, because most of those institutions have as their role to manage the pension funds for all our retirements. (I'm referring to the private sector, not the public sector.) I've often observed that the heavy breathers of a company on which I serve as a director will hire and fire their pension-fund managers on a year-to-year basis because they didn't produce an adequate return relative to the Standard & Poor 500. But you should hear the same heavy breathers scream bloody murder when they are selling out the stock of the very company whose pension funds are being managed. The irony is profound, but that's the world in which we live. To repeat, it is a rare chief executive who would knock his quarterly earnings down and risk his personal recompense (his bonuses are tied to his stock price), and his company's rating. If he kicks his stock price down because it didn't meet the expectations of the street with respect to his common-stock return, he puts himself at risk with the rating and playing public out there.

There are some chief executives who worry about these developments. There are some, believe it or not, who are not players in the Wall Street game, although there are plenty of players, too. They know that, in the pressures of the short-term events surrounding them practically every day, the reduction of the long-term investment, be it R or D or both, is putting their company at risk in the fundamental social sense, not the Wall Street sense.

Having said all this, and having described the bad news, namely that industrial R&D is becoming short-term, more D than R, which in the long run is totally devastating to the economic health of this country, there *is* some good news. There is a growing number of chief executives who know all of this and who are quite interested in strengthening their relationships with universities and other broad-based research organizations as an increasing source of R. These relationships have some economic advantages to industrialists. Starting at the university level, with which I am most familiar, the plain fact is that R at the university level is a lot cheaper than the industrialist's R. In fact, my university friends complain a bit when I say that the universities can play the Kelly Girl role for R: as needed, no permanent overhead at the industrialist's level, and all the fringe benefits that go with it. This is an opportunity and it is growing, it's not a minor trend. Increasingly, the industrialist who knows about this opportunity and thinks about it, realizes that the best thing to do under the pressure of the circumstances is to turn to his local university or, in some cases, a research organization *exparte* to a university. I can think of the Batelles, the Arthur D. Littles, the SRI's of the world. I may even suggest Fermilab. Turn to them and say, "Can you do this job for me?" There's a certain amount of give and take here because the industrialist is not interested in a Nobel Prize. But he *is* interested in getting to a more broad-based place than he could ever expect to be if he had the old R. By tapping into the universality and the depth and the constant growth of science, and getting a sense of what is going on in some defined field on a much broader base than his organization can ever achieve, he can get a perspective available at no other place.

So the research organizations and industrialists are increasingly turning to the non-private, and in most cases non-profit, sector. My own company, which is not out of the mainstream, is an example. It is decentralized. I closed up the central R&D laboratory; I gave up on them years ago because they never did understand they had to talk to a salesman. Now we have seven R&D centers in the world today, and all seven by deliberate policy are located next to a major university somewhere in the world. That's the future and that's the good news.

So have fun, guys, when you try to commercialize some of these things. There are at least a few people who would like to help you.

1988 Fermilab Industrial Affiliates Roundtable: The Science-Technology Spiral and the Pace of Progress

Keynote Speaker

Joel Goldhar

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Panelists

Hirsh Cohen

(Moderator)

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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. Individual 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, often 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 truncation 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.

1988 Fermilab Industrial Affiliates Roundtable: The Science-Technology Spiral and the Pace of Progress

Panel Discussion

Hirsh Cohen

(Moderator)

Hirsh Cohen

I'm very grateful to be at this fine laboratory and see all of the quarks and leptons chasing around out there. When Leon Lederman wrote to me to set out my task, he said that he hoped for a wild, visionary free-for-all. My assignment, should I accept it, was to introduce, provoke, and see to it that these proceedings were not *too* much of a free-for-all. I did accept the assignment, and then I immediately burned his letter.

I want to tell you that all of us have very carefully thought about the title of this panel discussion, which is, "The Science-Technology Spiral and the Pace of Progress." I think each of my colleagues understands thoroughly what Leon meant when he invented that title. I also want to tell you that I think particle physicists are amongst our most eloquent scientists, besides all the great science that they do. Just to start things off, and to be sure that at least one spiral gets into this discussion, let me show you one view of a spiral (Fig. 1, page 28). I think you recognize what the mapping is - T^2 in this environment can only stand for technology transfer. There is a notion that science falls in some helical fashion down into the marketplace, an idea which we ought to talk about today. But the transformation has to go the other way, too. The marketplace has all kinds of things in it, including fun, which I hope some of you are thinking about giving to us.

Let me prejudice what everybody else says by telling you that, in my view, technology itself will move in and be useful to us if there is a use for it. Science moves to become useful technology when there is a use for it. Later on, I hope we can talk about some of the cases where that turned out to be true very quickly, and other cases where it wasn't so true.

I'll show one other spiral (Fig. 2) just to remind you of some of the problems that have to do with spiraling from science into technology. I hope you can see what that's intended for. Spirals have to fit.

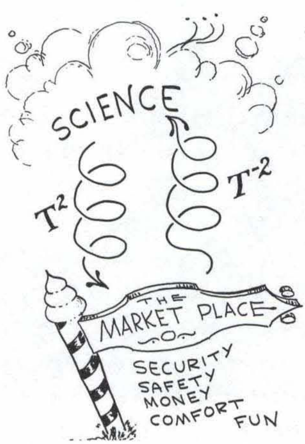


Fig. 1. Science in the marketplace

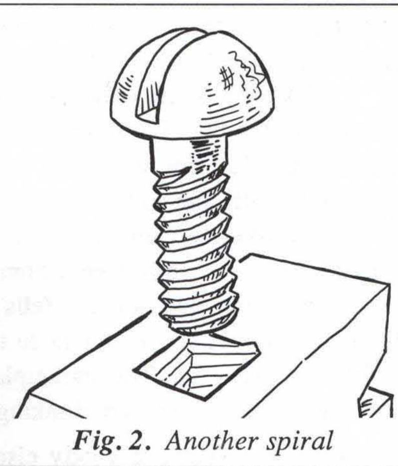
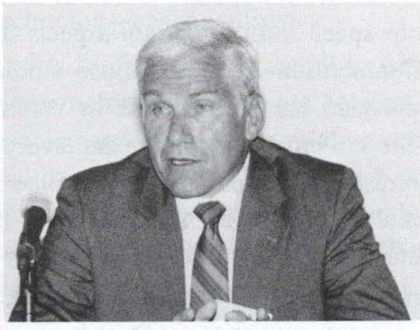


Fig. 2. Another spiral

Steven Lazarus


Steven Lazarus

In order to adapt to the thematic challenge that we were given, I have decided to give this presentation in German, and it's title is, *Untergang des Abendlandes*. That is all the German I am going to use. I'm sure you will be relieved. Some of you may recognize that title. It is the name of a book by an Austrian author/academician of dubious academic reputation from the mid-1920s. His name was Oswald Spengler, and it translates as *Decline of the West*. I was struck by that title when I recently read a book by Paul Kennedy called *The Rise and Fall of the Great Powers*. I was prompted to observe that in my lifetime, or at least starting shortly before my lifetime, in an absolutely rhythmic 20-year cycle, there have been books about the profound implications of the decline that Western civilization was going through. We can trace this cycle by starting with Spengler. Then, in the 1940s, there was Arnold Toynbee and *Civilization on Trial*, and then when I was in graduate school in the 1960s, there appeared a very interesting book by Professor and Mrs. Professor Meadows, called *The Limits to Growth*, which was a linear extrapolation of consumption of resources suggesting that we were going to run out shortly after the turn of the century. And now, almost 20 years later to the day, comes, not only the Kennedy book, but something much broader than that, the "School of Decline," as the *New York Times Magazine* put it recently. Moncur Olson, David Caleo, and others, are writing about the same theme: As in 16th-century Spain and 19th-century England, we in the United States have gotten ourselves into a posture of what Kennedy calls "imperial overstretch." Even the jacket design for Kennedy's book shows a John Bull character down the negative side of a mountain, while Uncle Sam is stepping off the mountain, heading for the negative side, and an easily identified oriental gentleman is about to assume pre-eminent position on top of the mountain.

This provides an academic backdrop for the subject of international competition. As Peter Peterson, the former Secretary of Commerce, former head of Lehmann Brothers, and current head of what is called an investment banking boutique in New York, has written in the *Atlantic Monthly*, competition is used to justify everything from the 65-mile-per-hour speed limit to certain aspects of the Strategic Defense Initiative program. Competition is one of those words that has been adulterated by overuse. Anyone who has served time in Washington, D.C., knows that occasionally one of these words will emerge and everybody will grasp it as a justification for their resource concerns. At the time I was in Washington, the leading concerns were the environment in the late 1960s and the energy crisis in the 1970s. But on this occasion, I think there is something to the idea of competition, and I'm a little sorry to see it going through such depreciation through overuse.

We are the world's greatest consuming economy. For a long time, our industrial enterprisers enjoyed a degree of success that finally led to what I think is an expanding degree of failure. Let me illustrate what I mean. In the automotive industry, it's been generally acknowledged that market studies were done by the folks who lived in Grosse Point talking to the folks who lived in Bloomfield Hills. They managed to confirm what each other thought: A very large car's enforced obsolescence was the wave of the future, just as it had been the wave of the past. By focusing narrowly and inwardly, we began to insulate ourselves from the flow of information, the kind of information that Joel was talking about before.

Meanwhile, in the last 10 years, we have seen the emergence of another economy, Japan, which is exploiting the myopia that we have exhibited for a period of time. Probably the most poignant example of that is the oft-cited VCR. The only reason I mention it again is because it's such a quintessential example of what happened. VCR's were beautiful technology developed by Ampex, an American company, available to RCA and other large American companies, but seen as applicable only to a narrow niche market in broadcasting. RCA chose to chase an alternative technology, the videodisc, which was ultimately written off as a $500 million failure. A number of Japanese companies, upgrading VCR technology through something approaching 10,000 patented improvements, ultimately captured the entire market. Last year in the United States, we bought 12 million VCR's, most of which were manufactured in two plants in Japan. As a matter of fact, I stood at the Sanyo plant and watched one of these CIM processes produce VCR after VCR, some being labeled Fisher, some being labeled Sanyo, some being labeled Phillips. That example extends to any number of technology-based industries.

It's foolish and not useful to conceive of the Japanese as muscular economic giants before whom we are helpless. If one had another half hour, one could inventory and contrast the relative strengths and weaknesses of the two economies and the two societies and make a pretty good case for the pluralistic, innovative approach that we take, even though we have greater difficulty forming into consortia and doing things the way MIDI is approaching superconductivity ceramics.

But it's worthwhile examining how the Japanese do it. I know you've been exposed to these torturous examinations of how the Japanese do it more often than you care to remember, but I want to cite three examples of the Japanese approach and then base my further remarks on them. If any of you have ever visited Tsukuba City, the Japanese science city near Tokyo, you will recognize it as the location of one of the major new superconductive-ceramic laboratories. There a combination of MIDI and other Japanese government agencies and upwards of 20 of the major Japanese companies are pulling together a set of financial resources and a set of scientists from both the public and private sector to pursue this new, seminal technology. That is only one of several such laboratories being developed in Japan. A recent British survey team reported on what they saw in Japan in February and March. Their report suggests that the combination of public and private investment in superconductive ceramics in 1988 is going to be about $100 million. Every time I see an estimate like that, I double it. I think that's a conservative view, because there is usually a hidden resource commitment going on as well. Furthermore, the Japanese investment in superconductive ceramics is being ramped at what I estimate to be about a 45- to 50-degree angle. That's an example of the Japanese ability to marshal resources and focus them on a particular technology.

Then there is the Japanese approach to patents. They now represent, by themselves, about 19% of the patents issued by the U.S. Patent Office. Canon, a single company, is up to about 1000 a year. Meanwhile, General Electric has declined from about 800-plus per year to the high 700s per year. That is an indicative example of the Japanese movement into protecting technology in the U.S. market.

Finally, there is comparative education, which may not necessarily be the text for this particular meeting or this particular group, but it is the aspect of the competition that worries me the most. We have, at the University of Chicago, a program, which has been going on for about five years, to develop a brand new mathematics curriculum for kindergarten through twelfth grade. That product is new. It is a complete departure from the curriculum development that has been going on in the U.S. public schools for some time. In the course of doing that work, the Japanese and Soviet curricula were translated. When one compares the objectives of the Japanese and the Soviet curricula in kindergarten through second grade and the current standards in the United States, you find, for example, the introduction of negative numbers in the Japanese kindergarten where, in the United States, closure on the concept of adding two numbers is not aimed for until the fourth grade. I could relate example after example of this kind of disparity. You've probably all read the statistics on how we do in comparative contests among our advanced-placement physics, chemistry, and biology students and the advanced-placement students from 15 other Western countries. We come in seventh here, ninth there, dead last in biology.

Helmut Schmidt, the former German Prime Minister, once ended a speech by saying, "Technology is the answer," and then he paused and said, "What are the questions?" It was a provocative ending. I believe that technology is one strong response to this competitive situation. We have the natural constituents in our economy and in our society which can be marshaled to allow us to be a lean and muscular competitor again. But we are doing an indifferent job of marshaling those elements. We as a nation spend about $120 billion on R&D. There's a strange symmetry, in that about half of it is channeled out through public institutions like Fermilab or Argonne or any of the other 700 or so national laboratories, and through research funded by the National Institutes of Health (NIH) and National Science Foundation (NSF) on campuses, and about another $60 billion through the private sector. Even though there is a lot of debate about too much of it being channeled into defense programs, in total we certainly have a higher absolute commitment than any other nation in the world.

But what we've been seeing is pressure and decline in the private sector. From the perspectives of both my previous life as a research and development executive for a major health-care and biotechnology company and where I am today, I see a drawing in of the junction or docking points on the part of private industry - the closing of the central labs. Probably the most poignant example of this was GE acquiring RCA and giving away the Sarnoff Labs. I think nothing better demonstrates the phenomenon I'm talking about than that. That drawing in is happening throughout industry in many different places, and it creates a vacuum. What is occurring in a sputtering and groping and stumbling way is the beginning of a reaching out by public-sector technology toward industry to try to fill the gap that has been created by the industrial recessional that we observed.

That reaching out has created several issues which I'm just going to touch on, because each one is worthy of a session like this. It has created the issue of what is starting to be termed "academic capitalism" or "laboratory capitalism." On the one hand are the institutions that have, over the years and decades, defined themselves as places that seek new knowledge, that freely disseminate new knowledge, that want to do good science, and have individuals looking for academic prizes or publications or seeking the high regard of their colleagues. Trying to reconcile that culture with the needs of an industrial enterprise that wants a certain amount of proprietariness and a certain amount of secrecy is a major issue. That issue is one that will grow in scope and tend to be exacerbated over time as we do more and more to organize and discipline our efforts toward technology transfer.

It is against that background and within that environment that the trustees of the University of Chicago, the contract manager for Argonne National Laboratory, created a mechanism called ARCH. I conceive of ARCH as being an experiment, because there is no protocol for it, and no blueprint. I've crisscrossed the United States looking for similar institutions whose work I could study in order to get an indication of how well they did or didn't do, but I found very few. I found quite a number of university-research and technology-transfer licensing organizations, but ARCH is only partially that. The mandate that ARCH has received from its Board of Directors is to be an enterprise creator. The main thrust of the work of ARCH is to create companies. ARCH also has a certain amount of geocentricity in that, wherever possible, ARCH wants to help create companies within a region defined by a radius of 50 miles around the Sears Tower. That's a different kind of organism. That's much more like a venture capital partnership akin to the 120 entities living along Sandhill Road on the border of Stanford University. Those entities are constantly going out and finding technologies within the university and putting them together with very-early-stage capital, and then finding management and creating things like Apple Computer and Genentech.

ARCH is some odd combination of the two, and it's very strange to try to reconcile the demands of each. ARCH is independent. While it's a creature of the University of Chicago, it is not part of the University of Chicago organization. It is wisely not-for-profit. I say wisely, because there was a debate at the outset of ARCH's creation over whether or not to make it a for-profit organization. What I found in the year-plus of ARCH's existence was that if one wants to operate within the cultural context of a university and a laboratory, it is much wiser to be not-for-profit. Oak Ridge National Laboratory, as you may know, is managed by Martin Marietta, a for-profit organization that has approached the same set of issues with a for-profit mentality. They have gotten severely entangled with certain skeptical congressmen and the General Accounting Office.

In addition to the twin missions of enterprise creation and regional development, and the schizophrenia of being a licensing organization as well as a business-creating organization, ARCH was fortuitously placed within the Graduate School of Business at the University of Chicago, of which I am also the Associate Dean. This has permitted a flow of, at this point, about 45 business-school graduate students who work with us on an unpaid basis, investing 10 to 20 hours a week, pioneering and prospecting in the divisions of biological and physical sciences at the university, and all the various departments at Argonne. It has allowed ARCH to become aware of new discoveries well before one day before the publication date, which is when one used to hear about them. Furthermore, it gives us the opportunity to do some competitive market analysis and embryonic business planning. The enthusiasm, energy, and activity of the graduate students has been one of the joys of this work and probably is a phenomenon, part of a model that could be picked up and used at other places around the country.

Just a few final comments about the future, since we appear to be in the business this afternoon of predicting the future to some degree. There's an interesting debate going on right now in the pages of the *Harvard Business Review* between George Gilder and Charles Ferguson. Gilder contends that we are entering the time of the small. It's a philosophical position that is resonant with the point Joel Goldhar made about economic order quantities of one or the ability to tailor production to the individual unit. As I wander around the country, I see this new emphasis resulting in a resurgence of economic activity in areas where one might not have expected it, such as western Pennsylvania and eastern Tennessee. It takes the form of a lot of new enterprise, small companies with very flat organization forms where the executives in the company are wired together electronically and there's no four- and five-person tiering in order to get management communications up and down the organization. For a long time, additional manufacturing employment in this country has come from this type of company as opposed to the very large company. I find that encouraging. Gilder calls it the time of the microcosm. I think that dresses the idea up a little too much, and yet, I think there is something to the idea that the information revolution also creates a platform that allows this to take place and be powerful.

One of the continuing problems, however, is the absence of slack, the absence of docking sites between university and laboratory technology, and industry of any kind. The small entrepreneurial organization and the large corporation are extraordinarily busy. They may not be busy on the best things, but there are very few people who exist to prospect in the public sector for technology and find ways of bringing it in. So we are gropingly bringing technology out. The problem of interdigitation between technology driven out of the university and the laboratory and what is sought or demanded by the industrial enterprise is extremely different. It's like trying to build the transcontinental railroad blindfolded.

Finally, there is the problem that Peterson underscores over and over in his paper. That is the problem of moving a consumptionist society toward, or returning to, an investment society with a higher savings rate and a renewed national political commitment to invest rather than consume. If there is a political issue for our time, I think that is it. It underscores or affects anything we will try to do in this area of moving technology into effective use in the economy. If we fail at that, then all the work of all the technology transfers in the world is going to go for naught.

Richard Nicholson

Richard Nicholson

It's probably not relevant, but I was talking to someone the other day about the VCR as an example of Japanese initiative, and their comment to me was, "It's better than having us build the VCR's while they make the movies."

It is a distinct pleasure to be here this afternoon. I especially want to thank Leon Lederman for inviting me to my first visit to this fabulous laboratory. I was gratified to get Leon's invitation, because at the time he called, I wasn't all that sure that someone from the NSF would be welcome here. That's because my boss, the Director of NSF, Erich Bloch, not too long ago suggested that maybe the National Science Foundation should no longer support high-energy physics. As you can imagine, that's created a certain amount of distress among the high-energy physics community. Erich Bloch is more provocative than I'm going to be. Recently, he was quoted as saying that the national laboratories ought to be required to get 30% of their funding from industry and if they can't do it, then shut them down. Industrialists who read this monograph are in for a really big surprise when Lederman sends an invoice in a few weeks.

When I approached the subject of spirals and technology transfer I had a sinking feeling. I decided that, even though I know nothing about technology transfer (I work for the government, after all), I could talk about that, because the National Science Foundation has an increasing number of programs that have some kind of technology transfer as one of their goals due to the growing concern about competitiveness.

Because technology transfer is one of the mechanisms proposed for improving the competitive posture of the country, it is useful to discuss the connection between economic competitiveness and the National Science Foundation, because NSF has claimed that it has a role to play. Many academic scientists view saying NSF and competitiveness in the same sentence as a non sequitur, or at least they hope it is. It scares academics, because they think NSF is really changing its mission. In what follows I want to explain to you how we see that connection from the NSF vantage point.

Why should scientists worry about economic competitiveness in the first place? The most obvious reason is that, unless our country has a healthy economy with increasing productivity, there's not going to be enough money to invest in scientific research. We're already seeing examples of that. In fact, the deficit and the recent stock market crash led directly to the demise of President Reagan's request to double the budget of the National Science Foundation.

Another manifestation of this problem we have with competitiveness, and the trade deficit, and the budget deficit, is the increasing number of calls one hears for prioritizing in science. All of a sudden, we're hearing the statement, "You've got to set your priorities in science because the country cannot afford everything anymore, and we're not going to be able to do everything." We hear that all the time now, at least in Washington. Another reason for talking about competitiveness is that, as Steve Lazarus noted, it's *the* issue in Washington. It has been for awhile. It is a buzz word. In fact, I heard a congressman say it's a buzz word squared the other day. On the other hand, most serious people regard it not as a fad, but as a truly serious problem for the future of this country. It's not something that's going to go away and it will be a serious issue when the next administration comes into office.

I want to say something about competitiveness at the national level and then try to explain the role that NSF has claimed in this area. Someone recently said that if the Seventies in this country were the decade of inflation, then the Eighties are the decade of debt. Some people call it the decade of conspicuous consumption in this country. Simply put, for too long a time we as a nation have been living beyond our means at a standard of living that's not sustained by our productivity. We've been doing that with a very simple expedient - we've been borrowing. Borrowing on a really big scale. The total national debt is now approaching $3 trillion, an incomprehensible number even to high-energy physicists. A little more comprehensible, when you think about it, is the interest we pay every single year to service that debt: $150 billion a year. One hundred and fifty billion dollars that doesn't buy a Superconducting Super Collider, that doesn't pave any roads, that doesn't double the NSF budget, $150 billion just to service that $3 trillion debt. Much of the borrowing that we've done has come from foreign investors, to the point where we now are the largest debtor in the world. We achieved that distinction in 1985. Our foreign debt now totals about $400 billion, almost 10% of the annual income of our country. It's interesting to ask how these debts are going to be repaid or who is going to pay them. I'm not an economist and I don't understand these things all the time, but I'm pretty sure I know the answer. The answer is that our children are somehow going to have to pay. In that context, it's sobering to realize that, because of demographics, never before and probably never again will this country have as many people working and paying taxes as it has right now.

What does all this have to do with NSF? After all, solutions to the trade deficit and these things are very complicated and controversial issues. What could NSF possibly contribute? There are two things that nearly everyone on both sides of the political aisle agree are necessary, if not sufficient. These are things that the nation has to do if it's going to remain competitive or be competitive in a strategic sense in the long-term future.

First of all, the United States must invest aggressively in basic scientific research to create new knowledge. Everybody agrees that's important. Second, the United States needs to continue to invest in the education and training of future generations of scientists and engineers so that we continue to have a skilled work force. Everybody agrees that those two things are important.

Bingo! That's a definition of the National Science Foundation to a first approximation. That's exactly what the National Science Foundation does and has really always done. In fact, those are the only two things that Erich Bloch or any of us has ever claimed NSF has to contribute to improving the competitive posture of the country. We have not said that we're going to do more applied research. We have not said we're going to do research for industry. We've not said a lot of the other things that I've heard us accused of, either.

Suppose you're sitting there in the Roosevelt Room in the White House, and you're making this argument to the President, and the President says, "Well, okay, I agree. Those two things are really important. But, after all, aren't we doing enough right now as a nation? I mean, aren't we okay when it comes to those two things?" I think the answer you'd have to give is that it's true. We invest an incredible sum of tax money into R&D, $65 billion. But if you look at basic research, at the creation of new knowledge through scientific research, if you look at education and training, then I think the answer you have to give the President is that we're not doing very well as a nation.

In terms of investments in R&D, the picture is not a particularly reassuring one. In fact, it's been greatly exacerbated just in the last seven years by the rather dramatic shift, at the federal level, in the balance between civilian and defense research. For a long, long time in this country, defense was about 50 cents of the R&D dollar. In the space of seven years, defense expenditures have grown to about 75 cents on the federal R&D dollar. Moreover, the fraction of defense-research expenditures devoted to basic research has declined.

What about the other NSF role, that of educating and training future scientists? I think you probably know the answer from your own experience in terms of education or from things you read in the newspaper or from some of the studies funded by the National Science Foundation. Instead of trying to give you all those statistics, I thought I would just relate a couple of personal anecdotes to illustrate the situation.

My wife is a high school chemistry teacher in one of the suburbs of Washington, D.C. Recently, a student came in after class for help. At one point he said to my wife, "Mrs. Nicholson, I ain't never had a course as hard as chemistry." She looked up at him and in all innocence said, "Oh, really? How are you doing in English?" And the student said, "Oh, I done real good there. I got an A." That is a true story. Or how about this answer that another teacher got on an examination question: "The pistil of a flower is it's only protection against insects." "It's," of course, is spelled with an apostrophe-s. And here is one student's attempt to explain the tides: "The tides are a fight between the earth and the moon. All water tends toward the moon because there's no water in the moon and nature abhors a vacuum. I forget where the sun joins in this fight." That's the situation at the front end of the education pipeline in this country.

What does it look like at the output end of that pipeline? How does the future look in terms of the supply of scientists and engineers? Again the news isn't very good. The 22-year-old cohort in the United States is now dropping like a rock and it's going to continue to do so late into the next decade. I'm talking about immutable demographic data. Even if all of us decided to start working on it tonight, we couldn't change that number. Moreover, Congress can't pass a law to change it. I suppose I shouldn't say the Congress can't do something. I do recall once that a state passed a law which made pi a rational number. The sharp decline in the number of 22-year-olds in this country surely portends a future sharp decline in the production of Ph.D.'s in this country. That trend will reach a low point at about the same time that, due to bad luck as much as anything, a lot of retirements will be taking place in all of our universities.

What's the solution? One thing we could do is try to get better representation from under-represented groups in science and engineering - women, minorities, and the like. For example, in the year 2000, 29% of the births in the United States are projected to be black. That's a significant resource for the future. But historically, blacks have shown very little interest in science, and the current trends are in the wrong direction. Another solution is to make up the difference with foreign Ph.D. students. In fact, that's how we're dealing with the problem right now, but in a certain sense, I think it's probably akin to the borrowing that I mentioned earlier. I think it's questionable whether it is good public policy for us to be so dependent on a critical resource that we don't control. I think that was illustrated very nicely just recently when we read that China, which has been the source of some of our most gifted students in this country, is going to turn off the valve. The number of Chinese students coming to this country will drop from 8000 to 600.

To make a long story short, I've just recited the basic arguments - improving investments in research education and training to underpin future competitiveness - that Erich Bloch made when he convinced the President to propose doubling NSF's budget a little over a year ago. I want you to know that we did everything we could to get that budget through Congress. Our astronomer friends arranged to have a little star they didn't need anymore, in the large Magellanic cloud, explode just a month after the State of the Union Address. That made the cover of *Time* magazine. And just for good measure, we had one of our program officers, a fellow named Paul Chu, publish a paper about high-temperature superconductivity in *Physical Review of Letters* just a week after the supernova. There's been all sorts of excitement about science this past year that we arranged in order to get the budget increase for the National Science Foundation.

As I said earlier, the stock market crashed and we lost everything when that happened. In fact, it was a double whammy, because the resulting budget summit also set limits on 1989 budgets with very little growth in domestic spending and no possibility to trade off domestic and defense spending. As a friend of mine says, support for science on Capitol Hill is a mile wide, but it's only an inch deep. I think that's really the state of affairs. Everybody's for science until a crunch comes. It's very frustrating, because I think all of us really do believe that the country, if it's going to be competitive in the future, does need to make these kinds of investments. But I don't think the prospects look very good, to be honest with you. We have these big debts and our country's now saying it can't afford all of these expensive things. The space station alone will cost more than the combined cost of all the big science facilities built in this country since 1945.

This leads to statements like the one that appeared in *Business Week* a few months ago: "The problem is that no one is setting priorities for increasingly costly science and technology projects. Scientists are asking for too much." More recently, *Business Week* said, "Lobbying efforts on big ticket projects have put the once lofty science community in the same league as other special pleaders seeking legislative pork." *Newsweek* puts it this way: "Suddenly, science is competing for scarce funding, not only against other national needs but against itself." And later *Newsweek* says, in an editorial, "Scientists need to curb their own excessive appetites. In an age of ever more costly science projects, everyone must accept the need for setting intelligent priorities." These are comments that I think we as scientists are not accustomed to hearing from the public in this country. I don't think they bode well for the future.

On this regrettably gloomy note, I'm going to stop. But I feel that this is a situation that all of us in the science community need to take seriously and think about, because something fundamental is changing now in the public attitude toward the support of scientific research.

Lee W. Rivers


Lee W. Rivers

I want to share with you some of the observations that I've made over the last two years while working in Washington. But first I want to establish my credentials, which are really industrial. I spent 38 years working for a very large American company, Allied Signal. In 1985, I went to the White House Science Office and spent 18 months there, 12 of them as the Industrial Research Institute Fellow. I was representing the industrial perspective, if you will, in the White House Science Office. Then I stayed on for another six months after that as a consultant to the Science Advisor. Last April, I formed my own company and went to work for a very interesting breed of cat, which is not an agency of the federal government, called the Federal Laboratory Consortium for Technology Transfer. The Consortium is a network of technology-transfer people from 300 federal laboratories. You may not know that we have 300 federal labs. The truth is, we don't have 300 labs. We have more like 700 federal laboratories. They're operated by 12 different agencies of the federal government and they're spread out all over the place. They range from very large laboratories with up to 12,000 people, down to six or eight agronomists somewhere out in North Dakota. The fact is that the nation has a vast reservoir of untapped talent in these federal laboratories.

You've heard all about competitiveness, and you've heard all about the problems this nation faces, and that's all true. I'd like to turn those viewpoints around and look at them from a much more optimistic point of view, because this nation is also a very great nation. I believe we have it within our power to recover the position that we've had in the past. We're never going to exceed it, but we're going to stop the fall of our standard of living by learning to work together much more collaboratively and collectively than we have in the past. This is really preaching to the choir, because you already know that we have federal laboratories. You're reading this because you're interfacing actively, or contemplating interfacing actively, with one particular laboratory. We've got to do a lot more of that.

There are some frightening things out there in the attitudes and the perceptions of the community that I came from, the business community. So I'm now going to address my comments to those of you from industry. Recently, the National Governors Association, the Conference Board, and the National Science Foundation prepared a study called *The Role of Science and Technology in Economic Competitiveness*. The study's Executive Summary states, "In spite of business support for industry-university partnerships, slightly more than half of the business respondents [to a survey] did not believe that cooperative research among industries and universities would have a critical impact on U.S. competitiveness. And even fewer, approximately one quarter, believed it would have a critical impact on the competitiveness of their firm." In contrast, over 80% of the state officials and two thirds of the university respondents believe that cooperative research among industry and universities will have a critical impact on U.S. competitiveness. Furthermore, the business respondents went on to say that they "do not believe technology transfer to be a critical issue affecting the nation's competitiveness." If that's the attitude that we're going to carry, we're going to be in for big trouble, because, again, the only way we're going to re-establish the strength of American industry is to learn to work much more collectively and collaboratively than we have in the past.

This vast federal laboratory system, accessible through the Federal Laboratory Consortium, spends somewhere between 18 billion and 20 billion a year of your taxpayer dollars within laboratories like Fermilab. The amount of technology and knowledge in science that is being generated from the minds of the scientists in these laboratories and is now being used by American industry is minuscule. Ever since 1980, Congress has been passing a series of pieces of legislation, starting with the Stevenson-Wydler Act in 1980 and culminating with the Technology Transfer Act of 1986, intended to open up these laboratories and make them much more accessible to state and local governments, and to small and large businesses.

There are a couple of problems associated with taking full advantage of that legislation right now. One problem rests within the government and one rests with this attitudinal feeling that exists within industry. We are so accustomed to being able to build technology and science in our own big corporate research laboratories, that we do not think as hunters and gatherers of technology. A vast number of your industrial brethren are not looking toward our federal laboratories as a source of creative interaction and the development of technology.

The battle is really a technology battle. During the 18 months I spent in the Office of Science and Technology Policy in Washington, I walked through a big door that had a gold eagle on it, and a sign that said, "Office of Science and Technology Policy." For 18 months, I looked for that technology policy and I could not find it. It does not exist. Now there's a lot of talk about facing up to the fact that we need to move our science, in which we're pre-eminent, much more rapidly into products, goods, and services for the world marketplace in order to compete internationally.

This attitude of not going out and looking aggressively at the federal laboratory system was recently brought home to me very vividly. I had come to recognize that a number of companies were beginning to look for new technology from the federal laboratory system. They were doing it by designating fairly high-level R&D officials as hunters and gatherers of technology. These R&D people were given the whole world outside of the corporate fence, including the universities and foreign alliances, as hunting grounds. In some cases, they were even being more specific than that; they were assigning an individual to just the federal laboratories.

Being well aware of this development, I put a little blurb in the *Industrial Research Institute Newsletter*, which goes to 265 of the largest American companies. The blurb said, if your company has designated an individual to interact with the federal laboratories, please let me know who that individual is so that I can plug him into the Federal Laboratory Consortium system. We have a monthly newsletter. We have two annual conventions. We have publications. We are a primary clearinghouse for federal-laboratory technology information. Four of the first six responses that I got to that inquiry were from European-based companies. What does that tell me? It tells me that the international companies we're competing with are much more attuned to reaching out for science and technology, and for collaboration and cooperation, than the average American company. That's my own personal observation, but it's reinforced by the study that was done by the Conference Board, the Governors' Association, and the National Science Foundation.

If you think we have a problem with industry working that way, I have to tell you that the problem is fairly acute in Washington, too. It was a pleasure to come here and see a facility where particles are traveling just a smidgen away from the speed of light. I come from Washington, D.C., a city where *sound* travels faster than light. There's only a handful of people out of the 535 members of Congress who have any real speaking knowledge of science and technology issues. I was talking to a senator the other day, and I said to him, "Senator, what are we going to do about this great ignorance and apathy that exists in the Congress over science and technology issues?" He said, "I don't know and I don't care."

Both government and industry have to face up to the fact that we've got to explore new ways to develop technology. The Cooperative R&D Act of 1984 allows companies to form consortia and do what I call generic applied research or generic development work. It's pre-competitive R&D. You know what it is because the Japanese have been showing us how to do it for years. We've got to examine new ways of doing that kind of development work in this country. The problem is that it takes two years for the bureaucracy in Washington to put into place the regulations and rules by which the laws are going to be implemented. We're in the throes of that process right now. The Technology Transfer Act was passed in October of 1986, and the President's Executive Order, which put the administration's arms around all of this enabling legislation, didn't come until April 10 of 1987. To this date, not all the rules and regulations are yet in place.

I want to close with a message to you industrial folks. I've looked at this enabling legislation and I've now had almost two years of looking at the federal laboratory system. I have a much deeper appreciation for the skills, talents, facilities, and capabilities of that system. And I say to you industrial people, you be the aggressors. You come and find the ongoing work that's of interest to you. That's where the Consortium can help. We operate a computerized database backed up by a network of federal-laboratory technology-transfer experts who are willing to go that extra mile on your behalf to try to uncover, among 700 laboratories and 100,000-plus scientists and engineers, the work that's of specific interest to you. By accessing through the clearinghouse or through my office, you're really accessing $18 billion worth of R&D.

These federal labs are equipped with excellent state-of-the-art facilities and equipment, and the legislation is there. If we in government don't yet know what it all means, or if we don't all have our act together, you, the industrialists, should come after us. You propose how you want to work with these laboratories. Shake them up. Talk to them about how you want intellectual property matters handled. I hope all of the government people in the room now are not listening, but you industrialists can fake them out, because the rules and the regulations haven't all been passed down. Do it either individually, or do it collectively in consortia, but take advantage of this resource. It's there. It's fully the intent of the Congress and now the Administration that it be used. That is the purpose of this meeting. It's the purpose of Fermilab reaching out to its Industrial Affiliates. But it won't work, in my opinion, unless the American industrial community aggressively seeks out constructive interaction with the laboratories.

Michael Odza of Technology Access Newsletter *(left), and Fermilab Director Leon Lederman.*

Carl Rosner, Intermagnetics General Corporation (left), and Fermilab Associate Director for Technology Dick Lundy.

Brian Frost, Argonne National Laboratory (left), and John Straus, Illinois Governor's Commission on Science and Technology.

Dick Carrigan, Head of the Fermilab Office of Research and Technology Applications.

Panel Discussion

Hirsh Cohen: We've successfully covered most of the general topics that have been brought up at sessions like these without getting to the spiral of science and technology and the pace of progress. I want to have a short crack at that, and then we'll let the master, Leon Lederman, see whether any of us have passed whatever test he had in mind.

There's been a lot written recently about the fact that we are moving technology much faster from the scientific laboratory through the technology phase and out into the marketplace. That is sometimes true. As in science itself, there are many, many frequencies and many, many time scales in this process. Some of those time scales are long periods and some of them are short. If you think high-temperature superconductivity just appeared, or even that the superconducting magnets made here at Fermilab just appeared, let's remember that the concept of superconductivity was first observed in 1911 in Holland. There followed a very barren period of almost 70 years when nobody could figure out what to do with superconductivity. The people that tried, like one small company named IBM that tried twice to make computer chips out of superconducting materials, found out it was hard to capitalize on.

Look at the transistor. Invented in 1948, it appeared in radios in a few years, and in 1956 in computers. I think I understand why and you probably do, too. There was a very direct mapping from the transistor onto the radio tube. The market and the use were there, and the consumers were there, and RCA and GE and other companies knew how to exploit the technology.

Or take lasers. I don't know what your favorite laser is, but mine is the semiconductor laser because IBM and GE invented it on just about the same day in 1962. Those lasers have been around for 25 years. They're just now coming into use because they had to wait for optical fibers and the kinds of speed that computers and communications require. When lasers were introduced, there wasn't any mapping from a new science directly onto an optical product. I doubt very much whether anyone knew that we were going to go blasting onto people's retinas with the laser. Let me give you one more example: photo-voltaics. We've done pretty good science in that area, but photo-voltaics aren't in widespread use because there isn't a marketplace.

This pace of progress, and this movement from science to technology, really does have a lot to do with whether there is a consumer available. But the press this year has been giving us the impression that everything is moving along faster than some things really are. Each of you has a guess as to where high-temperature superconductivity is going to land. My own prediction is that it will be in places that none of us have thought about yet.

I think Joel Goldhar hit it right on the nail when he talked about the product cycle. That is an absolutely fundamental change. The thing that I didn't hear Joel say, but which Lee Rivers talked about a bit, is that our product developers have to learn more about the hunt and search process. In my business, and in a lot of businesses, we get a product pattern going and we really know the technology of that area. What we don't have are all of the other inputs from new science and technology because we don't have time. We're under pressure, the product isn't getting out the door, and we have to pull people away from whatever advanced technology we have going. That goes on all the time. But that search for the new science and new technology, that sort of enlightenment at the product development phase, has to go on all the time in a highly competitive technical product business. If you're in a company with a research lab, and a product development group, and advanced manufacturing, then there are people in your own company who are supposed to be doing that for you.

How do the great national laboratories, such as Fermilab and the other DOE lab, get their scientific results, and what potentially marketable technology falls out of the work they're doing? That was the subject of the panel that I chaired for the Energy Research Advisory Board during the past year. One of our observations is that it's very difficult for a lab like Fermilab to connect to companies. This effort that's going on today is a reasonable way. I think there are better ways, but it's not clear to me that labs like Fermilab, and the Princeton Plasma Lab, and maybe Brookhaven can do that as well as Oak Ridge, and Argonne, and a few other places. The recommendation that our panel will give is that those labs that have the skills and capabilities to plan scientific research that can yield technology transfers should also focus some fraction of their work on particular industrial sectors. What's happening now is that what is transferred out of Fermilab is what we've called spinout. Fermilab is not planning for a potential consumer to use this spinout technology the way companies' research labs plan technology for their own product people. Some of the DOE labs can do that because of their backgrounds and management styles and the way they undertake their missions, and some will have a more difficult time.

That's one of our recommendations - this focusing effect. There are examples. Argonne and their Idaho lab are trying to work with the midwestern steel industry. It amazed me to find, in the *Commerce Business Daily*, a request for procurement from INEL, the Idaho National Energy Laboratory, for research and development proposals from industry on foundry research. Other labs like Oak Ridge have begun to be an important component of the advanced materials efforts in this country. The Ceramics Center at Oak Ridge is doing some fine work. There will be superconductivity centers set up at Los Alamos, Argonne, and Oak Ridge.

Our panel will also give recommendations on how DOE manages all of this. We'll recommend a much stronger policy statement by the Secretary of Energy. We will recommend that in addition to the easing of the proprietary procedures, that contracts and agreements with industry be delegated to the laboratory manager, with certain limits and restrictions as to dollar level, so that all agreements and contracts don't have to go back up the chain to the field office or elsewhere. We'll propose that in addition to patent awards, there will be much more effort toward creating incentives for technology transfer of high value. This can be done through rewards, promotions, and additional research funding. What I'd like to see our panel recommend is a prize given by DOE for the best technology transfer effort by a group or individual at any of the DOE labs. I was amazed to find that the German Ministry of Education has just announced such a prize for German universities. If the Germans can do it, maybe we can, too.

Michael Odza (Technology Access Newsletter): Maybe some of these issues are related in terms of the problems and barriers. There is a cultural view which holds that, in federal labs and universities, one of the nice things is that you can just concentrate on basic science. You don't have to worry about applications. I've heard people at the University of Chicago say that if one of their staff found out that there was a use for something he was working on, he switched and worked on something else. On the industrial side, there's fear of that very culture which says, how can I make a product or adopt a process if it's not going to be considered proprietary regardless of the laws or the regulations?

Steven Lazarus: First of all, you're dealing with two institutions, on the one hand the academy and the laboratory, and on the other hand the industrial enterprise, which are all in transition as a consequence of fundamental changes in the societal environment. Even though I come from the University of Chicago, I recognize the phenomenon that you describe.

But what I observed at the University of Chicago is an accommodation with an entering industrial culture. There are those at the university who find that abhorrent. There are many more at the university who find it curious and interesting. What we are discovering are positions along the spectrum that people are willing to take, and the emergence of other experimental entities, like ARCH, that operate in a catalytic fashion. The same is true at Argonne. There are folks at that lab who, given the problems of doing good science and making sure their programs survive, don't have a lot of time or interest in the issue of technology transfer. And then there are a whole host of people who are curious to see the implication and application of what they are doing. What Brian Frost and I, and others who are working on this, try to do is spot the ones who are curious and ready to participate to some degree. Then, when we're successful with those, we have a demonstration that others can observe and form their own judgments. So you're not dealing with a fixed-point situation, you're dealing with a dynamic that is very much in motion right now.

Joel Goldhar: The problem is that it's dangerous to generalize about the federal labs, just as it's dangerous to generalize about industry. There are something like 800 federal labs and other institutions doing science and technology. They're not all at the leading edge of uncovering the most fundamental secrets of matter, as is Fermilab. There's an army laboratory in Framingham, Massachusetts, that works on food and clothing. Years ago, they invented something called mud-phobic rubber. It repels mud. When you use it as a boot sole, you can walk in mud without sticking and without making noise. As far as I know, no company ever picked that up and said, wouldn't that be nice for a hunter's shoe? As a matter of fact, I'm not even sure that the army picked it up and used it, which is all right. That market may not have been big enough because soldiers don't walk much anymore. The Vietnam War was almost over, the next war we were sure was going to be fought on the sands of the Middle East or on the fertile plains of Germany, so that when we got out of the jungles, we didn't need mud-phobic rubber.

But clearly, there are thousands of neat little pieces of technology that are available. You don't have to be a corporate version of a high-energy physics laboratory. It's not clear to me how to commercialize the quark. When we figure that out, we'll write a paper on it as all academics do. But if you go down a level within the Federal Laboratory Consortium, there are millions of ideas, even within the most basic of the labs. If all of these labs were doing nothing but basic science, we'd have a lot of basic science in this country, and it's just not true. Brookhaven National Laboratory kept appearing on the yearly list of winners in the IR-100 Awards, which are given to the cleverest new ideas of the year. I recall one, a Braille reader, that was a spinoff of some work going on at Brookhaven. Another one was a polymer that mixed with cement to create a cross-linking activity that quickened the hardening of cement and made it a better product.

When you look at a lab like Fermilab or Brookhaven, you want to look, not at their mission, but at all the things that they do in getting to the mission. The great big science projects have much of their value in the solving of the problems along the way. That's part of the science-technology spiral. For years, you could argue that technology drove science. We had engines before we had thermodynamics. We started the thermodynamics to understand why engines did what they did and how to improve them. When they improved enough, tinkerers got back into it and started to do new things. On the other hand, we are seeing in microbiology, in materials for electronic uses, and so on, new science moving the technology forward. There's a double helix in this.

Cohen: That's true. These guys at the labs are very clever and they do great things. But the gap is there and the gap is pretty broad. You have to do some experimentation with bridges across those gaps. There's not a very large payoff for the people in small or large companies to go searching through the lab literature. You have to build better bridges, such as some of the consortia or joint projects that have been created in the past several years. Those are important because they bring the laboratory together with the people in industry.

Goldhar: I'm not sure I want to close that gap too tightly. I feel the same way about the university-industry consortia. When the university gets too business oriented, it stops doing the things universities are supposed to do, which is to work on the unpopular things.

Cohen: But you've jumped to the conclusion that I want all of Fermilab to march into the gap. I want some bridges.

Goldhar: Maybe what we need are some third-party bridges.

Lee W. Rivers: That's an excellent point and I'm glad you mentioned it. I think it's particularly relevant to small-to-midsize companies. I absolutely applaud the existence of ARCH. We need to create a lot of other variations on that theme. The strength of this nation is that we don't have to find one model, we're strong enough and big enough that we can have a lot of different kinds of creative models of that bridge.

Mike, to come back to your question, since the Technology Transfer Act of 1986, for every scientist who would express the feelings that you heard today, I can find one in the federal labs who's on the phone to some entrepreneurial guy outside the walls saying, "Give me two more weeks and I'll be ready, we're going to have a commercial success on our hands." We're moving toward one another. You're not going to convert 100,000 scientists and engineers, nor are you going to convert the attitudes of industrialists in this country overnight, nor completely. I'd like to share with you the part of the speech I didn't give.

A Vision of the Future

- **Precompetitive collaboration is routine**
- **Laboratories engage in short-term and long-term relationships with businesses of all sizes**
- **A significant fraction of the technical staff in federal laboratories are on assignment from industry and universities**
- **Cooperation is strong at technical and management levels**
- **Cooperative research, development and innovation emphasizes a strategic view of future possibilities. . . with a healthy acceptance risk**

Federal Laboratory Consortium

Fig. 3.

The figure (Fig. 3) is obviously not complete, but I think it's indicative of where we as a nation should be moving, and I'll come back to a point that Joel made before. The common denominator, the one thing that's equal among all of us, Japanese, Europeans, and Americans, is that we all operate off the same 24 hours. Time is of the essence. We do not have the luxury of time. The quicker we move our institutions toward one vision, the faster we'll erode this decrease in the standard of living that is now under way. We'll be well on our way to redressing the balance of trade and we will no longer have to pay that $150 billion a year in interest on foreign debt. Time is the critical element here. We're not going to shift it overnight 100% from one direction or another. We're moving in the direction. The faster we can move, the better.

Carl H. Rosner (Intermagnetics General Corporation): This has been a most provocative and thought provoking set of presentations. They're very enjoyable intellectual exercises for someone like myself who is in a high-tech business originating from a technology-transfer experiment that was launched by the General Electric Company because the research laboratory wanted to explore whether superconductivity had any future. That was 16 years ago, and we have been struggling to make a living ever since.

I am impressed also by the fact that there exists an earnest desire on the part of the labs, the universities, and the government as a whole to address the question that's tagged by the label "national problem of competitiveness." As the saying goes, you can lead a horse to water, but you can't make it drink. Industry, as was pointed out, really isn't sufficiently interested in the management of the tremendous intellectual resource, and innovative capability, and real opportunities that exist among the laboratories and in the universities. But identifying competitiveness as a problem is really wrong. The problem isn't competitiveness. The problem is that the world has changed and the rules by which businesses, and universities, and laboratories interact has changed. I don't think U.S. industry has awakened to these changes. It may take another major setback, either by the stock market or by the economy, for industry as a whole to wake up.

In the meantime, what can we do? I would like to give you my perspectives. My feeling is that rather than searching for these global solutions and trying to find ways that benefit U.S. industry as a whole, it would be advantageous to pick a few technologies or industries or companies. Then, collectively, with the support of the government, industry, and the laboratories, we should make those into major success stories.

The problem with trying to improve competitiveness by intellectual exercise, as I see it, is that the solution that's found here today is in Moscow or Tokyo via fax machine or a telephone call in a half an hour. The advantage of the time element has vanished. There's a vision that is required to identify the products or the technological inventions that are going to carry the day three to five years from now, because it takes that long for a sophisticated product to reach the market. Look at lasers or superconductivity. It doesn't happen overnight. So speed is not the answer. The answer, as I see it, is to really think ahead and try to determine what the world is going to be like three to five years from now, and work like hell to be there before everybody else gets there.

Goldhar: What you've just described is good corporate strategic planning. We've got a number of examples of that in the U.S. as well as overseas. To talk about it as a public-policy issue presents one small problem and that is, none of us knows anyone else whom we would trust to be smart enough to choose which of those areas or industries should get all of our resources.

Sidney Kulek (Allied Products Corporation): I don't believe that industry is asleep to the opportunities that federal laboratories have to offer. I myself have worked with laboratories in the past. What industry is concerned about is the huge amount of bureaucracy that it must go through in order to, number one, be able to talk to someone about ideas that we're interested in, and second, all the steps that industry has to go through in order to clear one of these brilliant ideas of technology transfer. That is a horrendous problem. Anytime you show an industrialist a chart and end it with two attorneys on the bottom, there are two very large red flags saying, watch yourself.

The second area of concern is the very successful Japanese approach of tying industry and the universities together with the government. Our problem in this country is that we are waiting for the government or some congressman to have the wisdom to do this. Instead, I think the idea would have to come, not from the government, but perhaps from a consortium of industry and the academicians. But if we don't do something like that, we will lose any competitive edge we might have achieved by a teaming of industry and university. We are being injured economically by illegal dumping and stealing of technology secrets. Our R&D budgets are being reduced as our profit margins erode. I agree this is the wave of the future, but I don't know how we can go about doing it. The idea is not to get Mr. Rivers to tell us what products are available to me. We have to go beyond that and say, how do you get it out of the system and how do you work together with this community to develop the things that we think we need jointly?

Cohen: We've seen an interesting example of your last point in the past year in the formation of SemaTech. That's a group of semiconductor-manufacturing companies who are fierce competitors. SemaTech got half of its funds from the Department of Defense, and half of its funds from these 10 or so companies. They're giving up some of their competitiveness to look at the development of manufacturing tools. Some of the companies are putting in a few of their jewels to get it started. That smacks of industrial policy, because the government's decided that an industry is important enough, at least to one sector of the government, to survive. If you can bear the weight of a terminology like "industrial policy," I'd like to see more of those consortia.

Rivers: The question that Kulek raised about the burdensome procedures you have to go through is not unrecognized by the federal laboratories. In fact, the General Accounting Office just completed a survey of a dozen or so major laboratories. They asked the laboratory directors, how goes it with the Technology Transfer Act of 1986? What are the constraints and impediments that you see? There were four points that the directors highlighted. One was the inability to copyright software, which is another issue. The second was the inability to do proprietary research for industry. Their recommendation is that they be able to do research that industry pays for, and maintain it as confidential information for up to a five-year period at a minimum. Third was this general question we talked about, intellectual property rights and the difficulty in going after individual waivers of rights to technology versus class waivers, a particularly acute problem with some of the GOCO laboratories. But the fourth and last one that the laboratory directors pointed out was what they called the burdensome and time-consuming procedures by which interactions between industry and the laboratories have to take place.

How are you going to solve that? Obviously, it's not an easy thing to solve, but don't look to Washington for a quick solution. Washington isn't the solution, it's mostly the problem. I think the solution rests with local people getting together at the local level. That's Steve Lazarus and ARCH, it's people working here at Fermilab. You can accomplish a lot if you get to know one another, work with each other, exchange scientists, start all kinds of exciting things at the local level.

Lazarus: Let me follow that up. Since we do operate in a scientific and technological frame, my question is, why not approach it the way scientists would? That's what we've tried to do.

As I said earlier, ARCH is an experiment. It's one of a thousand flowers which are blooming right now in this area. There are a thousand experiments out there. ARCH can copyright technology and vend it. ARCH has an advanced waiver from the Department of Energy. The relationship between Argonne and its Department of Energy Chicago Operations Office is very cooperative. We don't have to negotiate individual waivers of inventions one at a time. ARCH can elect and immediately start negotiating with industry. The first licensing action that Brian Frost really accomplished was four weeks in duration from the time that the CEO of the company came in asking about the invention to the time we signed the papers and he passed over the front-end royalty payment. We still have cumbersome procedures. You are going to have cumbersome procedures as you move through this kind of change. But I think we have several working proofs around the country that it can be done. It's very important that you invest some time in observing what's going on where and try to hook into the process at a level where you can make use of it.

Gary Gustafson (Eastman Kodak Company): You identify three major players in this process: industry, academia, and government. How do you define the role of each of these institutions?

Cohen: Let me ask that we not try to define those all separately, because I think one of the purposes of a session like this is to try to bring all three of those things together and remove some of the barriers that have arisen. Leon Lederman always refers to Fermilab as a university, and yet there are big procurement orders that are going to go out from this university in the next several years. Rather than take the time now to have us stumble around with definitions of function, we ought to agree that we're all here to try to bring these three bodies closer together and have them do something about the economic situation.

Goldhar: What we haven't done, though, is point out that there's a fourth player, either venture capital or an entrepreneur who wants to start a business. What's missing is enough emphasis on the catalysts and the bridgers. Two decades ago, we did all the studies on NASA technology transfer. NASA probably spent more money studying the spinoff benefits than anybody ever realized in spinoff benefits. What was clear was that technology moves through people. It's just like international technology transfer: You can move technology to the border of a country, but if there is no infrastructure inside to move it from the border to a place of use, it dies there on the border no matter how much willingness or incentive there is. The two parties have to have a reasonably equal balance of sophistication.

We used to talk about matching innovation quotients, IQ to IQ. If there is no one in the company, particularly in smaller companies, who can talk the language of the lab or of the source of technology, it isn't going to work. On the other hand, if there's no one in the lab or the source of technology who can talk the language of the company, it isn't going to work. You can't do that through formal programs. You do that through individuals who slowly learn both sides of the fence. You learn it through companies stealing away Leon's best people at absurdly high salaries so that they can afford to leave their government pensions. Universities lose their best people through venture capital. Within a year after a hot Ph.D., there's someone around offering an assistant professor not only a higher salary, but options, the new magic word. There's a tremendous movement of technology that way. I think we ought to encourage that, but we discourage it because pension funds aren't movable and we have lots of bureaucracy around. I don't know whether Fermilab can let someone work one day a week at a company somewhere without taking a year to make that arrangement. Then again, if you've ever tried, as an independent venture, to sell something to General Motors, their process of getting new technology in makes Fermilab's process of getting new technology out look simple and straightforward, and there are 20 lawyers involved in that process.

Cohen: Let me tell you about people and whether you can get scientists to learn about technology transfer. When we get a new Ph.D. fresh from graduate school, he's never studied how to transfer technology from the research laboratories of the IBM company to the product development laboratories of the IBM company. IBM tried to figure out how to indoctrinate people. I'd like to bless it with the word education, but it isn't that. And you know, it actually worked. We started talking about case histories and responsibility and so on, and now, 15 years later, managers in our research laboratories understand that part of their job is to transfer technology to the product development area. It's built in at this point. Our experience was that you can change people from the raw material you get out of the academies into industrial scientists.

But that didn't turn out to be enough. We also had to build those bridges inside our own company. We had to set up formal structures between our research laboratories and the product laboratories. We have done that in the past six or seven years. I think there's a people element that's vital and I think there's an organizational activity that has to go on that the labs ought to do, that industry ought to do, and that the universities ought to do. And there are, as Lee has said, lots of experiments.

Brian Frost (Argonne National Laboratory): I've spent the last three or four years in technology transfer working with companies. I've found that the ease of doing this is inversely proportional to the size of the company. Steve Lazarus mentioned that we achieved a licensing agreement in four weeks. That was with a small company of about 40 people. The CEO himself got involved. The other side of the scale is that we have been trying to set up consortia in which we've been asking $70,000 a year from a firm. We talked to the middle management and they said, "Great idea. But we can't approve that." Sometimes, approval has to come from beyond the vice president of research, and once you're beyond that level, you're talking to M.B.A.'s and people like that. It gets to be very difficult. You get a lot of lawyers involved. There's some symmetry in the difficulty here. Industry needs to make its procedures simpler just as we do.

Leon M. Lederman (Fermilab): He just used the magic word: M.B.A. Lazarus gave us a nice history of doom and gloom that was echoed by Nicholson. We're in bad shape, we're not educating well enough, things are very bad. One hundred and fifty billion dollars interest. Rivers was more optimistic. He thinks things are going to go O.K. What I want to know, in case he's wrong, who's the villain? I want to beat up on somebody. Who got us into this? Maybe he doesn't want to get us out. I need a big budget next year and if the stock market crashes, it's bad for quarks.

Rivers: I think Hirsh Cohen ought to answer that question.

Cohen: Maybe it's the particle physicists that got us into this with those dreams of glory they've had all these years. Promises and promises.

Rivers: I think if there's a villain, it's a collective one and it's going to be found in the culture and attitude that we have in this country of being litigious with one another. If I'm from the government and I say I'm here to help you, I've just told a joke. But when our international competitors say they're here from the government and they're here to help, they really mean it and they do. It's a cultural and an attitudinal thing that we share. We've got to get over that and turn good old Yankee ingenuity around, not be so litigious and adversarial in the way that we try to work with one another. There's plenty of blame to go around.

On the question of interaction between the various sectors of this society and technology transfer, maybe technology transfer - in my firm, I call technology transfer "initiatives" - has the wrong connotation, because transfer implies that you're handing over the documents or you're handing over the instrument. It's really not technology transfer that's important, it's something you could call technology flow, because it is an ebb and flow situation. What we should be talking about is working together to jointly develop technology. In my opinion, the interaction between federal labs and industry is not a one-way street at all. The government investigator is going to be richly rewarded, and I don't mean only in dollars, by a much more involved interaction with the industrial scientists. That technology flowback will benefit the primary mission of that principal investigator within the laboratory system at the same time that the technology flow in the other direction, through constructive interaction, is benefiting the company and the company's ability to rapidly develop new products, goods, and services.

Richard Nicholson: I believe it's cultural, too, but just saying that doesn't lead to the solution. Our young people don't have the work ethic they once had. There have been fundamental changes in our culture. That's the root problem. I don't know how to deal with that. But some NSF studies have just revealed something interesting. We've conducted studies of the performance of Asian kids. As you know, first-generation Asian students out-perform American students by substantial amounts. What the studies reveal is that, by the time they're second- or third-generation Americans, the Asians perform just like Americans, namely, pretty crummy. So there's something about living in this country for two or three generations that changes performance.

Cohen: I think we should hear from the M.B.A.'s. What do you say, Joel?

Goldhar: I want to address Leon's question: If things go wrong, who should we beat up? Certainly, some of the fault lies with M.B.A.'s like Steve Lazarus. But in the last issue of *Forbes*, they listed the 800 most powerful people in American industry, the CEO's of all the companies, where they came from, where they went to school, and what degrees they have. I was depressed to realize how few of them, in fact, were M.B.A.'s and how many of them were lawyers, which is one good candidate to beat up on. A lot of them were ex-scientists or engineers. The biggest group were B.A.'s from Yale.

I believe this really is a pluralistic problem. One part is culture, and I don't know whether it's the culture of the work ethic or lack thereof so much as it's the culture of the quick return. The other part of the problem is public policy which encourages the culture of the quick return, ranging from tax policies to regulation of the financial markets to our bilateral relationships with trading partners. All we have to do is increase the transaction costs on Wall Street and we'll see a fundamental change in the way people view the value in a company and whether or not technology that takes more than a quarter to show its value gets any ranking in the stock price. We simply go to a capital-gains tax plan that takes 10% per year over 10 years off the tax total on a stock exchange. If you hold the stock a year, you pay 90% of the taxes; if you hold it for five years, you pay 50% of the taxes, and so on. All of a sudden, you'll see people recalculating on their 1-2-3 spreadsheets the optimum time to keep a stock and the value of an investment in science and technology as it pays out over three, four, five years hence. I think it's a public policy issue to be dealt with.

Cohen: I'd like to make a contribution to Lederman's question, too, but it's quite a bit more general than Joel's. I think we're all guilty, the academics (and I include the free-spirited particle physicists), the industrial people, and government. We're guilty of still dealing with the old models of how this triad is related to its parts and to the rest of the people. The models are still the models of the 1940s, 1950s, and 1960s. We would like them to continue working because they were successful then. We had that great boom-time for everything. We haven't renewed any of those models. The things that people have been talking about up here are part of that renewal process and so I am not going to go into that litany again. But I think that's the sort of underlying malady we all have. We'd like the government to keep on funding Fermilab the way it used to, right? That's a reasonable hope. But the models of those things may have to change in the economic warfare of the 1990s.

Lazarus: I don't want to let the work-ethic observation stand. First of all, the M.B.A. candidates that I work with at the University of Chicago are the most impressive group of young people I've seen in a long time. The job opportunities and financial services have been cut in half this year, so they're making the adjustment into entrepreneurial studies. They're committing themselves to working 18- to 20-hour days. I just wish we had more of them. The demographic point that was made earlier is true. They're part of the so-called Baby Bust group and we could use a lot more of them. I think they're terrific.

Furthermore, I believe that the natural raw talent that we have in our children coming up through the elementary and secondary school system is terrific. But we fail to challenge them. We are teaching them in a way that is almost an insult to their innate capability. We've somehow internalized this Piaget thinking, that a young child is incapable of learning tough things. But we have all this evidence piled up around us that says the young child is the greatest natural linguist in the world and can understand mathematical concepts. We can do something about that, and should.

Finally, a comment about the black population that is going to be so numerous. Sure, they're disinclined toward technical pursuits, because most of them have to fight their way through an inner-city educational system that is a disgrace. But give them the same educational opportunity that you have out in the suburbs, and you will find the same kind of talent coming out the other end.

If I were to choose my first priority for investment, it would be to invest in those education systems. It's not going to happen unless each one of us individually makes a political judgment that we're going to work for it. If you listen to the campaign rhetoric today, this is supposedly going to be an education election, but I don't hear the underpinning plans coming out of either side of the political spectrum.

Goldhar: Steve, would you trade that off against the Superconducting Super Collider?

Lazarus: I won't answer that until I leave this Laboratory.

James S. Kahn (Museum of Science and Industry): It's a pleasure listening to all these discussions. I'd like to add something and I'll only take a few minutes.

I've heard all of this before. I've heard ERAB tell me what we ought to do with Livermore, and most of the time we could never do what you suggest we do anyway. I've heard the complaints from the back about bureaucracy at the laboratories. Let's try to fix this right now. I think it's time for us to stop talking. It would be a shame not to take advantage of Leon's beautiful, ambiguous challenge in this Roundtable's title - the spiral and which way is it going?

What we've got to do here, and we'd be remiss to leave this room without doing it, is to try and establish a new national strategy to resolve this issue. That is what we've been saying. I believe we have all these elements. (We left one out, by the way, which is American labor.) We need a national congress or a national board where the elements that are in this room today are heard loud and clear, and then something is done to change the mind set in America. We haven't got the time to continue to spend six years "playing" around. The strategy should be established now. Otherwise, we're going to fall further behind.

The Japanese have a marvelous national policy designed to make them number one in trade. We don't have that. Why don't we think about what we're going to do to solve the problem, rather than talking around the elements?

Cohen: I thank you for describing what we've been doing this afternoon as playing around. It's been fun. I'm not sure that we're going to get national policy evolved in seven minutes, although it seems at times it's been done that way in the past eight years. I must say, it's appeared in the conversation this afternoon. I like what Frank Press has been saying, that it's time to set some priorities. I would assume that we're the science and technology people no matter which of the three areas we come from. It's time that we thought about whether we have to set priorities, because big and little science, when you put them together, is pretty big. If you want to talk about a national science and technology policy, it has to start there. That's a subject for another afternoon and another panel.

I agree with the earlier comment. This happens to be a summer when some of us can perhaps have an effect on what the next president and the next congressmen will be saying about these questions. This is the opening that occurs every four years where we get a crack at that. Isn't it about this time in an election year when committees of scientists begin putting ads in the paper for this or that and get behind candidates? That hasn't started yet. That's a way to start policy going.

I think we had better close down this soapbox.

Interacting with the Technology at Fermilab

Richard A. Carrigan, Jr.
Head, Fermilab Office of Research and Technology Applications
and
Coordinator, Fermilab Industrial Affiliates
Fermi National Accelerator Laboratory

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The Fermilab Industrial Affiliates organization was initiated in 1980 to improve university-industrial research communications and facilitate the "spinoff" of state-of-the-art developments from the Laboratory. As one of the premier high-energy physics installations in the world, Fermilab is the off-campus research facility for some 70 U.S. universities. Our experience in cooperative development of complex technical components has encouraged us to seek a more systematic format for the exposure of our needs, problems, and our achievements to industry.

The Affiliates are a group of about 40 organizations with some interest in the research and development work under way at Fermilab. They include a wide spectrum of high-technology companies from the very large to vigorous new organizations. We hold a two-day annual meeting for company research directors and other senior personnel. This is a direct opportunity to see the work here at Fermilab. We encourage Affiliate staff visits to Fermilab and visits of our staff to Affiliate organizations. We also distribute Fermilab technical reports on a monthly basis to the Affiliates, based on their particular technical interests. Last, but not least, we know the Affiliates are interested in the Laboratory and that often means they are the first ones to know about interesting activities going on here.

These are some of the specific activities of the Industrial Affiliates. More generally, we are looking for concrete and effective ways to enhance collaboration of industrial research organizations, academic institutions, and national labora-

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**This is an updated version of material that appeared in the monograph of the 1987 Industrial Affiliates Seventh Annual Meeting.*

tories. Of course, the interest of the Affiliates also serves to support the Laboratory in its dealings with the Department of Energy and the general public!

The annual membership fee for the Affiliates is $1000. If you are interested in membership, please get in contact with me, Dick Carrigan, (312) 840-3333, or Dr. Leon Lederman, (312) 840-3211, at Fermilab.

Technology at Fermilab

Now on the national agenda is an accelerator 20 times the size of the TEVATRON, the Superconducting Super Collider. Technically that project is a direct outgrowth of the TEVATRON at Fermilab. The TEVATRON is the world's first (and only) superconducting synchrotron. It is also the most powerful accelerator in the world. It operates like a Swiss clock. The TEVATRON is, by far, the largest superconducting project ever built.

How did the technology for the TEVATRON come about? The answer is several-fold: partly through a concerted program at Fermilab to develop a new magnet technology and partly through an informal program between U.S. industry and Fermilab to develop the superconducting-wire technology. Parenthetically, that relationship had its genesis more than a quarter of a century ago as a collaborative effort between the Westinghouse Research Laboratory and some particle physicists. This wire development has been technology transfer in the "good old-fashioned way," namely, a laboratory and vendors working together to develop an industrial-scale supply of superconducting wire. Today, we have a TEVATRON *and* a billion-dollar medical-imaging industry using superconducting wire. The success of that industry, with a quick start in the early Eighties, must have been due in part to the wire R&D for the TEVATRON in the Seventies. There is much valuable and relevant information and technology at Fermilab on dewars, sensors, oxygen deficiency hazards, quench protection, and cryogenic controls. Fermilab is where industrial-scale superconductivity is at!

Another technology at Fermilab is the award-winning Advanced Computer Program, or ACP for short. This is a good illustration of a technical development needed for special work here that has already gone on to become an industrial product marketed by an Affiliate, Omnibyte. Technology transfer has been an intrinsic part of the activity from the outset. Now further developments are under way as the researchers set out to address the knotty problem of quantum chromodynamics, or QCD.

Another major effort has been the Loma Linda-Fermilab proton medical accelerator. The accelerator is now almost complete. This has been a so-called "work-for-others" project. From the outset it was envisioned that Loma Linda University Medical Center would find an industrial partner to commercialize the technology. That has now happened - the partner is an Affiliate, SAIC. Clearly, one can expect to see more technology spilling out of this unique hospital-industry-national laboratory collaboration. For example, there may be developments that could be important for the construction of compact synchrotron light sources for microchip lithography. By the way, an important member of the team fostering the transfer of this technology has been the State of Illinois. This was done through a grant from the Department of Commerce and Community Affairs. In effect, the Loma Linda project created about 100 man-years of employment in the state.

There are many other technologies that we have not discussed in detail at the meeting. These include such areas as software, controls, VME, and fast electronics. Some of these are summarized in the box on page 73. If you are interested, get in contact with us.

How to Interact with Fermilab

The best way for industry to interact with Fermilab is to join the Fermilab Industrial Affiliates. As noted earlier, the purpose of the organization is to set up a two-way street where we can work together. We're willing to try any good idea as long as it's legal. Remember, though, Fermilab is not an engineering experiment station. Our activities have to fit the Fermilab profile, and they can't be breaking somebody else's rice bowl.

The good old-fashioned way to interact mentioned earlier still holds. Successful bidders on Fermilab contracts can carry away a lot of very useful experience. Our sister laboratory, CERN, once estimated that most CERN contracts led to several times the business elsewhere.

Fermilab has now moved into a new area for us - licensing. We have much to learn. If there are technologies at Fermilab that you are interested in licensing, let us know. You may have to teach us how to do it, but we are willing learners.

The Loma Linda project is an illustration of another way to interact. This is as a joint project or a work-for-others arrangement. From our standpoint these are fraught with problems. On the other hand, the Loma Linda project has been very successful as a technology transfer. Some of our Affiliates have also suggested some interesting ideas. A good arrangement is one where the Laboratory gets some direct benefit or service out of the collaboration, both parties contribute equally, and the company goes away with a technology they can pretty much call their own. But remember, DOE and our business people see this as trouble, trouble, trouble.

In some cases we have "modest" requests for technology. These are requests for individual circuit board layouts, items of software, or access to some special measuring equipment. Even these can get to be complicated, but we are trying to handle them as flexibly and quickly as possible on a direct cost recovery basis.

Finally, there are many possibilities for individual visits. Fermilab is about the best place in the world to visit. There are very few complications about passes or permission. It's certainly easier to park here than at most university campuses.

Summary

Clearly, there is lots of technology at Fermilab. This includes superconducting and cryogenic technology, advanced computer concepts, and accelerators to be used for medicine and software. There is a Chinese menu of other possibilities. Recent years have seen a real breakout in the tools available to transfer this technology. Universities Research Association will now own the Fermilab inventions, and Fermilab inventors will share in royalties. In addition, the Laboratory is developing a marketing arm and has retained legal counsel in the area of patents and licenses.

There are now many ways to access the Laboratory technology, including the Affiliates, the normal process of working on Fermilab procurements, licensing, joint projects such as Loma Linda, a willingness to support "modest" requests for specific items, and the obvious possibility of visits.

We are pleased with your interest in Fermilab. If you are an Affiliate, we are very gratified for your involvement with the Laboratory. If you are not an Affiliate, please join! We are not exclusive.

Some Fermilab Technologies

• Accelerators - Some of the most powerful and sophisticated accelerators in the world are in operation at Fermilab. A sparkling new development is the proton accelerator for medicine being built for Loma Linda Medical Center.

• Superconducting Magnets - Fermilab is the world center for superconducting magnets. This technology has relevance to many fields, including medical diagnostic imaging.

• Large-Scale Cryogenics - A substantial portion of the helium liquification facilities in the world are installed at Fermilab. Laboratory staff members have extensive experience in cryogenic control, compressor systems, simulation, and other areas of large-scale applied cryogenics.

• Radio-Frequency Systems - Fermilab has extensive experience in rf, including traveling-wave technology.

• Supercomputer Architecture - New, award-winning approaches to very-high-speed parallel computing have been developed at Fermilab.

• Computer codes - Fermilab has developed a vast array of computer codes including VAX system software, drivers for FASTBUS, VME, and CAMAC, and controls systems. Some of these will be available for licensing in the near future.

• Fast Electronic Data Handling - A number of control and data transmission systems using the FASTBUS, CAMAC, and VME standards are in operation.

• Particle Detectors - The heart of the Fermilab experimental program is detection and tracking of particles - protons, neutrons, photons, and charged ions. This has required the development of sophisticated scintillators, lead glass, wire chambers, and silicon detectors.

• Neutron Therapy - Fermilab's Neutron Therapy Facility, using the Linac beam, has treated more than 1400 patients - more than any other facility.

Appendices

Appendix A

The Fermilab Industrial Affiliates

AT&T Bell Laboratories
Air Products and Chemicals, Inc.
Allied-Signal Engineered Materials Research Center
Ameritech Development Corporation
Amoco Corporation
Babcock & Wilcox
CBI Services, Inc.
Commonwealth Edison Company
Cray Research, Inc.
Digital Equipment Corporation
Digital Pathways, Inc.
R. R. Donnelley & Sons Company
Environmental Monitoring Laboratories, Inc. (Waste Management, Inc.)
General Dynamics
General Electric Company
GTE Laboratories
W.W. Grainger, Inc.
Harza Engineering Company
Hewlett-Packard Company
Hutchinson Technology, Inc.
IBM
State of Illinois
Inland Steel Company
Intermagnetics General Corporation
Kinetic Systems Corporation
Litton Industries, Inc.
Major Tool & Machine, Inc.
Martin Marietta Denver Astronautics
NALCO Chemical Company
New England Electric Wire Corporation
NYCB Real-Time Computing, Inc.
R. Olson Manufacturing Company, Inc.
Omnibyte Corporation
Oxford Superconducting Technology
Phillips Scientific
Plainfield Tool and Engineering, Inc.
Schlumberger-Doll Research
Science Applications International Corporation
Sulzer Brothers
Swagelok Companies
Union Carbide Corporation
Varian Associates, Inc.
Westinghouse Electric Corporation

Appendix B

Agenda of the Fermilab Industrial Affiliates Eighth Annual Meeting

Fermi National Accelerator Laboratory
Batavia, Illinois
May 26-27, 1988

Thursday, May 26

10:00 a.m. -	Tours: 1) General, 2) Electronics 3) Supercon-cryogenics-medical accelerator	
1:00 p.m.	How Goes Fermilab?	Dr. Leon M. Lederman (Fermilab)
1:30 p.m.	High-Energy Physics and Industry	Dr. Richard A. Lundy (Fermilab)
2:00 p.m.	Roundtable: "The Science-Technology Spiral and the Pace of Progress"	
	Keynote: "Science and Technology: the Basis for Global Competitiveness" Dr. Joel Goldhar (Illinois Institute of Technology)	
	Moderator: Dr. Hirsh Cohen (IBM T.J. Watson Research Center)	
Panelists:	Mr. Steven Lazarus (ARCH Development Corporation)	
	Dr. Richard Nicholson (National Science Foundation)	
	Mr. Lee W. Rivers (Federal Laboratory Consortium)	
6:30 p.m.	Banquet	
	Speaker: Mr. Donald Frey (Illinois Governor's Commission on Science and Technology)	
	"U.S. Industrial R&D: the Good News and the Bad News"	

Friday, May 27

8:30 a.m.	Future of Parallel Processor Computing	Dr. E. Thomas Nash (Fermilab)
9:15 a.m.	Detector Development at Fermilab	Dr. David Anderson (Fermilab)
9:45 a.m.	Muon Catalysis and Hydrogen Fusion	Dr. Steven Jones (Brigham Young University)
10:45 a.m.	New Developments in Electronic Busses	Dr. Marvin Johnson (Fermilab)
11:15 a.m.	Progress on the Loma Linda-Fermilab Proton Accelerator for Medicine	Mr. Philip V. Livdahl (Loma Linda University Medical Center)
1:00 -	Tours: (These tours duplicate the Thursday morning tours)	

Appendix C

Other Volumes in the Fermilab Industrial Affiliates Roundtable Series

1982: *Fermilab Roundtable on Technology Transfer and the University-Industry Interface*

1983: *Fermilab Industrial Affiliates Roundtable on Supercomputer Developments in the Universities*

1984: *Fermilab Industrial Affiliates Roundtable on Industrial Participation in Large Science Projects*

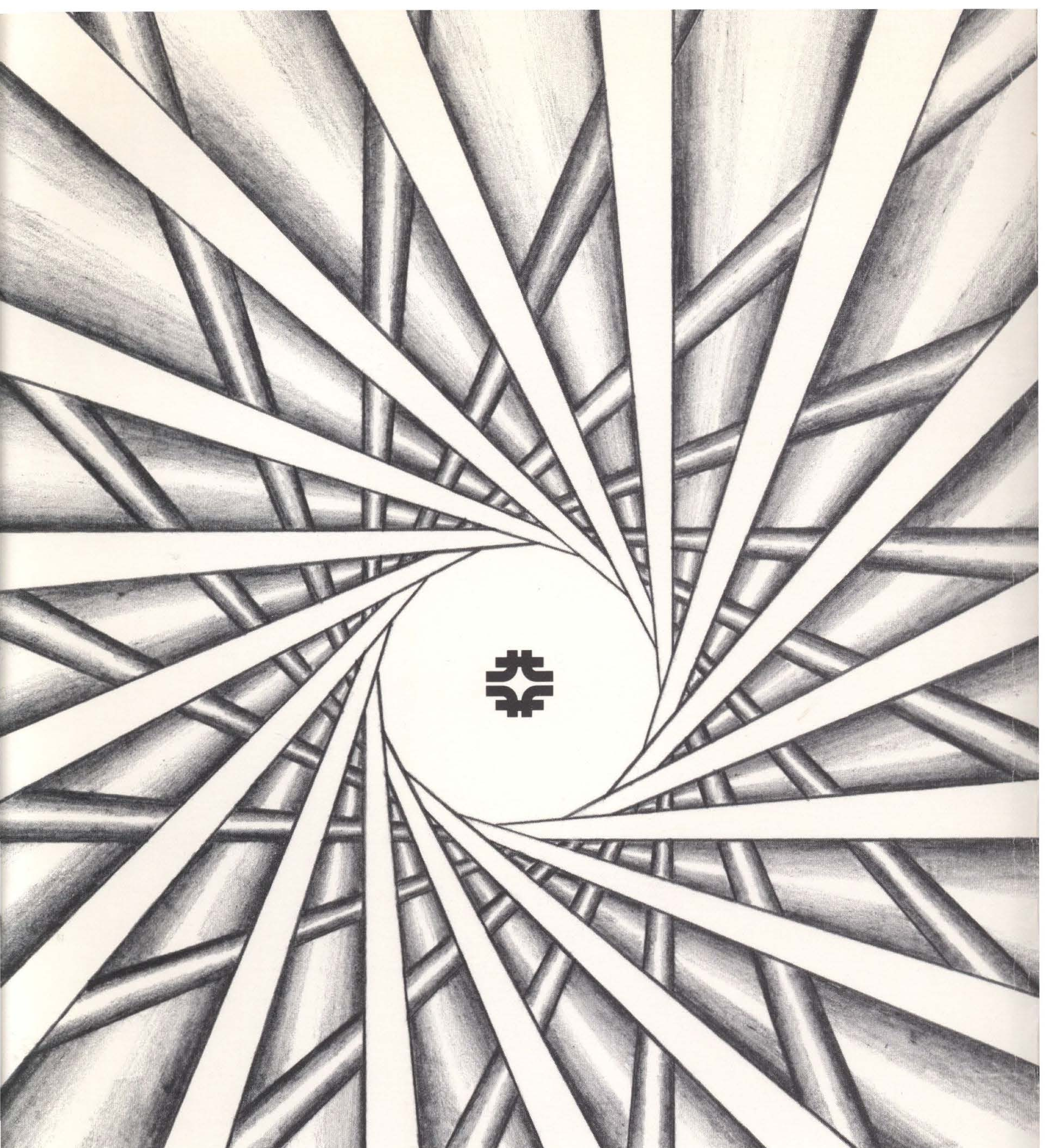
1985: *Fermilab Industrial Affiliates Roundtable; Applications of Particle Physics: Out on the Limb of Speculation*

1986: *Fermilab Industrial Affiliates Roundtable on Science, Economics and Public Policy*

1987: *Fermilab Industrial Affiliates Roundtable on Research Technology in the Twenty-First Century*

Copies of these monographs can be obtained by writing to:

Fermilab Industrial Affiliates Office
Fermi National Accelerator Laboratory
P.O. Box 500 - MS 208
Batavia, IL 60510



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