Introduction

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National laboratory directors Leon M. Lederman (second from left) and Alan Schriesheim (right) converse with Affiliates during the Sixth Annual Meeting.

The Fermilab Industrial Affiliates (FIA) organization, the sponsor of this meeting, was established in 1980. The purpose of the FIA is to improve communications between academic and industrial research. Some people question the fact that I use the word "academic" instead of national laboratory. Technically, Fermilab is a national laboratory, but in every sense it really is an off-campus facility for some 70 universities in the United States. There are 56 that are formally organized into a consortium called the Universities Research Association (URA) which has an office in Washington and a board of trustees of some 20 members. URA manages the Laboratory under contract with the United States Department of Energy.

Essentially all the action here at Fermilab is carried out by university scientists. Whatever we do here is so intimately interwoven with the research activities of the universities that we really are a central location where you can see some of the work, at least in our field, that is carried out at most of the major research universities in the United States.

Technology Transfer at Fermilab

Initially, the objective of the FIA was technology transfer, although I didn't know that was the buzz phrase when the FIA was established. In 1981, at our first annual meeting, the approach was simplistic. The session began with a very spirited talk on particles and what we were doing about quarks and leptons at Fermilab. Then we had all of our bright engineers and physicists tell the audience how clever we were and all the things we were inventing. We expected that the participants would go back to their companies and immediately manufacture these nifty items and then sell them. The GNP would take a big jump for which we could claim credit.

Of course, nothing like that happened. We had a wrap-up at the end of the meeting and the best comment we got was, "You should have told us more about quarks, THAT was interesting!" Then we began to have some respect for the complexities of this process called technology transfer, so the theme of the 1982 meeting was just that: What is technology transfer? How do you do it? The keynote speaker at that meeting was Bob Frosch, Vice President for Research at General Motors, who pointed out that it is very difficult to transfer technology from a GM laboratory to a General Motors manufacturing facility. This is a point of continuing study and interest.

In 1983 we picked as a theme "Supercomputer Developments in the Universities," which was kicked off by Ken Wilson, a recent Nobel Prize winner from Cornell. I remember the highlight of that Roundtable was a challenge that Burton Smith, Vice President of R&D for Denelcor, made: "Can somebody guess as to the factor of increase of speed of computers by the year 2000?" The highest factor suggested was 10^{14}. The basic idea that emerged from the discussion was that one of the interesting things that has been happening in the last five years or so is a resurgence of interest on the part of universities and labs like Fermilab in *much* more powerful computing. The needed factor of improvement vastly exceeded what one might expect from the computer industry. The developments in university labs of enormously powerful parallel processors, organized for special purposes, was surely influential in the developing supercomputer architecture.

In 1984, we talked about basic science projects, in particular something called the Superconducting Super Collider (SSC) as an example of some very large pure-research projects which will depend very heavily on industrial participation. I believe those discussions helped to further the industrial understanding of the SSC and helped us scientists to better understand what industry could bring to a mammoth project like that and how industry should be approached.

Last year we thought we would have some fun, and we decided to go way out on a limb of speculation. We had serious people, a Nobel Prize winner and people of that ilk, discussing the practical applications of anti-matter and quarks and muons and other such exotic things. The ground rules were that Roundtable participants were allowed to speculate as long as they didn't violate the basic laws of physics. All of these Roundtable monographs are available from our Office of Research and Technology Applications (ORTA).

This Roundtable covers a less exotic theme: science, economics, and public policy. The subject has largely been stimulated by two factors: my interest, as well as that of others, in trying to measure the value of basic science; and the deepening fiscal crisis in the government and the perception that, in fact, basic research and even applied research in this country are not all that healthy. Several years ago, I reviewed my own perception of the value of basic science in a *Scientific American* article. One of the initiatives I called for was a study of the economic value of basic research. Edward Steinmueller, one of our Roundtable participants, and David Mowery have now proposed to undertake just such a study of high-energy physics. Likewise, Norman Metzger, of the National Academy of Sciences, has recently nurtured a somewhat similar study on the federal role in research and development. The basic question is, "What are some of the issues related to how one supports basic research in this country in the face of the Gramm-Rudman-Hollings environment?" Once you get professional economists into the act however, there is no telling where they will take us.

Research at Fermilab

Now that is the history of the Industrial Affiliates. At Fermilab we have a very simple-minded mission, to do research in particle physics. We are quite modest; we just have three questions we would like to answer: What are the fundamental objects that make up the Universe, what are the fundamental forces, and how does the Universe work? Try as I might, I have not been able to put how far we've gotten, on both sides of a t-shirt. Just to summarize, we believe that we are really in a revolutionary phase. I believe that in the 20th century we can recognize a revolution produced by the relativity theory, and another revolution produced by the quantum theory. We are in the middle of a third revolution that doesn't have a name yet. It has something to do with the basic particles and the basic forces. It also includes the merger of interests, in the last five years, of the particle physicists who use giant accelerators, like the one at Fermilab, to probe into the structure of inner space, and the astronomers who have been using telescopes and space probes looking at outer space. Both of these groups are now finding that their progress is linked to one another. Here we are talking mostly about the cosmologists and astrophysicists who are interested in the early Universe. It turns out that the early Universe was simply an accelerator laboratory with an unconstrained budget. Therefore, astronomers, in order to model the Universe from creation onward, have to know more about what are the fundamental objects and forces. So we now have, at Fermilab, an Astrophysics Group that institutionalizes this new symbiosis.

Fermilab was created as a result of a Ramsey Committee recommendation to the Atomic Energy Commission in 1963. In a typical planning cycle of some 10 years, the first beams arrived at Fermilab in 1972. At that time, it was a 200 billion-volt accelerator. In 1973, again a 10-year cycle, R&D began on superconductivity as appropriate for accelerators here at Fermilab, and in 1983 the TEVATRON was brought into operation. The new accelerator had a funny series of names. It sometimes has been called the Energy Doubler, because it was going to double the energy of Fermilab's accelerator, and sometimes the Energy Saver, because superconducting magnets don't get hot and don't use as much energy. In fact, the Energy Doubler/Saver (whatever it's called) *did* double the energy and *did* save some 30 or 40 megawatts of electrical power. Before construction started on the TEVATRON, the original Fermilab machine had evolved to 400 billion volts in 1974. We started operating the TEVATRON at 800 billion volts. That continued through 1985. We hope to come on in 1986, after a shut-down, at 900 billion volts, and we should ultimately get close to 1000 billion volts. Thus, the new accelerator is called the TEVATRON because "TeV" stands for 1000.

The TEVATRON construction program began in 1979 and should terminate in 1986. If you drove through the site, you saw a lot of civil construction going on. This is the last stage in the TEVATRON construction program.

The first really full-scale application of the 800-GeV machine occurred in 1985 when we extracted 800-GeV protons and fed them to a large number of experiments for the so-called Fixed-Target Program. In October of 1985, we had our first test of a more exotic application, namely head-on collisions of protons and antiprotons, both of them circulating in the Energy Saver magnet ring. We achieved collisions at the world's highest energy: 1.6 trillion electron volts.

Now we are in the early stages of another, hopefully, 10-year planning cycle for a new accelerator called the Superconducting Super Collider, which had its official birth in 1983. That will be a 40-TeV supercollider.

Socially Redeeming Activities

There are a number of other programs at the Laboratory not directly connected with the basic research mission that are quite interesting. One has to do with the work on cancer. We have been probably the largest facility in the world for treating tumors with fast neutrons. That program is more than 10 years old. Now we are involved in a process which could be called "technology transfer," or perhaps spin-off is a better word. This is the construction of a small proton machine. We were asked, in fact, by the medical people involved in neutron therapy to provide protons as a byproduct of our accelerator operation. However, when we looked at the cost of having a facility here, including the treatment rooms and all that, we decided it is more sensible to build a proton machine that can fit into a hospital room. The State of Illinois gave us a grant which encouraged us to do a preliminary study. We have now entered into a collaborative agreement with Loma Linda University Medical Center and we are building a prototype here that will eventually be turned over to them.

An activity that I'm very proud of is something called the Illinois Math-Science Academy. Some of you who live in Illinois may know about this. It will open in September. It took us about three years to bring it to reality; to convince the Governor and the legislature that this is a good idea. This is a school for gifted math-science students. It is very rare, I think, in history that somebody hands you a blank pad of paper and tells you to design a new educational strategy for bright kids, with no constraints. Forget about boards of education, forget about all of the rules and sit down with the best possible advice you can get and design a school for bright kids. That is exactly what is now happening.

The Topic: ECONOMIC DEVELOPMENT

The subject of today's Roundtable is not exactly brand new. It was first broached by Francis Bacon in about the year 1600. Bacon, at that dim period between Galileo and Newton, had grasped the power of science and forecast the great social value of scientific knowledge. Science, Bacon said, is for improving the condition of the human race - not to make humans perfect but to make imperfect humans comfortable. Bacon did understand the cultural drive but stressed the payoff: to endow human life with new inventions and riches. This was early technology transfer; I'll be interested to see if our panel makes it any more clear.