Thirteenth Fermilab Industrial Affiliates Meeting and Industry Briefing

September 9 & 10, 1993

Roundtable on

Beyond the Cold War: The Changing Arena of Science

Sponsored by Fermilab and the Fermilab Industrial Affiliates

Editors
Judy Jackson, Joseph Lach and John Venard

Fermi National Accelerator Laboratory
Batavia, Illinois

Operated by Universities Research Association, Inc.
Under contract with the United States Department of Energy

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Welcome

Kenneth Stanfield
Deputy Director, Fermi National Accelerator Laboratory

We are living in rapidly changing times. The end of the Cold War marks the beginning of a new era in which we are going to have different lives from the ones we've been living. This is true for every sector of American society—for industry, for government, and certainly for science and our national laboratories. Even in changing times, some things don't change. We still believe, as we always have, in the importance of exploration and discovery, in the inherent worth of understanding our universe, and in the value of long-term investment in knowledge.

Nevertheless, we know that science, even so-called basic research, always takes place in the context of the greater society, the broader society. A combination of factors over the past 50 years may sometimes have led those of us who do basic research to overlook or even to take for granted our connection to the rest of the world. First, national security needs during the Cold War, and our country's consequent willingness to pay for basic research, especially in physics, led to a scale and stability of funding for research facilities that insulated some individual scientists from thinking about our connection to the greater society. A further separation between science and society comes from the widening gulf between the layman's common-sense understanding of the world and the scientific view, with its own distinct language and culture. Even the geographic isolation imposed by huge scientific facilities, fenced off in remote places, has contributed to the disconnection between science and society. These and other factors have tended to encourage an illusion among some scientists—among them some high-energy physicists—that pure scientific research occupied a special, perhaps privileged place in our national life, somehow separated from the rest. Since the time of Vannevar Bush and the "Endless Frontier," we have been able to go on believing that everyone, especially the taxpayers, shared our view of pure science as a high calling that deserved generous funding. Some have compared it to a sort of secular priesthood.

Quite frankly, right now there are those who believe that science is the problem with the world. Vaçlav Havel, the President of the Czech Republic, has referred to this phenomenon as the crisis of objectivism. He essentially blames science for the ills of our current society. Congressman George Brown has used Havel's comments as a starting point to talk about reconsideration of the role of science in American society in general. Suddenly, the end of the Cold War and the consequent shift in national priorities have given scientists a healthy dose of reality. Every day brings reminders that we are, and in fact always have been, firmly connected with the society in which we live.

It is a good time to take a fresh look at the connections between science and society. We are happy to have this opportunity to explore with you what the nature of these new relationships will be. The Department of Energy's national laboratories represent one of the greatest investments ever made in science and technology. In the past, we've seen how basic science at those labs has provided the foundation for our national security, and we fervently believe that science has also contributed immensely to our national prosperity. We value opportunities like the one we have today to look at new ways in which the national laboratories can serve as a resource for a productive and competitive economy. We believe that the laboratories have worthwhile, even unique, contributions to make. In fact, long before tech transfer became a buzz word, Fermilab recognized the importance of creating strong ties with the industrial community. In 1980, Fermilab's second director, Leon Lederman, founded the Industrial Affiliates to build and strengthen the connection between basic research at Fermilab and the productivity of U.S. industry. We hope to make these links even stronger in the years to come.

Since you'll hear from Leon Lederman later in the day, I will not attempt to tell you a joke, because that's something only he can do in these environs, but I do want to take the opportunity to tell you a story. We are always glad to have visitors at Fermilab. We are proud of the fact that we have an open site where anyone can visit one of America's liveliest research laboratories. I think with the close of the Cold War we can count on remaining an open site. Among our 50,000 guests last year was a 13-year-old boy from Oregon. He was extremely interested and excited about his tour of the Lab, and when we took him up to the 15th floor of Wilson Hall, he looked wonderingly out across the vast expanse of the prairie and the large accelerator ring, the cooling ponds, the Booster, the Antiproton source. Clearly, he was impressed. He said, "Gee, this is a big place." He paused. "But I don't exactly understand what crushing atoms does for the country." Welcome to Fermilab and this meeting of the Fermilab Industrial Affiliates. We should all use this process to take another look at just what crushing atoms really does do for the country and what basic science in general really does do for the country. ❖

Introduction

Joseph Lach
Physicist, Fermi National Accelerator Laboratory

Our topic today is "Beyond the Cold War: The Changing Arena of Science." Although we have seen changes for many years, the end of the Cold War has crystallized these changes and their effects on industry, academia, and government. The science research patterns that have been emerging over the last decade have been brought into sharper focus by the ending of the Cold War. What are these changes and where are they leading? What are the forces behind them? This is a forum where we can start to discuss them. What is the relevance of science research after the Cold War? Where should this research be done?

I think there is a general agreement that science research, like motherhood, is a good thing, but there is less agreement about who should pay for it. Where should the distinction be drawn between basic and applied research? We need to address changing public perceptions of science. We recognize that there has been a change in how the general public views science. What is this shift? How is it affecting us? Our distinguished speakers will address these and other topics. ❖

Participants

John Peoples is director of Fermilab. Before becoming director in 1990, he served as deputy laboratory director. Prior to that, he was head of the Magnet Division at the SSC Central Design Group at LBL. Dr. Peoples originally joined Fermilab in 1972 and, in addition to his experimental research work, has served as head of the Proton Laboratory, head of the Research Division, project manager for the Antiproton Source and deputy head of the Accelerator Division. He received his Ph.D. in physics from Columbia University.

Ken Stanfield is deputy director of Fermilab. Since arriving at Fermilab in 1977, he has had a broad range of assignments including associate department head of the Proton Department; head of the Experimental Areas Department, head of Business Services and head of the Research Division. Dr. Stanfield holds a Ph.D. in experimental elementary particle physics from Harvard University.

Joseph Lach is an experimental physicist in Fermilab's Research Division. He joined the Laboratory in 1969 and since then has served as associate head of the Neutrino Laboratory and later as head of the Physics Section. Dr. Lach has participated in collaborative experimental programs with institutions in Russia, Brazil and Europe. He has had a continuing interest in issues involving science and public policy. His Ph.D. in physics is from the University of California at Berkeley.

Roald Sagdeev is the former director of the Institute for Space Research of the then Soviet Union's Academy of Sciences. From 1985 to 1988 he also served as an advisor to Mikhail Gorbachev on space and arms control issues. Dr. Sagdeev is currently the director of the East-West Space Science Center and a professor of physics at the University of Maryland. He is a member of the Planetary Board of Advisors.

Richard Slansky is the leader of the Theory Division, Los Alamos National Laboratory and adjunct professor of physics at the University of California at Irvine. Before joining Los Alamos in 1974, he taught physics at Yale University and prior to that was a postdoctoral fellow at CalTech. His Ph.D. in physics was earned at the University of California at Berkeley.

Leon Lederman is director emeritus of Fermilab. He won the Nobel Prize in physics in 1988 and the prestigious Enrico Fermi Award for 1992. Dr. Lederman was Fermilab's second director and on his watch the Tevatron, the first superconducting synchrotron, was constructed. He is founding trustee of the Illinois Math and Science Academy, co-chairman of the Board of Trustees for the Teachers' Academy of Mathematics and Science in Chicago and serves as the Governor's Science Advisor. He holds a Ph.D. in physics from Columbia University.

Lewis Franklin is currently a visiting scholar at the Stanford Center for International Security and Arms Control. Prior to his early retirement in 1992, he was vice president, Special Studies for TRW's Space and Defense Sector and an expert in international military technology and military threats to U.S. security. For the past four years, Mr. Franklin has been involved in assisting ex-soviet military factories in defense conversion and restructuring. Mr. Franklin holds a B.S. in electrical engineering from the University of California at Berkeley and he completed the Stanford University Executive Program. He has served on numerous U.S. advisory committees. ❖

Roundtable Presentations

Changes in Science: East & West

Roald Sagdeev
Professor of Physics, University of Maryland

There is an old Russian theory, dating from the early 19th century, that Russia is predestined to serve as a guinea pig of history. A famous Russian poet and philosopher, Chaadayev, suggested with a sad irony that among global experiments first tried in Russia was serfdom, which persisted until the second half of the 19th century. Soviet power, of course, was another great historic experiment. Perhaps the future of Russian science is now also an experiment. The amplitude of change, and of its impact on science and scientific society, industry, and technology, are much greater in Russia today than they are in the United States in the new world order.

Soviet Science in the Cold War

With the Soviet Union dismantled, there is still much debate about who should get the credit for its demise. There are quite exotic candidates for the principal contributors. The latest contenders are the Star Warriors. Recent articles refer to theories that a fake 1984 test of the intercept in space provoked the Soviets to spend so much money that they collapsed prematurely. If this is true, I think we need a different interpretation for "SDI"—Strategic Disinformation Initiative. Having had a part in the Soviet planning for space defenses, I think it would be rather funny to accept such an explanation.

In general, however, it is true that the budgets, support, and, eventually, the power of the former Soviet scientific and technological community derived from this tremendous political and economic confrontation of the Cold War. It started in the early 1930s, when Stalin implemented his great plan of industrialization. After World War II, it was enhanced tremendously by the Cold War. How did science gain from the Cold War confrontation? First, there was direct involvement, on a huge scale, of the scientific and technological community, in weapons design. At least half of the total R&D money in the Soviet Union during the last several decades was spent for direct involvement in military and weapons research and development. Second, much of the basic hard science in the Soviet Union was involved indirectly in military and defense programs, with researchers serving as subcontractors to military industries and the Ministry of Defense. And third, even the areas of science clearly irrelevant for any kind of foreseeable military use were supported on the basis of their political visibility, for their usefulness as a political instrument in the hands of the Soviet government—the first peaceful nuclear reactor, the first nuclear power electric station in the world, the first Sputnik, and so on. These three components dominated the life of the scientific and technological community in the Soviet Union.

The Morning After

Now we are paying the bills we accumulated. Suddenly, all three components have become irrelevant. The military budget is shrinking. The military-industrial complex has lost its client, the totalitarian state, and is barely surviving. The very first cuts were the almost 100 percent elimination of supporting military contracts for basic science. There is no more interest in supporting science just for political visibility. The Russian taxpayers argue in a very simple way: In the past we had to build impressive accelerators and launch spectacular space missions in order to prove the superiority of the Socialist system. Probably it's time to stop proving it anymore.

The scale of change is overwhelming. How is society reacting? How is the scientific community in the former Soviet Union trying to survive? We have all heard a lot of horror stories. Among the most popular is "The Brain Drain." Although it might be the easiest resolution of the whole problem, in reality you cannot organize a brain drain on a massive scale. The Soviet system inflated the size of the scientific and technological community. Until a few years ago, we used to say that every third scientist and every second engineer in the world worked in the Soviet Union. It had no parallel, except perhaps in the legal profession, with every second lawyer in the world working in the United States. Statistical data about the scale of the brain drain have been hard to come by, but recently the Russian government itself decided to find out the truth about how many scientists had left the country. Every scientific and technical institution was asked to provide figures. The total turned out to be rather modest. I know what happened at my own institute, where I served as director for more than 15 years. We had 3500 employees on the payroll; 30 left Russia. That is the scale of the brain drain. Altogether, my estimate would be that the overall brain drain is less than a few thousand. Most of the people in that number have temporary contracts that they are trying to renew. In a climate of recession, that is not easy. So I think there is a natural self-regulation mechanism at work.

But suppose the brain drain were on a much larger scale. It might be a very positive phenomenon. A large-scale brain drain took place before World War II from Germany, and there was a massive brain drain to the U.S. from all over Europe during the years immediately after World War II. Later, many of the scientists who came originally from Europe eventually went back when Germany, France, and, to a smaller extent, the UK, started to build their own modern institutions. I'm sure you're familiar with a number of American scientists who took positions in European scientific institutions as directors, or researchers, tenured professors and so on. If Russia were to share its brains with the outside world, some of these brains would come back when Russia could again take care of its own brains from its own budget. It's a very natural process.

However, we are living in a period when size of the scientific community is going to shrink everywhere in the world, because we have changed the paradigm. There is no more support directly from the military arms race, or indirectly from the political confrontation. That paradigm for science has been replaced with another, which I would call "the loneliness of the long-distance runner." The moment taxpayers and their delegates in public office sense this change, there is much less incentive to support sophisticated, expensive scientific projects. I think my colleagues working for the Super Collider now are experiencing something like the same paradigm shift that happened in Russia, "the guinea pig."

What's Left?

High-energy physics in Russia is essentially wiped out. What we have left is the network of institutes. They are completely dependent, financially and in every way, on their chance to participate as junior partners in international projects such as the Super Collider. I think the defeat of the Super Collider could create a strong shock wave in Russia, because the Russian SSC collaborators were going to be very important contributors to Russian science, even financially. They were going to earn a bit of money.

We see the same picture across the whole spectrum of disciplines. The Russian aerospace community lost approximately two-thirds of their budget. You can follow the decline of the Russian space program by counting the number of launches. At the peak a few years ago, Russia was launching more than 150 spacecraft and space probes annually, many more than the United States. Russia was launching cheaper, simpler, short-lived spacecraft to compensate for the more sophisticated and almost immortal American spacecraft like Voyager. Now the number of launches has dropped to about one-third of the previous total. The biggest loss may have been sustained by the Russian computer and electronics industry. On top of the breakdown in the budget, at the end of the Cold War Russia was immediately flooded with foreign-made computers, mostly PC's. Russian-owned home-made computers, backward compared to those produced in the rest of the world, were immediately wiped out. There was no more need for research in microelectronics, and huge crowds of experts in software, for example, now hope only to get contracts from United States companies or even the U.S. government.

What do the Russians hope for? There were very promising beginnings. The first and boldest initiative, to recruit Russian brains working in their own institutions, came from SDI and the U.S. Department of Defense. Connoisseurs of political history could probably have predicted such an ironic outcome after Reagan's 1983 Star Wars speech suggesting that he would share SDI technology with Russians. Now, DOD has procured several copies of a Russian spaceborne nuclear reactor specifically built for space launches. Some U.S. companies, as well as the federal government, have procured a number of so-called plasma thrusters—rocket engines that work like small, low-energy accelerators, accelerating ions, which pick up electrons, yielding a neutral plasma flow, as a potentially innovative future rocket engine. Russian technology is finding some modest yet stable ecological niche in the market. Many of the software groups in the former Soviet Union were contracted by Silicon Valley companies, such as Sun Microsystems. I understand that Motorola has opened a research branch in Russia. But, with some time delay, American science is facing the same kinds of problems as its Russian counterpart, because of the same paradigm shift. The Russian government is trying to take measures to help. They are probably far from enough to protect the scientific and technological brains of the former Soviet Union, but they are at least making an effort to control the loss of the world-class assets of the scientific establishment.

The Way We Were

Let me explain the structure of the former Soviet scientific establishment, a structure still largely intact. It was subject to very strict control by the party and the military industrial complex in the former Soviet

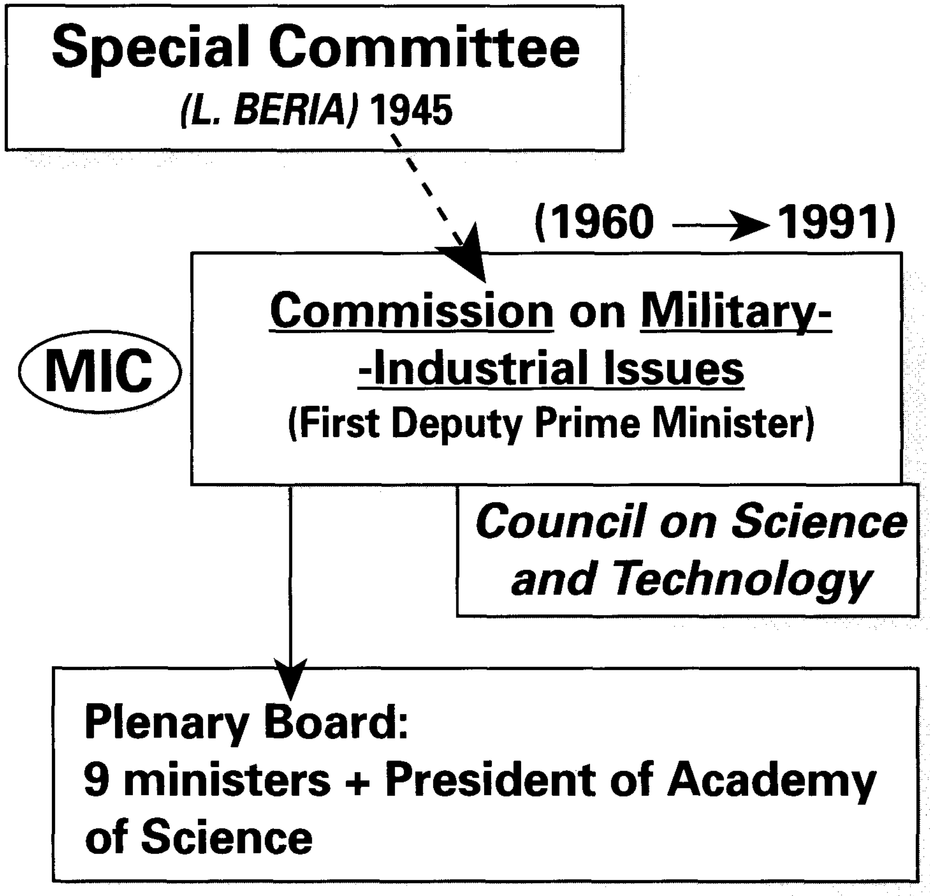
Union. Now there is some relaxation of control (and much less budget) but still the same type of structure. While it is well known that Sputnik gave a tremendous boost to the scientific and technological revolution in the United States, it is perhaps less well known that the Soviets had their own boost for the scientific and technical establishment much earlier. It came in 1943, when Soviet intelligence delivered important information about the Manhattan Project. Stalin created a very high-level committee to supervise all strategic R&D projects. It had the name "Special Committee," and Beria, who at that time was the head of the KGB, was asked to supervise science and technology as well.

This Special Committee had a board of advisors, and I am sure you are familiar with a number of the names. The first and most important figures in this advisory board were Igor Kurchatov, essentially the founder of the Soviet counterpart to the Manhattan Project, and Peter Kapitsa, who won the Nobel Prize for his discovery of superfluidity of liquid helium. But Kapitsa had specific political disagreements with Beria and was eliminated from this committee in 1946. He was kept under house arrest for seven years until Stalin died. He was not sent to gulag because of his tremendous international reputation and, as we are now discovering from the formerly secret archives, because of his peculiar one-way correspondence with Stalin. Kapitsa kept writing letters to Stalin; Stalin apparently never wrote a single sentence in response. When Kapitsa stopped writing, he immediately got a phone call from Stalin's aide: "Why don't you write anymore? The boss enjoys your letters." Encouraged, Kapitsa explained his gross conceptual ideas in his very next letter. It was an idea on what we would now call SDI technology, dated about 1950. The regime was not ready yet to appreciate such exotic technologies.

After Beria's arrest and execution a few months after Stalin's death, there was substantial reorganization of the system. From the time of Krushchev until the August putsch in 1991, the huge scientific establishment probably consumed 18 to 20 percent of the Soviet national budget. The scientific community was controlled by another governmental body, the Commission on Military Industrial Issues. It was classified as a top secret commission, so we never used the full name when we talked with each other; we used the acronym MIC, for Military Industrial Complex, which we denied that we would ever have. This commission was chaired by charter by the first deputy to the prime minister. There was always a member of the Politburo designated to watch over it.

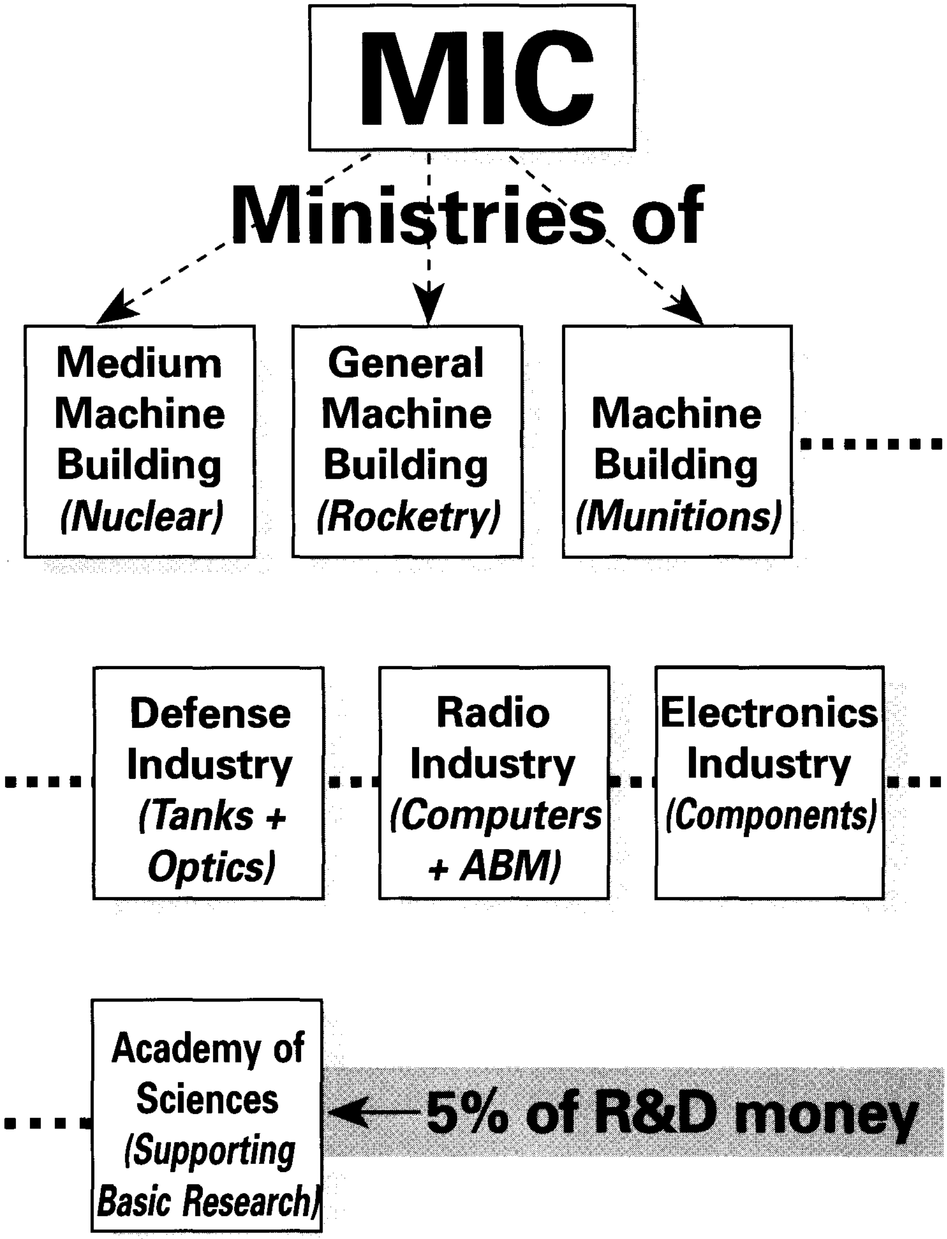
The commission also included leading scientists as members of the Science and Technology Council, just as Beria had at the beginning, including such figures as Kurchatov and Sergei Korolev, a designer of Soviet ICBMs and Sputnik. As a matter of fact, I also was a member of this council for a number of years, but I don't think I ever attended any of the meetings. If I had, I am afraid a few more marks would have appeared on my clearance records, complicating foreign travels and so on. But the actual power on the commission did not lie with the scientists; they were only advisors. There was a plenary board, which by charter included ministers from the military industrial complex. The president of the academy was also a member of the board, ex officio, providing all the basic research support for the military industrial complex. They made all the decisions about what projects to accept and how to allocate the money. They even followed up the detailed fulfillment on an everyday basis, with rather strict discipline and sophisticated forms of punishment for unmet deadlines—not punishments like the ones Beria administered, but still quite sensitive.

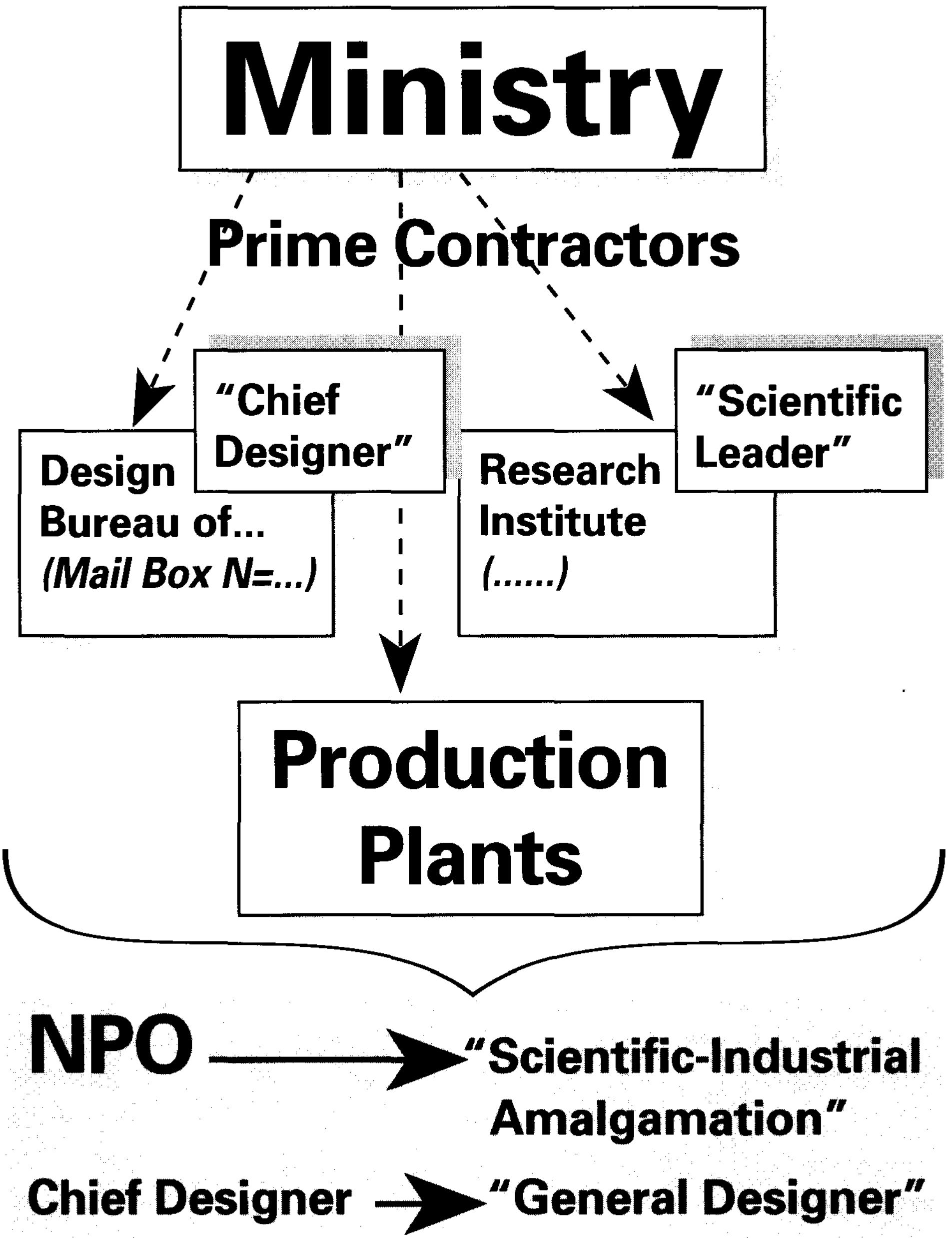
What we have now is no longer called the Military Industrial Commission. Yeltsin has instituted a new board, called the Committee on Defense Industries. It has many familiar faces, but of course their influence and budget is much smaller. The primary task of this board now is not so much to contract and procure new weapons systems, but to keep organizations alive and try to avoid the social upheaval that could result if millions of employees were be suddenly thrown out on the street.

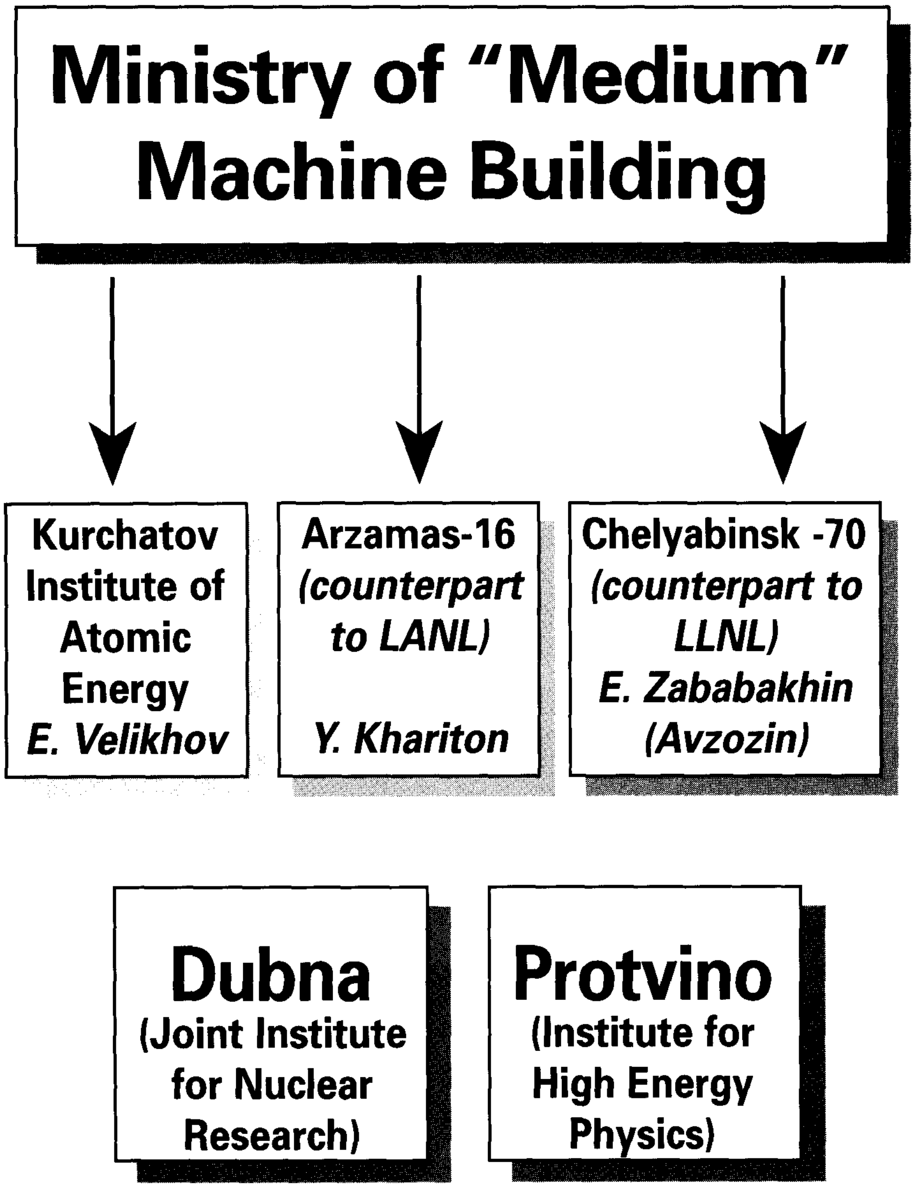


— top decision-making on technical scenarios, budgets
— orders to contractors
— schedules, deadlines

The organization charts on pages 19-22 depict the structure of the former Soviet scientific establishment, a structure still largely intact. In the former Soviet Union, this information was the subject of very strict control by the party and the military industrial complex.


MIC
Ministries of
Medium Machine Building (Nuclear)
General Machine Building (Rocketry)
Machine Building (Munitions)
Defense Industry (Tanks + Optics)
Radio Industry (Computers + ABM)
Electronics Industry (Components)
Academy of Sciences (Supporting Basic Research)
5% of R&D money


Ministry
Prime Contractors
"Chief Designer"
Design Bureau of...
(Mail Box N=...)
Research Institute
(......)
"Scientific Leader"
Production Plants
NPO
"Scientific-Industrial Amalgamation"
Chief Designer
"General Designer"


Ministry of "Medium" Machine Building
Kurchatov Institute of Atomic Energy
E. Velikhov
Arzamas-16
(counterpart to LANL)
Y. Khariton
Chelyabinsk -70
(counterpart to LLNL)
E. Zababakhin
(Avzozin)
Dubna
(Joint Institute for Nuclear Research)
Protvino
(Institute for High Energy Physics)

The Birth of Sputnik and the ABM

Here at Fermilab, you were of course familiar with one of the ministries from the complex, the one with the funny name of "Ministry of Medium Machine Building." Now it has another name, the Ministry of Atomic Energy. For a delivery vehicle, the government created a new branch, the "Ministry of General Machine Building." Serge Korolev was given a contract with the technical requirements to build an ICBM big enough to deliver heavy warheads. In the end, as a byproduct, he created Sputnik; and later helped Soviet leaders move to multiple warhead systems and the whole generation of heavy ICBM's.

What about the other ministries? There was a ministry with a very simple modest name, Ministry of Machine Building. This ministry was the prime contractor for the government in munitions, powder, rocket fuels, and other things. In size, it was the largest by far. Of the other ministries, I will describe only a few. The Defense Ministry—no mystery in the name here—did not work in exotic technologies. They produced tanks. The government knew it would be very difficult to hide the fact that the Soviet Union produced more tanks than the rest of the world. Since standard tanks would have optical equipment for directing fire, this ministry was chosen as the best place to host sophisticated optical technology. Most of the biggest telescopes and other sophisticated optical equipment were produced by this ministry.

The Ministry of Radio Industry may be familiar to some of you. Anything related to high-power radio equipment would be designed and built by this industry. All the generators for the accelerator community were done by the Radio Ministry, specifically by the Radio Institute in Moscow, which supplied all of the existing big accelerators—Dubna, Serpukhov, and so on. This ministry was the prime contractor for most of the computers in the country, both mainframes, and, in the last decade, personal computers.

What is less known is that the Radio Ministry was the principal ministry responsible for antiballistic missile systems. From the very beginning it was understood that terminal navigation was the most complicated problem in ABMs. It would require sophisticated precision measurements using radar and phase array systems, so this ministry eventually became the prime contractor. I think the system it built is now the only existing operational antiballistic missile system in the world. It protects the area around Moscow.

Recently, there was a discussion on joining U.S. and Russian efforts in antiballistic missile defense. But I still don't understand the reason for investing in it. The United States has nobody to defend itself from. (Maybe in the long run, third-world regimes will be dangerous, but large-scale ABM systems will not protect us.) And Russia, in its deep economic crisis, has nothing left to defend. The Russians tried to keep within the existing ABM treaty, providing a fixed-point defense around Moscow. But there was always the doubt inside Russian scientific and technological circles whether it really did give some protection, or merely created additional danger, because the Russians chose nuclear warheads as a kill mechanism. Imagine megaton-sized warheads triggered to explode by an ABM system over Moscow for its protection. It is still the only existing operational system.

Technology Transfer the Old-Fashioned Way

The Electronics Ministry was responsible for components. The story of the origin of this ministry is quite remarkable. In the late 1950s, two young American engineers defected to the Soviet Union. It was at the time when the very first transistors were being developed. They took from the United States a small attaché case of early, simplistic transistors—they were considered a miracle at that time. Eventually, they were brought to Krushchev, and he signed the decree establishing the Ministry of Electronics. The traces of these two fellows faded very quickly, because Russia's own experts established a lot of institutes and took over.

In addition to these nine or 10 ministries, the Academy of Science was always an important part of the establishment. The Russian counterparts to Fermilab, such as the Joint Institute for Nuclear Research (Dubna), the Institute for High Energy Physics at Serpukhov or the Institute of Experimental and Theoretical Physics in Moscow, never were a part of the Academy. Instead, they were a part of the Ministry of Medium Machine Building. I think the government decided that sophisticated and expensive equipment should be controlled and supervised by an industrial ministry, not by the Academy of Science.

What has happened now, with the destruction of these ministries? Some of them have simply changed names. Medium Machine Building is now Ministry of Atomic Energy. Another is called the Russian Space Agency, and will probably be involved as an important partner if Congress supports the Space Station, almost an equal partner with NASA. In talking to legislators, I have a feeling that they approach the issue of the Super Collider and the Space Station in a very peculiar way. They believe that somehow they have been given a hunting license for one of two animals, resulting in a zero-sum game. Everything will be decided on the basis of political arguments, lobbying, and so on. I think the U.S. aerospace industries and NASA have a much stronger infrastructure of grass root organizations and lobbyists than high-energy physics can claim. In the eyes of taxpayers the space program is not as attractive as it was in the past, but it is still sexier than high-energy physics.

Los Alamos East

Let me say a few words about the area of nuclear physics and high-energy physics. It is still controlled by the Ministry of Medium Machine Building, under a different name. You are familiar with a number of institutes, the prime contractors for different components of the program. There is Kurchatov Institute of Atomic Energy, established as the first nuclear center. Originally it was established like Fermi's group at the University of Chicago. This is the place where the first critical reactor, the Kurchatov reactor, was built in 1947, four years after Fermi built his reactor in Chicago. When Arzamas 16 was established as counterpart to Los Alamos National Lab, Kurchatov Institute was still a huge place. At its peak it had more than 10,000 employees. It supervised everything in nuclear physics and nuclear technology. For example, the space-borne nuclear reactor Topas 2, which was procured by the U.S. Department of Defense, was designed and manufactured by Kurchatov Institute. The current situation in the Institute is extremely difficult. One of the most advanced components of the program at Kurchatov Institute is controlled fusion. The very word Tokamak, a key word in controlled fusion, was born at Kurchatov Institute. They started to build Tokamaks very early, and they still have a few of them operational, including one using superconducting magnets. In superconducting know-how, they are probably the counterpart to Fermilab in Russia. But they are unable to operate this machine, which could still produce interesting results, for the simple reason that the cost of electric power has risen so tremendously that they do not have the budget to run the machine. It's a Catch-22. So Kurchatov Institute survives by letting anyone who can get the permission of the government leave Russia to work on contracts outside Russia. There was even the case when a few of their employees were stopped at Sheremetyevo Airport. They apparently had tickets to Libya. Second, they're trying to sell their services to American customers, as in the case of the nuclear reactor Topas 2. The fusion team of Kurchatov also has a few contracts, including one with DOE to support Tokamak research.

Arzamas 16 was the first national nuclear weapons center, established in 1946. There was a very bold plan to rescue the former Soviet nuclear weapons community. The idea was to establish a fund in hard currency to give grants for nuclear weapons experts to do nonmilitary, nonweapons work—to give them enough money to create an incentive to stay where they are, not to go to third world regimes, where of course they would be most welcome. This fund was finally established: the International Scientific Technical Center in Moscow. It is a rather substantial fund, about 75 million dollars, but not a single dollar has yet been spent, because the Russian Parliament, which opposes Yeltsin, has not ratified the treaty on establishing this fund. It is a most dangerous and dramatic situation. Everyone knows the money is in Moscow, virtually in the hands of Parliament. The staff of the foundation is working. By the way, this foundation has an acronym, which the Russians invented immediately. They call it the KGB fund. KGB, in this case, stands for Kozyrev-Gentscher-Baker fund. As a result of the hold-up of funding, in the last few months several leading nuclear experts have threatened to start a strike. What would a strike mean? There is a big program underway to dismantle tactical nuclear warheads. The physicists and engineers threatened to stop dismantling, so now the hope for further nuclear disarmament may be associated with the strike breakers. It's very dangerous.

A similar situation exists in Chelyabinsk 70, in the heart of the Urals. I remember when the Soviet government decided to establish such a center. "For some reason," they said, "the Americans have opened a second nuclear weapons lab at Livermore. Clearly, they have something behind it. Let's do the same." So they built Chelyabinsk.

Meeting the Socialist Commitment

All of basic science was in hands of bureaucrats. I wish we had Universities Research Association in our country. Dubna, despite being a semi-closed facility, was made an international center for East Bloc countries. Each government contributed toward building a new accelerator. Each time, it was "the biggest in the world." When the Synchrophasatron was built in Dubna at 9 GeV in the late fifties, it was bigger than the previous American machine, and it was expected to come up with a lot of interesting discoveries. The principle of the machine was the Soviet invention of autophasing, familiar to many of you, which provided stability of the bunches in the accelerator ring. What went wrong? The nominal energy was 9 GeV, but the current was two orders of magnitude smaller than projected, so the final luminosity was very low. It took a long time to do experiments. Detector technology was backward at that time. Thus, the results were really quite modest from this accelerator, which had a nominal advantage for a number of years as the highest-energy machine in the world.

Pressure from the government was tremendous: "You guys have to discover something." The life of the scientific community was controlled by government discipline. For every planned period, we had to come with certain promises, which they called "socialist commitments." The typical commitment for Dubna, for example, would be to discover a new elementary particle before the next celebration of the Great October Revolution. As you know the only new particle discovered as a net result in Dubna was the antisigma-minus hyperon. During the Chinese cultural revolution it was especially painful for Russians when the principal investigator went back to China. Political pressure did not play a very good role. Political considerations drove the budget, and everything put pressure—sometimes excessive pressure—to control everyday life. In Novosibirsk, some of my colleagues came up with a simple response to government pressure: "Okay. We're ready to undertake our socialist commitments. We promise during the next year to make one discovery of worldwide importance, two discoveries of all-Union importance, and three discoveries of regional Siberian importance." That was enough.

"You Have Seen the Light of Antimatter"

Protvino, successor to Dubna, also kept the nominal energy lead, and it had a rather successful implementation. It had sufficient luminosity. Overall, I think it simply had bad luck in that range of proton energies, about 70 GeV. It was simply that nothing dramatic happened, so they were unable to find new elementary particles. The next big success with accelerators came with the colliding beam idea. Budker was the first to suggest the colliding-beam principle, and he quickly built a couple of small storage rings in Novosibirsk. I remember it vividly, because I was working in the Plasma and Controlled Fusion Division of the same institute, and I saw a lot of visitors. Even Krushchev visited the institute and, for me, Budker still represents how we should approach the issue of communicating the importance of science. He would invite a big boss to the storage ring, with a few positrons already captured and kept in the storage ring at energies of a few hundred MeV, able to provide a very bright glow of synchrotron radiation. He would say, "Remember, and tell your grandchildren, that you have seen the light of antimatter." It worked.

Getting By

I think the hangover and sobering-up process we have now is especially painful because of the strong dependence of Soviet science on military clients and the highly political approach of the government to science. What's happening now with the Yeltsin government? While the bureaucratic structure is largely intact, the budget is gone. The space industry has only about one-third of its old budget. The Academy of Science survives on about one-fifth of its former budget. How does it get by? Most of the institutes were given the buildings and the property they stand on by the government. If they rent part of the property to newly established private industries, they get paid in hard currency. That gives them a chance to keep on almost the same list of employees they had before, although on very small salary and with no chance to build new instruments or experimental devices. They have very little chance to pay electric bills or to subscribe to scientific literature. All the foreign hard-currency journals subscriptions were wiped out until the American Physical Society and a few other organizations started to send journals as a charity.

Among these discussions about creating an international fund to support Russian science, there was an idea to support basic science, generated by Congressman George Brown. A couple of years ago he spoke at a AAAS meeting. Since then, I have watched the evolution of his idea. He fought very hard. The original idea was to spend $200 million, $100 million for basic science, $100 million for applied science. A year ago he told me that he hopes the modest fund of $25 million will be established. George Soros, the prominent financier, has established his own foundation to provide small grants to Russian scientists; the fund has delivered $100 million. It is a noble, generous move; but now the European community, which originally planned to establish a fund, has decided they are off the hook, since George Soros is giving money. But this money is far from enough to rescue the scientific community. Support comes in the form of emergency grants of $500 to individual scientists. Many American physicists are involved in reviewing the proposals; emergency funds are given based on very simple criteria—a few publications in internationally recognized scientific journals during the last few years. That much money probably could support a very modest minimum cost of living for about a year. Now the Foundation is taking the next step. It will start providing bigger grants; and a new requirement has been put forth that I think is a good one. The idea is to single out those groups or labs working in association, in cooperation with international projects. They would receive Soros matching funds. If you have any kind of cooperation with Russians, here is a good chance to support your Russian partners' applications for this type of matching funds.

Let me finish with a very brief story. I spent a few hours yesterday considering a particular project where Russians might get a little bit of money from the Soros Foundation, and maybe from other funds, in conjunction with a dramatic event next summer. You know that in late July of 1994 we could witness an unusual phenomenon. The debris of the Swift-Tuttle Comet, a very old, well-known comet with a known trajectory, will plunge into the atmosphere of Jupiter at a velocity of about 70 kilometers per second. Nobody knows for sure the mass, but one could expect it to be only a few times smaller than the mass of Halley's Comet. If so, the encounter with the atmosphere of Jupiter would release energy equivalent to 20,000 megatons. Even Dr. Teller probably never dreamed of such a fireball. Clearly it could be seen from a distance. Unfortunately, it is happening on the invisible hemisphere of Jupiter. Several institutions, including NSF, have issued calls to suggest what might be done. Yesterday, we were trying to figure out whether we can make estimates for the electromagnetic pulse, to see its impact on Jupiter's plasma, on the magnetospheric environment that is always being monitored by radio astronomers.

Of course, I look at what is happening now in Russia from a great distance. Probably I now know more about the intrinsic problems of the American scientific community. Nevertheless, I hope this small experience of what is happening in Russia will be helpful. I hope that eventually Russia will find its own place in the free world and can stop simply playing the role of guinea pig of history. ❖

Changes in Science: An Example

Richard Slansky
Leader of the Theoretical Division, Los Alamos National Laboratory

We have lived through remarkable times. The period between the Second World War and the end of the Cold War has been one of the most creative periods of science and technology in the history of mankind. Propelled by the kind of enthusiasm expressed in Vannevar Bush's metaphor of the endless frontier, and building on earlier achievements, scientific and technological advances have created a novel world for us. The 50-year exploration of the endless frontier drew some of its strength from the premise that science in all its diversity contributed to the national security, a premise made more tenable by the collective social optimism about science engendered by successful construction of the first nuclear weapons during World War II. But, while national defense provided some of the motive for funding basic research, the real motivation for science has always been more fundamental: the sense of frontier, the sense of exploration, and the natural human curiosity that has led us to explore the corners of nature, from the vast reaches of the universe to the smallest building blocks of the atomic nucleus.

Particle physics at Fermilab has had an important part in this grand adventure, as the frontier of the structure of matter has moved from atoms to nuclei to nucleons, and still further to the intricacies of the interactions of quarks, leptons, vector bosons, and the not-yet-seen Higgs particle. As we look back to the Second World War, quarks and leptons seem far removed from that crisis of national defense. Nevertheless, many of those who worked in Los Alamos in the 1940s have served as leaders in these explorations: for example, Bob Wilson, who built Fermilab.

In the research territory between the extremes of the great universe and the tiny quark, there is also cause for excitement. Here occur discoveries that often find their way to the marketplace on a rather short time line. Frontiers in biology, in chemistry and in many fields of physics have been pushed back significantly. In engineering and in industrial research, product improvements and increasing competitiveness have, in many respects, revolutionized the way we do business, from computing and the control of the flow of massive amounts of information to process control in manufacturing. Progress in biology continues at an unprecedented rate, and the systemization in biology promises even larger contributions to the health of mankind. Biotechnology, materials science and atomic physics all line the highway that leads from the frontier to the marketplace.

Until budget problems caught up with our country's economy, the nation seemed content to define the national defense interest broadly enough to include support for basic, frontier science. Now, however, we are in the midst of a transition that is far from over. The end of the Cold War and the ensuing political and economic instability are all major factors in this transition of scientific research. Forces acting in many directions make it difficult to predict the role of science in the world that will emerge. What is the reason for the problems now facing science and scientists? The root cause, in my opinion, is the decline of public trust in science and scientists.

Clearly, the Cold War is over. As a nation, we are rapidly forgetting any benefits that may have accrued to national security from winning the arms race. We have a new set of problems, and science is the scapegoat for the problems the arms race left behind. Science, after all, gave the world a gigantic nuclear arsenal. Why shouldn't science get the blame for the resulting environmental insult? Scientists and their products are not to be trusted.

Indeed, it would be easy to conclude that the nuclear age has left us with more problems than solutions. Some national laboratories are entirely devoted to dealing with the legacy of the arms race, and, even with no other activities, some of these laboratories have grown appreciably. With something like 50,000 nuclear warheads in the world's stockpiles, we find the threat that a terrorist will seize one of them more fearful than the familiar stand-off of the two superpowers. Terror of terrorism has replaced the stability of the Cold War. Of course, some of this reflects the collective national anxiety that goes with change. Instead of the gigantic problems of the interactions of two superpowers, many see the insoluble problems of a fragmented new world.

The "evil scientist" has become more insidious than ever. We live in a culture of distrust. Science is accused of wasting the taxpayer's money and polluting the environment. Moreover, the snail's pace of most scientific progress is troublesome for people accustomed to wars that last only a few days. There are many rational defenses against this kind of negative image, but we cannot deny its existence. Even when people support science, they often have little sense of urgency for understanding new frontiers. The frontier can wait. And without the support of our society, scientists may begin to lose the commitment required for truly great advances in science.

I spent several years of my life pushing for the SSC, and I am a strong advocate for this project, so when people ask me "What will the Supercollider do?" I try to answer. What should I say? "Discover the Higgs?" Many would reply, "So what? We already know enough about mass or weight or whatever." Should I say the SSC will look for new phenomena beyond the standard model? What will this do for the man in the street, or for defense against terrorism, or to curb crime in the streets? Bob Wilson's reply, "It makes the country worth defending!" seems to be a nonstarter today. I might be able to explain why we need the SSC in a 30-minute discussion, but most people want a 30-second explanation. Nevertheless, I will keep trying, since I believe the diversity of the science we do is a strength in this country. It is important to understand what we are made of and how the building blocks of nature interact.

We must recognize that the role of science in our society has changed. We had better wake up if our commitments are to survive. It is time to pay attention to the society that supports us, and to re-prove our worth. Unless we do, we may come to be viewed as just another lobby, trying to extract as many dollars as possible from the government. For I believe we can say some positive things about the changes of science. The new definition of national security, for example has moved far beyond nuclear weapons, armaments, and military surveillance and communication. It includes counter-proliferation, counter-terrorism, economic competitiveness, and other important directions needed for survival in the post-Cold War world. More broadly for American science, the need to renew our social contract will require redirection, so that Americans will understand just how special our scientific heritage is in this country. Not everyone will hear the message, but we must start the pendulum of understanding swinging in the other direction. We must do our best to change the average attitude to one of greater understanding of the role of science in our society.

Science is changing, and science will have to rededicate itself to society if it is to continue to advance. In the new world, there is the opportunity for an even stronger union between the more broadly defined national defense and basic science. The old metaphor of the marriage of frontier science and national defense can have more meaning than ever. Of course, this marriage has problems to solve, both environmental and political. National security is taking on new challenges, including economic competitiveness, that will require an even broader commitment from science. To carry out this social contract, we must make clear the positive difference that science makes to our society. The issues of national security and the laws of man change, but they still require the advice and advances of science. ❖

Industry and Science After the Cold War

Lewis R. Franklin
Visiting Scholar, Stanford Center for International Security and Arms Control

Why are we, and many others in similar meetings, just now beginning serious discussions of "what's next?" Is it the lingering recession? The elusive new world order? The Clinton political agenda? Or is it society's waning interest in sophisticated nuclear weapons? The massive Cold War cleanup job to be faced? Foreign professional and industrial and scientific competition from the former Soviet Union? Dangerous proliferation, and export policy confusion? Each of you could add to this list of reasons.

Industry After the Cold War

As business people, scientists, and engineers, it is in our nature to identify and analyze the problems we encounter, and to take steps to solve them, using our experience, skills and abilities. Then, possibly, it is in our nature to procrastinate while planning experts develop and analyze scenarios. It is both a useful reflection and a sobering process to remind ourselves of the training environment in which we learned our problem-solving skills and acquired the intuitive senses that guide our approaches; and where we learned the acceptable boundary conditions that constrained "practical" solutions. The great training ground where all of us have spent our professional careers was the Cold War. Because of the thorough conditioning we have all received, it may be somewhat harder to chart our collective courses in the absence of this great guiding environment.

Many find this easier to perceive when looking over the now-crumpled Iron Curtain. We intuitively appreciate the difficulty Russian factories have in adopting market economics, and the problems for the weak Russian government in subsidizing these factories to avoid layoffs and social unrest. Their initial response is to urge deferral of changes, continuance of subsidies, restriction of imports, restructuring of ministries, and other stop-gap measures to buy time. They must buy time to find capital to modernize and develop industrial or civilian product lines or services, retrain managers and workers, develop needed business infrastructures, and learn marketing skills. But, just like us, they are victims of Cold War training. Even though they know that they face difficult tasks, and that many endeavors will ultimately fail, they come from a heritage and a culture of growing military needs and growing enterprises. It is thus not surprising that they rarely consider the option of downsizing or closing parts of the system. For some, possibly for many, it will nevertheless come to that, as it belatedly came to General Motors, Pan American and IBM.

There are bright spots in this picture, which I will discuss later in more detail. They include the Russian factory equivalent of automobile "parting out," where entrepreneurial teams start up in corners of factories, renting tools and facilities—the so-called incubation centers.

Not surprisingly, Russians do look westerly, where they observe inefficiencies and patterns that they find hard to understand how we continue to tolerate. They see an addiction to regulatory behavior—specs, contracts, procedures—, the perception of a continuing need for a large nuclear infrastructure, and a continuing expectation of high defense expenditure levels. The American point of view that we have much to teach and little to learn may be somewhat naive. Russia may have now gone through much of the early optimistic phase following the Cold War, and, as they say in Olde England, is about suited up for battle, having reached, or nearly reached, a realistic understanding of the difficulties to be overcome. Where are we now?

Science Before and After the Cold War

Of the international activities that sustained a degree of normalcy across the Iron Curtain during the Cold War decades, two that stand out are cultural activities (music, ballet) and science, especially space, geological and Antarctic science. While these areas were regularly handicapped by infringement into potential military relevance, a surprising number of East-West university and research laboratory collaborations flourished, with exchanges of scientists, data and research equipment. Unlike the case for the business picture, there is something to build on here, and, more important, a world resource to draw on that is only today beginning to be appreciated.

Under the Soviet Academy of Sciences, a team of some 20 million or so scientists and their associated technical specialists addressed an extensive array of scientific pursuits, funded primarily (70 percent) in support of potential military needs. As we all know, there are very few areas of science that cannot be justified as having potential military relevance; witness recent concerns about rogue designer viruses as a potential future weapon of mass destruction in the wake of AIDS research. With the breakup of the Soviet empire and the former Soviet Academy of Sciences into separate national entities, Russia retained the majority of the laboratories and scientists, but to date an estimated 30 percent of the pre-1990 staff has left, mostly to nonscience jobs for economic betterment. But since the Coup, even this remnant, in the view of politicians, is more of a burden than a benefit. The Russian Academy laboratories, numbering over 5000, cannot compete with the clout of the military industries. (Sound familiar?) Further, it is widely reported that much of the top talent has already left, considerably diminishing the remaining laboratories' capabilities.

So far most of the political attention has been paid to the military-industrial infrastructure, because of near-term needs for economic recovery. As I have mentioned, there are numerous plans for assistance, conversion, privatization, subsidies, trade assistance, and so forth. This makes considerable sense, as in the Soviet era the military industries commanded the best and most modern facilities, which incidentally compared favorably with western weapons systems through the mid-1980s. In contrast, in Russia, the newly reorganized laboratories of the—now—Russian Academy of Sciences are faring rather badly, with effective budgets, considering inflation, about 10 percent of those of 1990.

Business and Science

It is not just documentation of the situation in Russian science that I want to present, but the opportunity for U.S. businesses to participate in a historic change in trade relationships that could lead the U.S. out of the current recession and into future decades of prosperity. At this meeting, we have already heard of the numerous transitions of technology from national scientific laboratories to industrial applications, and a few to consumer products and services. I repeat, a few to consumer applications. Let's call this Lesson One.

Lesson Two, from what we have heard, could be converting pre-owned military systems (high-tech war surplus) to civilian or scientific uses. Oceanographic research using SOSUS, the high-sensitivity submarine detection system and low-cost, $1000-per-pound satellite launches, using converted START surplus ICBMs, are examples.

Lesson Three could be joint partnerships to search the ex-Soviet Republics' science laboratories for talent and capability and developed technologies to improve a company's products and market performance. Apple's Newton is a current example; it uses the Russian company Paridigm's handwriting analysis algorithm.

I conclude with some observations that I believe we would ignore at some peril for both companies and national laboratories. First, nearly one third of the world's scientists have been effectively walled off from the scientist marketplace. The laws of supply and demand cannot be forestalled indefinitely, and the above-market prices for U.S. scientists probably cannot be sustained much longer. Recall what has happened to airline pilots' salaries and housing prices. Get familiar with the ex-Soviet science laboratories in your areas of expertise or business. If you don't, expect that your competitors will.

Second, the global economy and global infosystems now require global thinking and international cooperation, not merely coordination, as in the past when protectionist forces would shelter old-style behavior. NASA's bureaucratic reluctance to draw on developed world capabilities, especially Russian boosters and MIR components, may shortly cost them the Space Station and the Shuttle. Personally, I would turn the space program over to the old SDI organization.

Third, become a vocal force, personally active in the international opening and exchanging of the vast wealth of scientific information bought by taxpayers or suffered by comrades during the Cold War. The difficulties of tapping this potential are daunting, with legions of self-appointed Cold Warriors waiting to thwart the normalization of international science and commerce, besides legitimate concerns about weapons proliferation. These actions will elicit cries of "disloyal," "unpatriotic," even "unfair" from protectionist and far-right camps. Nevertheless, our future security will depend increasingly on being economically strong, and on Russia's near-term economic stabilization. It makes sense for our economies to work together, especially when it comes to peaceful applications of nuclear capabilities, as we observe that maintaining an adequate deterrent force for our legitimate security needs is moving farther down the nation's list of priorities every day. ❖

Global Science: The Universe and Batavia

Leon Lederman
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Professor of Science, Illinois Institute of Technology

The Industrial Affiliates program started about 15 years ago when, early in my tenure as director, I thought that people from industry ought to hear about all the clever things we had done at Fermilab. They would then rush back to their companies and manufacture these things and praise Fermilab. The Department of Energy would be so impressed that they would give us a one percent increase in the next year's budget. That was my idea. At the first meeting of the Industrial Affiliates, we had a good showing—about 20 companies. The people who came were the research directors of large companies like Westinghouse, and little teeny companies, like Podunk Systems, Inc., and so on. To begin the proceedings, I talked a little bit about what Fermilab was doing with its accelerators, and the quarks and the leptons. Then I turned it over to the laboratory, and engineer after engineer and physicist after physicist got up and talked about the incredibly clever technical things they were doing at Fermilab. We had a day and a half of this, with tours and exhibits, and so on. At the wrap-up session, we said, with great smiles, "What do you think, fellows?" They sort of shuffled and looked a little embarrassed, until finally one of them got up and said, "Gee, that stuff you told us about quarks, that was great. The rest of it, well, we didn't understand any of it."

The End of Innocence

That was a profound lesson, so the next year we concentrated on the techniques for technology transfer. I remember that meeting, because Bob Frosch, who was vice-president for research at General Motors, told us how hard it is even to transfer technology from one department of General Motors to another. After that, we got into changing the whole philosophy of Industrial Affiliates from one in which we would show you how clever we are and you guys would turn it into commercial value, to a much more modest goal of communication: Can Fermilab, an off-campus facility for 80 or so universities, engage in a conversation with industrial scientists and managers? We'll tell you our problems, you tell us your problems, and maybe out of this conversation something good will come.

Each year for eight or nine years we struggled for an interesting new theme that would set the mood. I remember one I'm very proud of, called "Out on the Limb of Speculation." We said, "Don't take notes. Turn off the tape recorders. Let's speculate on the most bizarre things that could possibly come out of far, far-out research, and how they might come about." Maybe some of you remember that theme, and the "Proceedings" that came out of it. Some of the things that were way out on the limb of speculation turned out not to be so far out after all. Therefore, I'm pleased to come back to this 13th Annual Industrial Affiliates meeting, with the theme "Beyond the Cold War: The Changing Arena of Science."

I notice I have chosen an absolutely absurd title, "Global Science: The Universe and Batavia." Where is the universe? Where is Batavia? Batavia is not the end of the world, but everyone says you can see it from here. I don't know what I meant when I invented that title—I always do that. But I do want to talk about the changing status of science. I think a large part of the issue has to do with the end of the Cold War, much to the surprise of many of us who are, or were once, enormously innocent. I never dreamed that the work we do at Fermilab had anything to do with the Cold War. In fact, one of the most famous interviews in this business was given by my predecessor, Bob Wilson, who, in testifying before Congress, was asked about the machine he wanted to build at Fermilab: "Dr. Wilson, what is this machine going to do for national defense?" He tried to wiggle out of the question, but the questioner bored in on him, and finally, in desperation, Wilson said, "It's not going to do anything for the defense of the country, but it will make the country more worth defending." That was a cogent, brilliant answer, and it was what all of us thought who work at Fermilab and labs like Fermilab—not quite as good, of course, but like Fermilab. All of us in this business of basic research and particle physics and how the world works have thought we were contributing our bit to society by bringing illumination to the world. We have believed that this is a good thing to do, and that it will enrich our culture. Our drive was largely a cultural drive. Now, much to our surprise, the Cold War is over and people are saying to us, "Well, the war is over. Maybe we're not so interested in science anymore."

Good Questions Then—and Now

Let me bring the current situation into historical context by reviewing the situation over the last 50 years. It was November 1944, even before World War II was over, when Franklin Roosevelt wrote a letter to Vannevar Bush, then chairman of the Office of Science Research and Development. That office supervised all that engineering did to win the war. Roosevelt's letter asked four fundamental questions. First, How can we publicize to the world the vast contributions to science and technology made during the war? Roosevelt pointed out that the fusion of such knowledge should stimulate new enterprises, provide jobs for returning servicemen and defense workers, and contribute to national well-being. (It's amazing how some of these phrases come up over and over again!) The second of his four questions was, What can be done to organize a program for continuing the research spurred by the war? Third, What role should the government play in aiding science research by public and private institutions? Fourth, Can we find an effective program for discovering and developing the scientific talent of American youth to ensure the future of research in this country?

These were four good questions in 1944, and they are four good questions in 1994. Bush's response was the famous document, "Science: The Endless Frontier." It wasn't the last report—there were follow-up reports such as the Steelman Report in 1946—but essentially Bush's response to Roosevelt's questions was a blueprint for America's fantastic post-war investment in research and education. It led to the creation of the National Science Foundation and to a civilian-dominated Atomic Energy Commission, which later became known by the curious initials "DOE." If you look at the Vannevar Bush report, you can find weaknesses in the proposals and even failures in the applications of some of Bush's ideas. Nevertheless, the program catapulted the U.S. into the world leadership of science and technology that we enjoyed in the 1950s and 1960s and 1970s, and in fact still enjoy. We still have a robust scientific environment, although there are danger signs that we need to discuss when we talk about the changing arena of science.

America dominated almost all fields of research. In the beginning, it was easy, because our competitors were countries recovering from the damage of the war. But even after Europe and Asia recovered from the effects of the war, American science and technology stayed ahead. It takes a long time to rebuild an infrastructure, and American industry profited from the opportunity to be economically competitive—more than competitive. What's amazing is that before the war, in the 1930s, the U.S. was a kind of scientific backwater. Americans who wanted to get a good Ph.D. went to Europe. Today they go to Harvard or University of Chicago. Some of the great leaders of American science got their Ph.D.s in Europe. To go in 25 short years from the status of backwater to world leadership was a tremendous feat. Of course there was a lot of luck involved, including the tremendous emigration of Europeans before, during, and after World War II. These emigrant scientists found receptive hospitality in universities and in industry and could promptly take up their work. There was also the respect that science and technology earned from the successes of World War II. Our country had a stable, vigorous economy and—perhaps the key—a conviction, a national conviction, that trust in the future would pay off. Investment in new ideas and new products and new explorations would yield great returns. These days, I think we sorely need such a belief in the future.

The returns were enormous. American science and technology made tremendous accomplishments. Feared diseases have been eradicated. We have reached the moon and launched the computer age and spread the green revolution and given birth to biotechnology. Our market shares were in the 90-percent range for all kinds of products: machine tools, high-quality metals, consumer electronics, airplanes, computers and so on. All kinds of new science and technology emerged from the war and after the war: semiconductors, integrated circuits, microwave telecommunications, high-strength alloys, antibiotics, medical diagnostic tools such as CATS and PETS and MRI, x-ray lithography, superconductivity. A long list of technologies that came out of the great post-war period are still supporting our economy today.

It Takes More than Science

Where did all of this research take place? There are three places where science research is done: by the government, largely in national laboratories; by industry, in industrial laboratories; and in universities. I think the success of the years from 1950 to 1980 came from a healthy balance of competition and collaboration among all these elements, sort of managed—or maybe not managed—by the U.S. government. That is how it worked. Nothing has happened to cast doubt on the potential for vast advances in our understanding of nature in many fields today. I have to admit that physics, which had an explosive growth from 1900 to roughly 1950, has probably been edged out by biology, which had its growth spurt in the second half of the century. It is not that physical science has decayed but that biology has exploded, with the incorporation of molecular structure, the discovery of DNA, gene splicing, genetic engineering and all of those things. We have also seen the information explosion, the blinding speed of communications, the continuing logarithmic growth in the speed of computers. In one of our Industrial Affiliates annual meetings, we concentrated on computers. We took a poll among the computer experts: By the year 2000, we asked, by what factor will computers be faster than they are in 1983? The pessimist said

10^4, and the optimist, (it was Ken Wilson, Nobel Laureate in Physics who has been devoting a lot of time to computers) said 10^{14}. I don't know how it will turn out. We have eight years to see what happens, but I think we've already reached about 10^8.

The potential for economic health, for enhancing human capabilities, for solving societal problems is mind-numbing today, if we survey our science. But as we know, or as we should know, it takes more than science and clever engineering to address the problems of society. What does it take? It takes determination, it takes vision, it takes will, it takes courage, it takes leadership—all are commodities that tend not to exist in surplus quantities. Let me look at the dark side of what's going on in the three organizations I mentioned above, where we still do all of our research. First, let's look at industrial research. I remember being fascinated by the willingness of companies like RCA and Westinghouse and Bell Labs and IBM and General Motors, General Electric, Xerox and so on to help us scientists when we needed some complicated gadget. The industrial laboratories provided the wherewithal for progress in American industry. Today, if you look for these labs, you will find that either they are not there anymore, they have been sold to the Japanese, or they have downsized to the level where they spend all their time trying to please some short-term CEO in a hurry, who does not have much patience with research, which, after all, sometimes takes months and months to get a result. More often, of course, it takes five or ten years. I think there is general agreement that something has happened to industry's interest in the investment in research. At a recent AAAS symposium, everyone agreed that, as a generalization, industry is no longer interested in long-term investment. On the other hand, the companies that are still interested in research do very well. It pays! I remember a vice-president of research telling me, "I proved to the company that I pay back 20 percent a year on every dollar invested in my laboratory. They said, 'That's very interesting. We're cutting you 20 percent next year, because we want to declare larger dividends, and the CEO needs a raise.'" I don't know all the reasons, but clearly loss of interest in the long-term future is widespread.

Research universities, where 70 percent of basic research is done, are in many ways in equally bad trouble. The universities' financial state is precarious. Even Harvard is having financial problems. The universities can't raise tuition anymore. I don't care how rich you are, if you are paying for three kids in college, you are a pauper. The state universities have been asked to contribute to meet the state budget deficits. Whether they've been asked or not, that's what they're doing. Overhead charges are moving in the wrong direction. Increased costs of meeting regulatory requirements, security, and harassment by congressional watchdogs add to their problems. As if that weren't enough, now those poor universities have to keep professors on after the age of God knows what, because there's no retirement anymore! What you have is hiring freezes, phasing out of departments, and all kinds of austerity measures, which does not cheer up the scientists in the universities who have to do research. They are depressed, and when the professors are depressed, their graduate students are depressed, the assistant professor is depressed, the undergraduates are depressed, the custodians are depressed. Everybody's depressed. Except the Dean.

National labs, the third place—look at Fermilab. I've heard that things around here aren't all that good. They have fantastic facilities, but the operating budgets for using these facilities are tragically limited; and the problem of keeping up to date and using the kinds of facilities that Fermilab and Argonne and other laboratories make available is growing harder. Some laboratories, such as Los Alamos and the other weapons laboratories, have to redefine themselves or they might find that they're not there anymore. Thus, the three places where we do research are all under enormous stress that comes, either directly or indirectly, from the changing arena of science.

Dark clouds hang over the failed pre-college educational system. We are still a nation at risk, ten years after the appearance of the report by that name. It convinced any reasonable person who read it that our educational structure has collapsed and that we're not educating children to join the science and technology workforce or even to be citizens with opinions on the life-and-death issues in which science and technology play a role. In our graduate schools over 50 percent of the graduate student body are foreigners. If not for foreigners, we would be in terrible trouble. As a nation—although it's wonderful to have foreigners come here and go to our graduate schools, and some of them will stay—as a nation, our long-term survival as a leader in science and technology has to depend on Americans going into science.

Uneasy Alliance

While I'm cheering you up with these dark clouds, let me tell you about another cloud, an important one, although perhaps a subtle one. I refer to a general disquiet among policy makers in this country over the stewardship of science. Part of this simply comes from our enemies, the cynical, dangerous, self-aggrandizement of bullying politicians. We could condemn them and worry about them, but we've seen them come and go before. I want to set these guys aside and worry instead about the more serious challenges that are increasingly heard in Washington, in the media, and even in polite intellectual circles in the universities. I recently learned that this cloud has a name: "post-modernism." Politicians, perhaps frustrated by the continuing social malaise of decaying inner cities, environmental problems, high crime, persistent poverty, have turned to science and said, "What have you guys done about all this lately?" I can only quote the words of perhaps the best friend science has in Congress, Congressman George Brown, who has been a proponent of science and is himself a trained scientist: "The uneasy alliance between scientists and politicians is beginning to come unglued. Budgetary stress, economic stagnation are forcing political tradeoffs and sacrifices that affect a broad range of federal programs." Congressman Brown goes on to argue that we must test the hypotheses—this blows my mind—that link economic and social benefits to research. In an expression of what I believe is frustration, he has noted that in spite of 50 years of strong federal support of science, we still have poverty, we still have pollution, we still have crime: and he figuratively asks, "Why haven't you guys fixed these things?" He expects that as the knowledge of the world increases, the problems of society should go down, and that's not happening.

If you think Congressman Brown is bad, you should see his staff. He impaneled something called a Task Force on the Health of Science that carried some of these complaints to an extreme. Some of the suggestions of the task force, which appeared in a government booklet, said, "Congress should exert greater control over the choice of research to be funded. Research should be addressed more immediately to current political, economic and societal pressures. Research programs should be linked explicitly to goals." Implicit in this suggestion is the assumption that it is in fact possible to determine in advance which research is most necessary for a given national goal. How many scientists would concede that assumption? The Task Force goes on: "Legislative mandates should be used to determine how research is evaluated." Inherent excellence of research is not considered a sufficient criterion for judgment because, I guess, excellence doesn't count. It doesn't guarantee policy relevance or potential applications. "Programs that are failing to meet stated goals should be terminated." Stop cancer research, right? Because it hasn't cured cancer—that's the clear implication. The members of the Task Force display an utter ignorance of the history and practice of science. They betray expectations that science can't meet, a misapprehension of its capabilities. They fail to recognize that the motors of policy can't mandate success in science.

Directions in science are ultimately dictated by feasibility. Science is the art of the soluble, of the possible. Our legislators ignore the substantial strategic planning that has guided both fundamental and applied research in the United States over the past 50 years, and the plentiful results that have redounded to the benefit of society. I think we've done very well. Saying that science should be more aimed at national goals is ridiculous. We're already aimed at national goals. Above all, Congressman Brown's task force misplaces the blame.

Science has, for example, long since produced vaccines required to control most childhood infections in the United States, but our society has not found the political will to deploy them. Science has long since sounded the alarm about acid rain and its principal origins in automobile emissions, but society has not found the political will to control the internal combustion engine.

Brown argues that we must test the hypotheses that link economic and social benefits directly to research, hypotheses that I thought were well proven. I think science has become a victim of its own success. We have accomplished so much that far more is expected than we can hope to deliver. Why haven't we cured cancer? Why haven't we cured AIDS? When will there be a remedy for the common cold? When will we be able to produce energy without waste or pollution? When can we convert sand to gold? This is a real problem, and it is having an effect. Complaints come from Congress. There's been an assault on the National Science Foundation, insisting that it focus on perceived national goals. We see increased manipulation of research funding by legislation. An erosion of the infrastructure for fundamental research in the United States is going on, and if we cannot reverse it, the pace of discovery will slow, with widespread consequences for industry, health care, and education.

The supercollider is in trouble. Its troubles are symbolic of the problems of science in general, but the supercollider is a big, big symbol and an expensive one. It raises the question of how much science is needed. When I worked with AAAS, we had to address that question, because people told us, "We have too many scientists—we're doing too much science, we don't need all that science. What good does it do?"

Science Pays Its Way

We know why we want the supercollider. It fulfills a deep cultural need, but the cultural argument is difficult to make. However, I believe we can make a different argument, that science yields paybacks to society in economic terms. That is a good way to talk about it, because science has a tremendous track record. I have a very simplistic notion to present. We have a GNP in this country of $6 trillion and a federal budget of $1.5 trillion. If we neglect the deficit, the ratio is about four to one: that is, one quarter of the value of any commercial activity is paid in taxes, as revenue to the government. So if Fermilab does something that generates an increase in the GNP, then Fermilab can be credited with one quarter of the increase, as revenue to the Treasury from taxes that wouldn't be collected without that particular commercial activity. So if I can find a billion dollars in annual U.S. commercial activity generated as a result of Fermilab science or technology, it means that Fermilab's $200 million annual budget is free to the American taxpayer; it has paid for itself. All I have to do is find a billion dollars in the GNP in order to pay back the Treasury, and more. We have to do this carefully. If I take simply accelerators alone, accelerators generate an annual commercial activity of about $5 billion a year. There are thousands of accelerators in place, curing cancer, treating plastics, doing diagnostic radiography, performing ion implantation. These accelerators were invented by scientists in their desire to learn about atoms and molecules and quarks and so on. If we add to the total the products of these accelerators—people who are living instead of dead, plastics that are irradiated, metals altered by ion implantation—the sum of commercial activity has been estimated to be an industry of about $25 billion a year. Fermilab can't take credit for the whole $25 billion; but, with the other labs, we do have some share of that.

To get an idea of Fermilab's share, I like the magnetic resonance imaging example, although it has sometimes been distorted by unreasonable claims. The MRI industry now generates about $4.5 billion a year. There are 3,000 MRI units in the United States, at a cost of about $2 million each. These MRI units each do 2500 scans per year at $600 dollars a scan, for a total of $4.5 billion. Add to that about a billion dollars extra from the sale of new units, although new sales are beginning to level off. We get a total of four or five billion dollars a year.

Although Fermilab didn't invent MRI, the Laboratory did have a big role in developing the materials that MRI requires for its superconducting magnets. We will give Fermilab 20 percent of the credit for the development of MRI. Twenty percent of five billion is one billion. We have found the billion dollars we need to pay Fermilab's budget. Fermilab is free.

I think similar calculations will prove true of any large scientific activity. I don't mean to say we're going to build the supercollider to pay the Treasury for our operating costs. That doesn't make any sense at all. But it is a different argument from the one NASA uses, the "look-we-invented-non-stick-frying-pans" argument. The difference is that we are doing research to understand how the world works, and the cost of this research is essentially free. Maybe the Treasury even makes a profit on it. That's the point, and I think it will be true of the supercollider. Whatever its operating costs, and its capital investment costs, they will be paid back. But that's not why we do it. We don't do it for the frying pans. We do it because we want to understand how the world works.

The Sense of the Universe

The real payback to society from a project like the supercollider comes from the way science influences human activity. We remind ourselves of the place of the supercollider and its cousins in the history of science. Newton revealed an orderly universe, and was able to understand the motion of planets. Today, NASA programs all of its satellites and its activities with Newton's equations, but the important aspect of Newton's contribution was his demonstration that the universe is an orderly universe, subject to laws that we can write down. Faraday discovered electricity, a notion that in its early days was probably as exotic as quarks, but is now as firmly incorporated into the human environment, human thinking, and human behavior as fire or the invention of tools during a much earlier epoch. Einstein showed us where we are located in the universe, and unified space and time. His special theory gave us the basis for the construction of accelerators and many other things in modern technology. The atomic explorations of Bohr and Schrodinger and Heisenberg gave us quantum theory, one of the revolutions of the 20th century. It had an enormous impact; one estimate says that quantum mechanics accounts for about 30 percent of the GNP. It's a good number—nobody can disprove it. After that came Enrico Fermi and Ernest Lawrence and the conquest of the nuclear domain. You can count something like six major revolutions that began as abstract studies whose implications for society were concealed in the very distant future. In each phase, some new piece of reality was revealed. Gravitation, electromagnetism, atoms, cosmic history, all gave us glimpses of a universe of incredible beauty and coherence, for the enchantment and the comfort of mankind.

The enterprise of science embodies a great adventure, a quest for understanding of the universe, which may or may not be infinite in all directions, not only above us in the large but also below us in the small. We began this quest very well, by building a science of increasing power that illuminates the living and the inanimate, all that surrounds us in time and space. For this, scientists are admired. (They are still admired, surveys tell us.) But they are also feared, mistrusted, even despised. We scientists may offer hope for the future, but we also bring moral conflict and ambiguous choice. The price seems large, but it pales in comparison to what it would cost to deny the future.

The American essayist Annie Dillard wrote, "Who can read what the wind-blown sand writes on the desert rock? I read there that all things live by a generous power and dance to a mighty tune. Or I read that all things are scattered and hurled." Will we live by a generous power and dance to a mighty tune or will we be scattered and hurled? ❖

Panel Discussion

Where Are We Going

(Panel Discussion)

Lewis Franklin, Panel Member
Visiting Scholar, Stanford Center for International Security and Arms Control

Roald Sagdeev, Panel Member
Professor of Physics, University of Maryland

Richard Slansky, Panel Member
Leader, Theory Division, Los Alamos National Laboratory

Joseph Lach, Referee
Physicist, Fermi National Accelerator Laboratory

Sagdeev: I think the job ahead will not be a quick fix. It will take perhaps a generation to find a new role for science and technology in the post-Cold War epoch. We have an identity crisis to overcome. The issue of national security will never evaporate. As we try to move toward a new role for science, we still have to discover how much the science and technology community will need to contribute to national security in the post-Cold War. It will critically depend on a new paradigm for national security. In both the United States and Russia, new military doctrines and new formulas for national security are under discussion. Environmental issues and economic competitiveness are now considered part of national security, which in turn is now a part of global security. We already face outstanding global issues that I don't think humankind can resolve without contributions from science.

We need a completely new way to communicate about science. Something in the old way didn't work. I agree with Leon Lederman when he says that both scientists and taxpayers have been spoiled with the seemingly easy successes of science. We became arrogant, and I think in communicating to the public sometimes we were guilty of overselling the projects we lobbied for. We sold each new big project as ultimate science. That's exactly what is happening with the supercollider. We imply that we will learn the origin of the universe from the supercollider, eliminating room for any further development for the endless frontier. The same thing happened in space. We said, "Oh, the problem is to find out if there is life on Mars or not." After the Viking mission, people said, "Okay, there is no life on Mars," and so Mars was abandoned. Now it is very difficult to build momentum. We have to renegotiate the social contract.

Slansky: I have talked about why we need to renew the social contract, and ways we might go about doing so. But I would like to ask a provocative question: What is the price of the peace dividend? Stated another way, how should we take advantage of the peace dividend in a creative and constructive fashion? We heard the example of using ICBMs as platforms for getting into space much more cheaply than if we started from scratch. We have heard discussion about the scientific results that have been developed by the cold warriors on both sides, and how they can be brought into the marketplace.

Interpreters of those results are very important. If we fire all the scientists and completely undo the morale of the field, there will be no interpreters for those results. We must get ourselves redirected before we find ourselves fired. If we don't, we will keep none of the benefits of the Cold War, those discoveries still shrouded behind classification. How do we get the maximum benefit out of what we learned during the Cold War? What is our peace dividend? Is it the savings of money in tax today, or is it in fact using for the benefit of mankind the many interesting things accomplished over the last 50 years behind the secrecy and shroud of the Cold War? How should we do that?

Franklin: I have been thinking of some of the examples of the great scientific and technological capacity that we have put together in Russia and the United States. How has the commercial sector had to deal with the economic realities of the new order? The word that came to mind immediately was "Greenfielding." That's where you take an existing factory in Detroit that is inefficiently building cars, and you walk away from it. You also walk away from the labor union and from an age bias toward older workers. You start up a new factory in Greenfield, Kentucky. Not only in this country but in Europe, this practice has become one of the new models of renewal. Given the extensive range of scientific laboratories we have, how much capacity will be needed? Should the national laboratories be subject to the same kind of economic pressure that industrial organizations have? Is there some equivalent that applies to the national laboratories of the corporate practice of Greenfielding? I think we should open our eyes and minds to what that might be, for the renewal process. Roald Sadeev gave the example yesterday of Russian labs subcontracting out corners of their national laboratories. Instead of undertaking a CRADA process, we could simply bring the companies inside the gates! I would leave you with the thought that there could very well be some new thinking, but it has been an education to me to see at Fermilab an unguarded research facility. That is very impressive, a major lesson that could probably be expanded.

Bruce Boardman, Deere & Co.: I'd like to follow up on your reference to changes that have happened in industry. In the farm-equipment industry, for example, we have half as many customers as we did in 1980. I think what has been missing from all the talks that I have heard is the customer. Who is your customer and what is that customer willing to purchase from you? The only thing that you can sell is what your customer is willing to purchase. I think I heard last night that your customer is watching "Days of Our Lives"—and you're trying to sell what? Somewhere there needs to be a recognition and a realization, and maybe a change in the mode of operation, to adapt to what your customer is doing so that with time you can sell him what he really needs. U.S. business has had a drastic shift in its market, much to do with what the customer is willing to buy. Likewise, you are having a dramatic shift in your situation, in the change in what the people who pay the bills are willing to buy.

Sagdeev: Just a change of customers might not be such a big problem, but the entire culture in military industries was oriented to a single customer, the federal government. I think this has a negative element; it spoils the industry, as if you were out of the market economy and part of a centralized socialist economy. Now what happens? The U.S. government is trying to help in conversion and in privatization.

Slansky: Our customer may not be quite the right place to begin the discussion. The cultural things that we stand for bring something particular to our national quality of life, so we pay our taxes to try to help with some of these things. The issue then becomes not whether we should do it, but what the balance is. In talking about something like Fermilab and the Supercollider, our customer is the American culture. It also has remarkable spinoffs, as Leon Lederman pointed out in trying to calculate how much Fermilab really costs. How much is the SSC costing? You get into second order effects and third order effects that end up driving the system in quite a remarkable fashion. When you ask outright who your customer is, you have to go through a rather subtle set of arguments to pin it down, because it has to do with the working of the whole culture.

Ken McNaughton, Physics Today: I think one of the reasons the government was able to sell defense to the public was that the public was afraid of being attacked by Russia. That fear is no longer there, but the public is still afraid. They're simply afraid of different things. The public is afraid of AIDS, they're afraid of crime, they're afraid of poverty, they're afraid of joblessness, they're afraid of the deterioration in city infrastructure. The government seems to be lagging in its ability to respond, and physics seems poorly positioned to assist the government to meet these needs. Physics could think about trying to fulfill the needs of the public. Somebody asked last night, how do we sell science to the public? Very simply, we solve their problems. But physics is not very well geared at the moment to solve any of the public's major problems.

Ruth Sweetser, Illinois Institute of Technology: You mentioned the need to change fundamentally the agenda of science in general. Considering the funding constraints that we mentioned, what can we perceive as the openness of the scientific community to statements such as those Ellen Fox Keller has made that defense and science have pretty much gone hand in hand, and now things have changed?

Slansky: Certainly, one of the messages I gave yesterday was how to approach that problem. I agree that we need to pay a lot of attention to it. I'm involved with an organization that does theory and modeling, yet we have started to reach more and more towards applications. I guess I would call it pre-competitiveness research in the marketplace. That has included a lot of negotiation with private enterprise in this country. We've been in the midst of doing this to a fair degree for over 20 years at Los Alamos; we were trying to carry out that change long before we encountered the funding crisis we are in the midst of now. Not all of science should do that, because applications are fed by places like Fermilab, whose immediate product is knowledge and whose secondary product is sometimes a breakthrough in the way that certain kinds of instrumentation and products can be used for other kinds of applications. I would argue that it can't be a revolution, because nature is not going to change her laws to adapt to the laws of man. It just isn't going to happen that way. The laws of nature are going to be what they are. We need to discover them. That is the thing that pins us to reality. Within that reality we can then look to the new social needs, but it has to be done carefully or we'll cut ourselves off from the laws of nature.

Sagdeev: I agree that we should not look for revolution. It would be a very painful process of perestroika, you know. I hope it would be more successful than it was in the Soviet Union. It could easily take the form of counterrevolution against the scientific community and all intellectualism. This is a real danger, at least from what we see in the former Soviet Union.

Franklin: Maybe I could reflect for a moment on the comment on solving the problems that the people are worried about. My father, as a young engineer, worked on the cyclotron at Berkeley. When a book came out on the history of the Lawrence Berkeley Laboratory, I bought it for him; and, since he wasn't around that week, I read it. It has some interesting information that was new to me on where the money came from for the cyclotron age. It came in large part from cancer medical funding sources. Even in the 1920s and the turn of the century, people viewed cancer as terribly dangerous. They knew it was fatal, and they were searching for the silver bullet. Whether it was skillful on Lawrence's part, or merely luck and serendipity, these two needs came together. While the effort didn't cure cancer, it carried the accelerator program; and of course, it contributed in many ways to solving the problem of curing cancer.

We in high-energy physics have a very sophisticated customer, in the Department of Energy and the Department of Defense, in buying technology. They are experienced in how to buy it effectively. On the whole, I think they do a rather fine job of procuring and deciding. Believe me, if you go to the FBI and suggest using technology to solve crime, it's another world. They have not learned how to buy technology, and they feel it's dangerous. They've had their fingers burned many, many times and they're never going to do it again. Then go down the street to the other government agencies—for example the Department of Labor. They're in charge of unemployment. They are struggling with antiquated computers and enormous amounts of data. Let technology come in and help them see clearly what's going on. Health is in a little better shape, but by and large, the health community is still in the chemical laboratory with reagents and liquids. They are resisting simulation and modeling. The education of the customer on how and why, when and where to buy these products is very much part of the problem in plying our product to these new customers.

Paul Betten, Argonne National Laboratory: There seems to be a contradiction between science and job creation. I think the public fears science, because, ultimately, it ends up causing more unemployment. For example, if you look at science in terms of farming, the whole point is to get more yield with fewer people. If you automate a factory, the whole point is to speed up production, get rid of the people. When you look at science, even though there may be spinoffs that are creating other jobs, I think the public has a fear that science will cause unemployment in the long run. Do you have any comments on how to change that?

Slansky: There are new industries at this point, especially associated with computers, communication and information. But your question is well placed. I don't know that there is an answer that deals with science alone, without including many other aspects of the way our culture as a whole is going to deal with unemployment, especially in conjunction with the problem of population growth.

Franklin: The public perception is probably as you see it. But is the perception accurate, or is it a misperception by the public? There are new jobs being formed, as we all know, mostly in small companies, not in big companies, in small laboratories, not in big laboratories. Of course those new jobs tend to either be in one of two extremes, either in service industries, the hamburger flipping, or at the other extreme, jobs that require a good education. There might also be a fear of inadequacy, a fear that "I may have to work harder." I think you raised a very good question.

Richard Bullock, Technology Development Int'l: I have a small firm that's interested in licensing technologies from wherever they come from. One area of interest of course is the federal lab system. My question draws on the comment just made. Where does the panel think incremental job growth is going to come from in the next 20 years if we basically stay with the industries we have? Does the panel think manufacturing job growth will occur, and secondly, do they think there are job-building opportunities in the portfolios of inventions that are residing in their lab file drawers at this time? I also want to respond to the labs' question "Do we have to open our gates?" I'd say, yes, I think you do, but I don't think that's sufficient. I think you're sitting in a situation where the R&D capacity of the industrial world is quadrupled if we remove defense as your customer. Defense is an industry that's in tremendous overcapacity. My experience in marketing tells me that's when you really have to go out and shake the bushes and understand what your customers need. You really have to start thinking in terms not just of opening the gates but of going out and bringing people in the gates. Personally I don't think people will come on their own, because the gates are already open now. You have to go tell people, show people.

Franklin: Let me take a quick shot at your job growth question, because I think it is very important. I propose for example, that we shift from a defensive action to protect the U.S. (rocket) booster industries, which currently crank out the magnificent number of nine missiles per year. The result is there are only nine payloads per year for U.S. industries to build. I could easily imagine launching 100, which wouldn't generate many jobs But that might generate a quite different business of not only 100 payloads per year that have to be built, but a whole infrastructure, including the scientists who analyze the data or the commercial users or the new kinds of satellite-related products that might come on the market. People wonder why Land Sat hasn't taken off, but if you want a picture every hour, you're not going to get it by waiting for government to provide it. You're going to get it only when you as a farmer or you as a traffic manager or you as a water resource manager decide it's worthwhile to spend the money to purchase this service from a satellite. Then the market will develop. But the market is inhibited right now, because the government has decided to control the space business. Jobs could flow rapidly from that specific example. I would be interested in other examples that might also have possibilities. Let the commercial market deal with surplus military material, with the exception of weapons proliferation. I would be a little hesitant to have these commercial missiles launched from Libya, for example.

Stanka Jovanovic, Fermilab: I am the manager of the education programs here at Fermilab. None of you has really said that your customer is the citizen, who is an illiterate citizen when it comes to scientific issues. If you want the taxpayer to support the nebulous things that we do as researchers, how do you perceive the role of scientists in enhancing science education, not of the college student, not of the graduate student, but of the kindergarten through 8th grade student?

Slansky: How do we boil down science education into 30-second sound bites? That's the demand of society at this point. It's very hard to say what's going on at Fermilab in a 30-second sound bite. I admire what you are doing in education. I think it's very important that some of us—more of us in the future—help provide to the American people what the basis of our culture is all about at the moment. I wish you the best of luck and I think that more should join you!

Rich Stanek, Fermilab: My question concerns the cohesiveness of the national laboratory system. Now that the defense laboratories are starting to look for other ventures to get into, do you feel that the labs work well enough together to share resources, move people around, as opposed to trying to promote their own programs, trying to keep their own laboratory fully funded and keeping people fully employed at their own laboratories and not really looking at the laboratory complex as a system?

Slansky: The implication of your question is correct—we do tend to compete with one another in a society of limited resources. That we should work together better, that we should have more cooperation, I absolutely agree.

Dean Waters, Oak Ridge National Laboratory: I want to address what I believe is the mistaken notion that technology is sitting on the shelf just looking for projects to be commercialized. There are a few exceptions; perhaps the booster launching capability of the United States may be one. Generally in the private sector, and in the Department of Energy, it takes far more than scientists to bring ideas to the point where they can be commercialized. We haven't said much about engineers in this room for the last two days, and we've said virtually nothing about production in the private sector. The Department of Energy's laboratories and production facilities represent unique assets of the United States. Do you have any comments about how we might utilize the private sector? And second, what methods would you use for success?

Sagdeev: I would like to speculate briefly on this issue. I think it is related to the previous question about the cohesiveness of the national labs. I think that I would rather drastically disagree with what you say. I think the military industrial complexes existed as an extremely well managed, centralized army of researchers. Everything was prescribed, with deadlines controlled by the all-important customer. Now when we have to deal with many customers, with a multitude of problems, with diversity, I think we have to decentralize ourselves. I believe in the future we are not going to act as a totalitarian substructure. I believe that organizations like Los Alamos National Laboratory will be forced gradually to move to a structure more or less like a regular campus, where each small group lives an independent life. People meet each other sometimes at seminars. Unfortunately multidisciplinary gatherings are becoming rarer and rarer. Staying together might mean that we should create an atmosphere of intellectual creative interaction with a lot of cross fertilization, but we should not be centrally controlled.

Slansky: The weapons complex is broken at this time. It has been broken for some number of years. It is not producing anything. When you put the microscope on this, the issue is whether you're looking at the whole complex, including Los Alamos, Livermore, Sandia, Rocky Flats, Frenault, Savannah River, Oak Ridge—Y-12 in particular—and Hanford. When you look at the complex you have to ask what it is producing, and it's not producing anything at the moment. It's generally broken. Environmental insults have caused some of these laboratories to increase in staff size by 30, 40, 50 percent, while the product is zero. What is broken down is the complex as a whole. I must say that the picture of this very central, wonderfully organized structure is not the way I've experienced it, but I've not been in the middle of it. It has seemed to me to be a little bit more disorganized.

Everything in the Manhattan Project for the Second World War was done in one place. There *was* only one place, except for the making of special nuclear materials at Oak Ridge and Hanford. But there are a few places—the labs that are represented here plus Livermore—where there are good things going on. We have been looking for other customers for 20 years, at least in the case of Los Alamos, and I think of Oak Ridge. But it is well recognized that the complex of weapons labs as a whole is indeed broken. There is a plan, called "Complex 21," to try to figure out how to deal with this fact. In the meantime, the environmental insults are driving the whole thing. The previous Secretary of Energy said, "It isn't our product but how we do our business that counts." We are still living with the effects of that view. We have made other products, especially at the research laboratories, Oak Ridge, Livermore and Los Alamos. To some degree, Sandia is beginning to try to cash in on it right now. But the production laboratories themselves—Rocky Flats, Frenault and Savannah River—have not done very well in being able to get over the environmental period. I think one has to use a sharp microscope to see any bright spots for these laboratories.

Franklin: I think the educational issue deserves a little more attention, both education of the population in general, the taxpayers, and in particular the kind of education and awareness that would lead young people to choose science and engineering careers. We talked broadly about PBS and the space science areas. We noted with some surprise the fascination of the American public with the Voyager pictures—very simple pictures of rings of Saturn. They weren't Arnold Schwartzenegger or "Days of Our Lives," but they tapped something in the American people that recognizes quality. People understood something about all the efforts and the pride of the nation that came through in these very few pictures. I think we can build on that. Carl Sagan's PBS sessions attracted the largest audiences ever for scientific programming. Now—about "Days of Our Lives!" Maybe we need the scientific equivalent of "General Hospital." Maybe we could bring science to the people with "Days of Los Alamos."

Slansky: You don't want to hear about it. We're reorganizing right now.

Sagdeev: I think it's an interesting idea. We could create a sort of scientific Disneyland for people to visit.

From the floor: I like it! How about "Six Flags Over Rocky Flats"?

Arthur Fisher, Popular Science: My magazine has the best of interest in the scientific and technical literacy of the American population for obvious reasons. We want to make money. We sell our magazine to people who are interested in science and technology. I did a three-part series last year on science and math education, and we got the largest outpouring of letters since I've been with the magazine. The letters spanned a great spectrum of reactions, and I want to comment on a few of them. We got a lot of letters from people asking, "How do you expect this country to be interested in science when my child's high school has an athletic department of 18 people and we don't have a single science teacher?" Letter after letter was in this vein. We pay athletes, movie stars and rock stars unbelievable sums of money. They are the idols that we have created for our children to believe in. We don't create any scientist idols as role models for our children. That was one of the strongest recurring themes.

Sagdeev: As a matter of fact, I think the audience, the general public, is much smarter than we think. I can give you another example. *Parade Magazine* ran a poll among their readers asking "Who is the smartest man in the United States?" Right after the Gulf War, even General

Schwartzkopf came out only number 2— after Carl Sagan.

Ralph Segman, National Technology Transfer Center: I have been a science writer, as Arthur is now. I found then, and I think it's true now, that scientists generally were insulated from life. They didn't think about the public, or believe that what they did was related to the public. They were doing things for themselves. They were doing wonderful research, finding out wonderful things, and building reputations for themselves. The reason the public doesn't seem to know as much as we all would like them to know is not because they're stupid, but because the scientific world has been stupid.

Bruce Boardman: Maybe that's all the more reason for you to put a business manager in charge of your facility.

Slansky: It depends on my product You're arguing that perhaps the product is wrong, but as long as our product is actually science, which is heading toward the new broader definition of national security having to do with economic competitiveness, with nonproliferation, with a number of new issues that are facing the world right now, managers have to understand the details of how people get their work done.

Boardman: Maybe you also need someone who can understand and identify who the customer and what the customer is willing to purchase and how to operate the facility in order to produce that product.

From the floor: Dick, the public perception of what you do is make bombs. Can you change that perception? What should it become? That's marketing. We're talking about how you change the viewpoint of a customer so that you can do what they really want. To what extent should you deal with this?

Slansky: Our director has tried hard. In his words, "We do large projects where science makes a difference." An example of a large project where science makes a difference is, of course, the nuclear weapons program. To continue our stewardship of that as long as there are bombs around is probably a very sensible thing. You don't want those just left lying around in the environment, of course. That we do other large projects where science makes a difference is a more problematic statement, because there aren't many large projects out there where science makes a difference. A green, compact energy source, public transportation systems that can be built at a reasonable price—there are new directions in which science will make a difference.

From the floor: How do you determine where science makes a difference?

Slansky: To some degree, that's done by the scientists themselves. They do vote with their feet. Even when they are given money to do something they tend to vote with their feet.

Jim Schultz, Fermilab: There appears to be no dearth of scientists but instead a lack of science interpreters, not only to educate children, but also to let industry know what's going on within our labs. We talked about opening up the gates to let people in, but there has to be more of an effort to let a wide audience know what is going on in the labs. What do you see changing in the labs to allow this communication to grow?

Slansky: Of course, an openness. I have heard expressions of surprise that Fermilab is totally open. If I told you how much of Los Alamos is open, I think you would also be surprised. I think that openness is badly needed, so that people do have a chance to learn more. We're still viewed as a bomb factory.

Sagdeev: I think there is another important component—honesty. Very often we try to oversell science.

Slansky: The SSC will not cure cancer, although there may be some technology spinoff that will be relevant for cancer issues. But it came out in the press and was widely quoted that the SSC advertised itself as curing cancer. One has to be very, very careful to not let these kinds of statements go by. Of course the SSC is not going to cure cancer. However, its technology can have some impact, some important impact. I completely agree that we've got to be very careful not only that we not oversell science, but that we don't let other people misquote us. We have to be careful to tell people what science can do, but we also have to be careful to tell them what science can't do. You know, we only have a certain bag of tricks to study nature. We can only answer certain kinds of questions. You can go down one level, and then the next level and the next level, finally down to quarks and leptons, but do we really understand human nature by understanding the interaction of quarks and gluons? Of course not, not really. In some sense we do, but in a more important sense, we don't. I'd like to think that the SSC is going to tell us more about the fundamental structure of matter, but we have to be very careful about how we sell that.

Chuck Horton, General Motors: Maybe we're being too kind to each other and avoiding some very hard issues. In industry we have so often been reactive and allowed others to control what we need to do, rather than being proactive. Why are you in the national laboratories not being proactive, why haven't you had a better mission in terms of what you want to do? Why do you keep looking at someone else to make that decision for you, and have Uncle Sam pay the bill for it? You have fancy mission statements regarding the general welfare of the public, and that is all very good. But businesses exist to make money. I just came from a conference on fuel cells, an area where there is complete disarray. Pure chaos! People see potential in fuel cells, and yet they cannot get their act together to capitalize on this technology. Then a venture capitalist addressed the group. Number one, he said, don't have all of these fancy restrictions on proprietary information; they create a lengthy, horrible waste of time. If your idea is that good, a lot of people know about it anyway. Second, don't worry so much about competition. Competitiveness is a good indicator that your idea might be a good business. Third, put together a complete strategy—where you're going, when, and how. Now those are the types of things that you at the national labs are getting into. I keep seeing a need for being more proactive from your end. I can respect that you have an infrastructure. You've got some wonderful resources. But you must determine where you want to go with them. If you rely on other people to direct you, you're going to have an awful struggle to get the answer.

Slansky: The starts and stops that I referred to yesterday in the CRADA process mean that it has not worked very well so far. It's an effort to get a new approach. But DOE had difficulty deciding, especially in the defense program technology transfer initiative, whether it should be short-term, long-term, intermediate term, precompetitive, be on the production line in a half a year, or whatever. What was funded was one corner of the field—immediate payoff. Insofar as we're having a little trouble getting off the ground, things are not going to work very well and your kinds of concerns and criticisms are something that we have to figure out how to solve.

Sagdeev: Perhaps we should reconsider our approach to intellectual property, to be more open. I think this really could open the gates for a much more creative atmosphere. It would probably remain important to keep technological secrets in the area where they're relevant to national interests—national economic interests, competitiveness, or national security. But in many respects our current approach very often is absolutely obsolete, a real obstacle for breakthroughs.

Franklin: There is a trend in universities to want to patent, license and generally raise revenue from the discoveries made on the campus. It became very clear at Livermore that a major motivation is in fact to generate a revenue stream independent of federal funding, in perpetuity. The price you pay for that is restricting this information to one company instead of taking the technology that the taxpayers paid for and making it broadly available. Instead, we're going to make it selectively available. I would say there are some new approaches that are restricting the flow of technology at the university level and possibly in the national labs that are serving a particular need of the institution—not the public—to raise revenue. That may not be in the public good in the long-term.

Henry Dreisilker, Dreisilker Electric Motors: For the last 12 months I have been working with the East West Corporate Corridor Association to get technology transfer. We haven't been successful. I believe it is an open secret that small business is the backbone of this country. How can we get together? I will not take what I learn from technology transfer to Germany. I just want to take it to Glen Ellyn. Small business has to be involved just like big business, but it's not being done. Small business cannot get anywhere. We haven't got the power. But we are the most important factor in the United States economy. There are millions of things we can do, but how does small business get into the picture? How can we get into this?

Slansky: You have to help us cut our bureaucracy. It's no more complicated than that. It costs the same to write a CRADA for $50,000 as it does to write one for $50 million. The amount of legal work that goes into these things is staggering. There has to be pressure on the government to decrease the amount of bureaucracy that we go through in this country. When you need 28 signatures, somebody proves his usefulness by stopping the process. The bureaucratic process in this country is really putting gum in the gears of progress, and something's got to be done.

Lach: Let's have lunch.

Appendices

Cooperative Interactions with Fermilab

John T. Venard
Head, Fermilab Office of Research and Technology Application,
Coordinator, Fermilab Industrial Affiliates
Fermi National Accelerator Laboratory

How to Interact with Fermilab

The best way for industry to interact with Fermilab is to join the Fermilab Industrial Affiliates. The purpose of the organization is to serve as a two-way street for dialog. The good old-fashioned way to interact, where the laboratory and its vendors work together to satisfy a programmatic need, still works. Successful bidders for Fermilab contracts often gain useful experience and the Laboratory gains from vendor expertise. In addition, there are a number of more formal mechanisms (Cooperative Research and Development Agreements, Personnel Exchanges, Intellectual Property Licenses, Work for Others Agreements, etc.) for structuring laboratory/industry interactions.

Small business firms that want to interact with Fermilab may be able to benefit from the Small Business Innovation Research Program or the Small Business Technology Transfer Program. Both programs have been specifically designed and funded to encourage small technology-based companies.

Occasionally Fermilab receives "modest" requests for technology. Typically these involve individual circuit board layouts, technology items that will not be patented or copyrighted, or access to some special measuring equipment. These requests are handled on a flexible and timely direct cost recovery basis.

The various ways to interact with Fermilab are listed at the end of this section in a box on page 58.

The Stevenson-Wydler and Bayh-Dole Acts (PL96-480 and PL96-

517), as amended, enable Universities Research Association, Inc. (URA), the organization that operates Fermilab for the U. S. Department of Energy (DOE), to claim rights in inventions developed at the Laboratory. URA has claimed rights in several inventions that we believe have commercial potential. We are actively seeking profit-making organizations interested in entering into royalty-bearing licenses for those patents. Similarly, URA may request DOE approval to register copyrights for software packages developed at Fermilab, and may then license that software to companies interested in bringing these programs to the marketplace.

The Fermilab Intellectual Property Licensing Program is designed to recognize that our technologies have a real value in the marketplace and to capture some of that value to share with our inventors and software authors. If you have a customer need that we can help you fill by licensing, please let us know.

By now, most business people are aware that the National Competitiveness Technology Transfer Act (NCTTA, PL101-189) enables Department of Energy laboratories like Fermilab to negotiate and enter into CRADAs. CRADAs provide both the laboratory and its industrial partner opportunities to leverage manpower, facilities, and financial resources while carrying out a project of mutual interest. These agreements include addressing who will own the rights to any intellectual property created (patent or copyright) and the protection of proprietary information brought to the project or created during the project.

The intent, of course, is that the CRADA program will provide an effective mechanism for "bridging the gap" from where a DOE-funded R&D program at Fermilab has brought a promising technology to the point that a company will be willing to pursue commercialization on its own. The intent, as for all our technology transfer activities, is to do what we can to enhance U.S. industrial competitiveness.

We believe that opportunities for cooperative programs exist throughout the Laboratory. Of course, the development of a particular opportunity depends on the mutual benefits to both the industrial partner and Fermilab. At Fermilab the benefit has to come at the division and section level so that these relations must be established and worked out by individual organizational groups within the Laboratory.

In the end, it is a truism that cooperative programs are a two-way street. The first step in forming a partnership is in beginning the dialog that leads to the identification of mutual interests. If you are interested in working cooperatively with Fermilab, please call or write the Office of Research and Technology Application at (708) 840-3333, M.S. 200, Box 500, Batavia, Illinois 60510-0500. The fax number is (708) 840-8752. ❖

Ways to Interact with Fermilab

1. Membership in Fermilab Industrial Affiliates
2. Patent and Copyright Licensing
3. Cooperative Research and Development Agreements (CRADAs)
4. Industry-Laboratory Personnel Exchanges
5. Contracts and Procurements
6. Modest Requests for Technology
7. Work for Others Agreements
8. Individual Consulting
9. Small Business Innovation Research Program (SBIR)
10. Small Business Technology Transfer Program (STTR)

Fermilab Industrial Affiliates

Air Products and Chemicals, Inc.
Babcock & Wilcox
Cole-Parmer Instrument Company
Commonwealth Edison Company
Convex Computer Corporation
CVI, Inc.
Everson Electric Company
W.W. Grainger, Inc.
Grumman Space Systems
Hewlett-Packard Company
State of Illinois
Intermagnetics General Corporation
LeCroy Corporation
Lindgren R.F. Enclosures, Inc.
Liquid Carbonic
Major Tool & Machine, Inc.
NALCO Chemical Company
New England Electric Wire Corporation
NYCB Real-Time Computing, Inc.
Omnibyte Corporation
Oxford Superconducting Technology
Plainfield Tool and Engineering, Inc.
Process Equipment Company
Rockwell International Corporation
Swagelok Companies

Agenda of the Thirteenth Annual Fermilab Industrial Affiliates Meeting and Industry Briefing

Fermi National Accelerator Laboratory
Batavia, Illinois
September 9 and 10, 1993

Beyond the Cold War: The Changing Arena of Science

Thursday, September 9

10:00 a.m.	Registration, tours, coffee	Wilson Hall, 2nd floor crossover
	Tours: 1) General 2) Magnet Facility 3) Science Education Center	
12:00 p.m.	Lunch	Wilson Hall, 2nd floor crossover
1:15 p.m.	Welcome Ken Stanfield, Deputy Director	Wilson Hall, 1 West
1:30 p.m.	Introduction to Theme Joseph Lach, Meeting Chairman	
1:45 p.m.	*Changes in Science: East & West* Roald Sagdeev University of Maryland	

2:45 p.m.	Break	
3:30 p.m.	*Changes in Science: An Example* Richard Slansky Los Alamos National Laboratory	
5:00 p.m.	Social Hour	Wilson Hall, 15th Floor, North
6:00 p.m.	Banquet	Wilson Hall, 2nd floor crossover
	Global Science:The Universe and Batavia Leon Lederman Fermilab Director Emeritus	

Friday, September 10

9:00 a.m.	*Industry & Science* Lewis Franklin Stanford University	Wilson Hall, 1 West
10:00 a.m.	Break	1 West
10:30 a.m.	*Where Are We Going?* Joseph Lach, Referee	1 West
	Panel: Lewis Franklin Roald Sagdeev Richard Slansky	
12:00 p.m.	Lunch	Wilson Hall, 2nd floor crossover
1:00-3:00 p.m.	General Tour & individual visits as requested	

Other Volumes in the Fermilab Industrial Affiliates Roundtable Series

1982: Technology Transfer and the University-Industry Interface

1983: Supercomputer Developments in the Universities

1984: Industrial Participation in Large Science Projects

1985: Applications of Particle Physics: Out on the Limb of Speculation

1986: Science, Economics and Public Policy

1987: Research Technology in the Twenty-First Century

1988: Science-Technology Spiral and the Pace of Progress

1989: Applications of Accelerators

1990: Fermilab III, the Great Computer Debate and Technology for the Nineties

1991: Fermilab-Industry Cooperation

Copies of these monographs can be obtained by writing to:

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Fermi National Acclerator Laboratory
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Batavia, Il 60510-0500