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 space-borne 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.

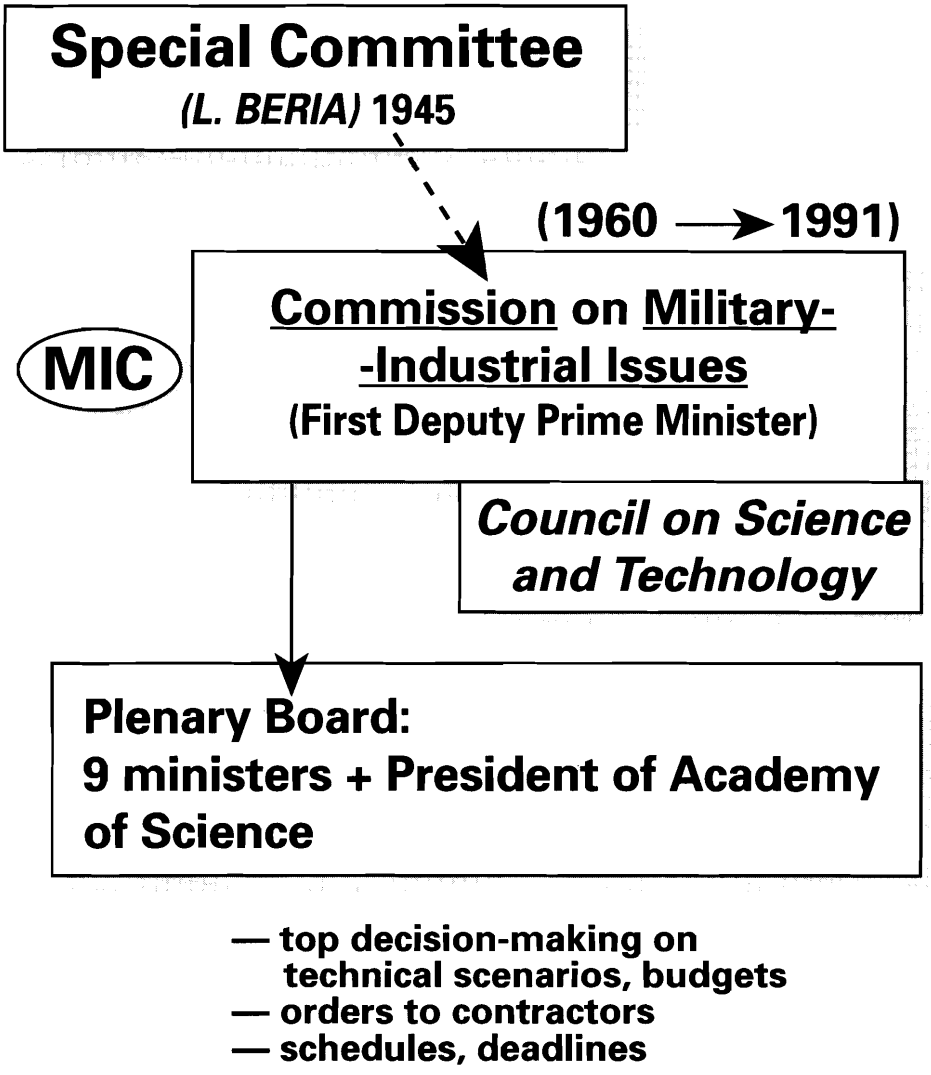
This Special Committee had a board of advisors, and I am sure you are familiar with a number of the names. The first and most important figures in this advisory board were Igor Kurchatov, essentially the founder of the Soviet counterpart to the Manhattan Project, and Peter Kapitsa, who won the Nobel 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

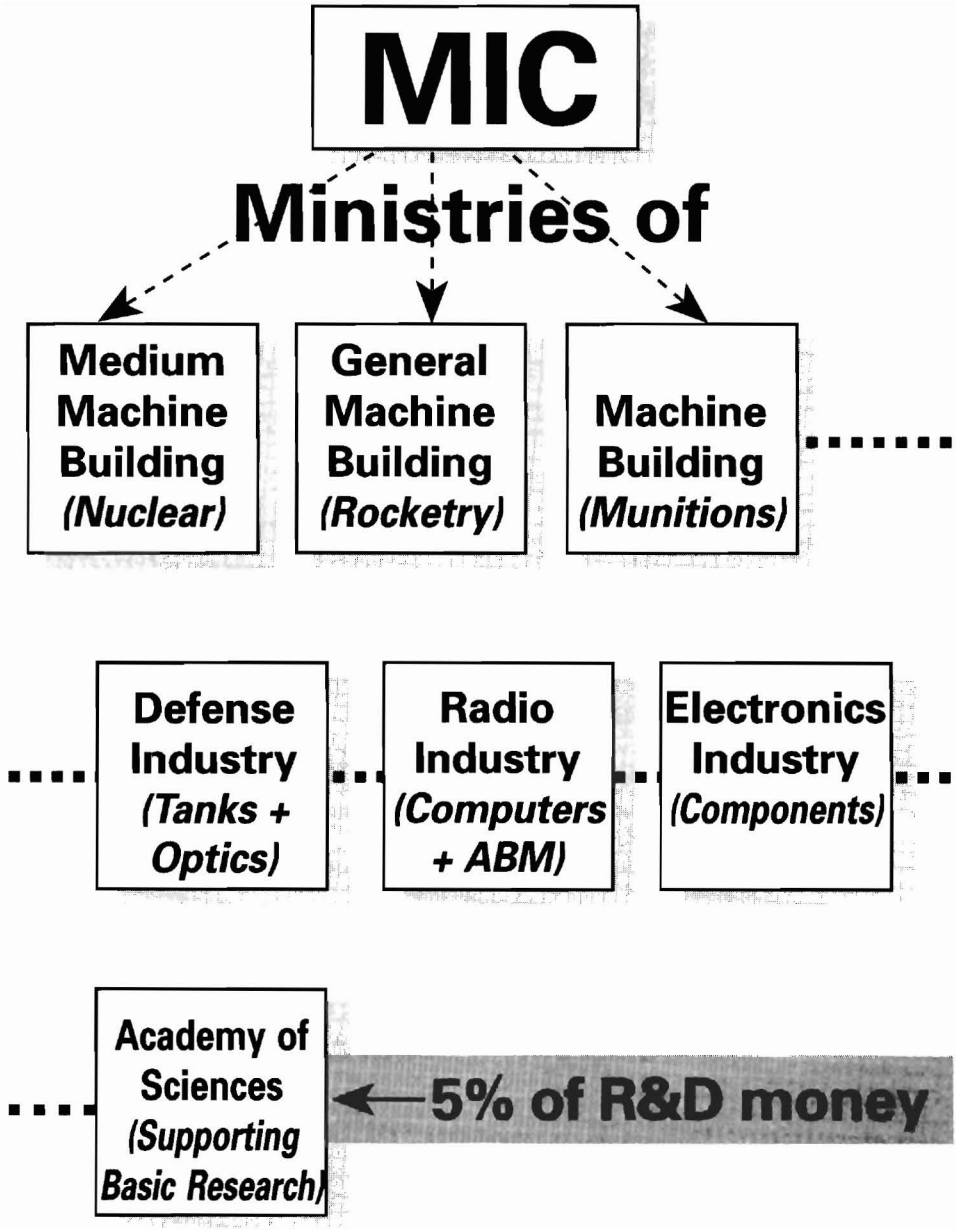
budget. The scientific community was controlled by another governmental body, the Commission on Military Industrial Issues. It was classified as a top secret commission, so we never used the full name when we talked with each other; we used the acronym MIC, for Military Industrial Complex, which we denied 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.

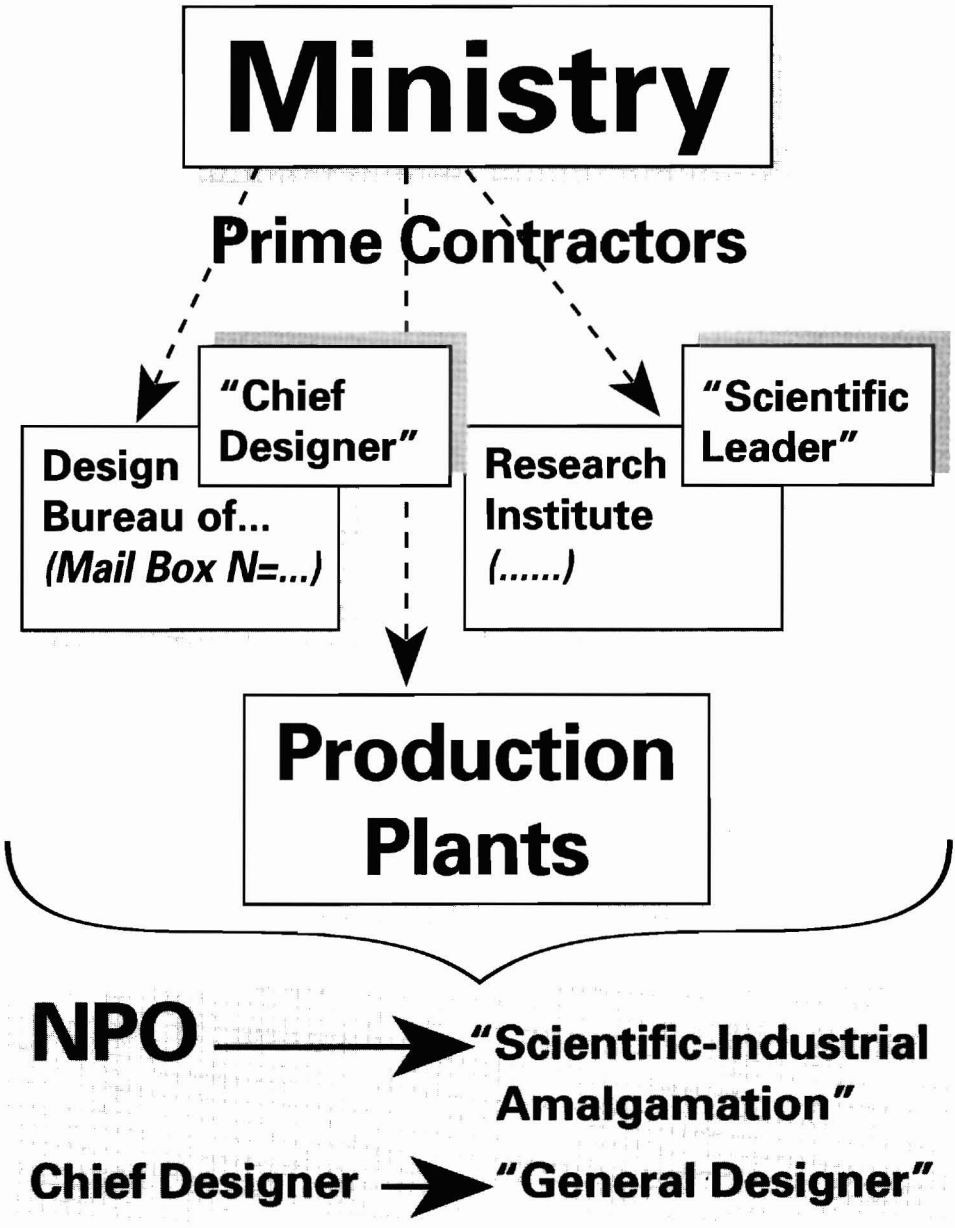
The commission also included leading scientists as members of the Science and Technology Council, just as Beria had at the beginning, including such figures as Kurchatov and Sergei Korolev, a designer of Soviet ICBMs and Sputnik. As a matter of fact, I also was a member of this council for a number of 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.

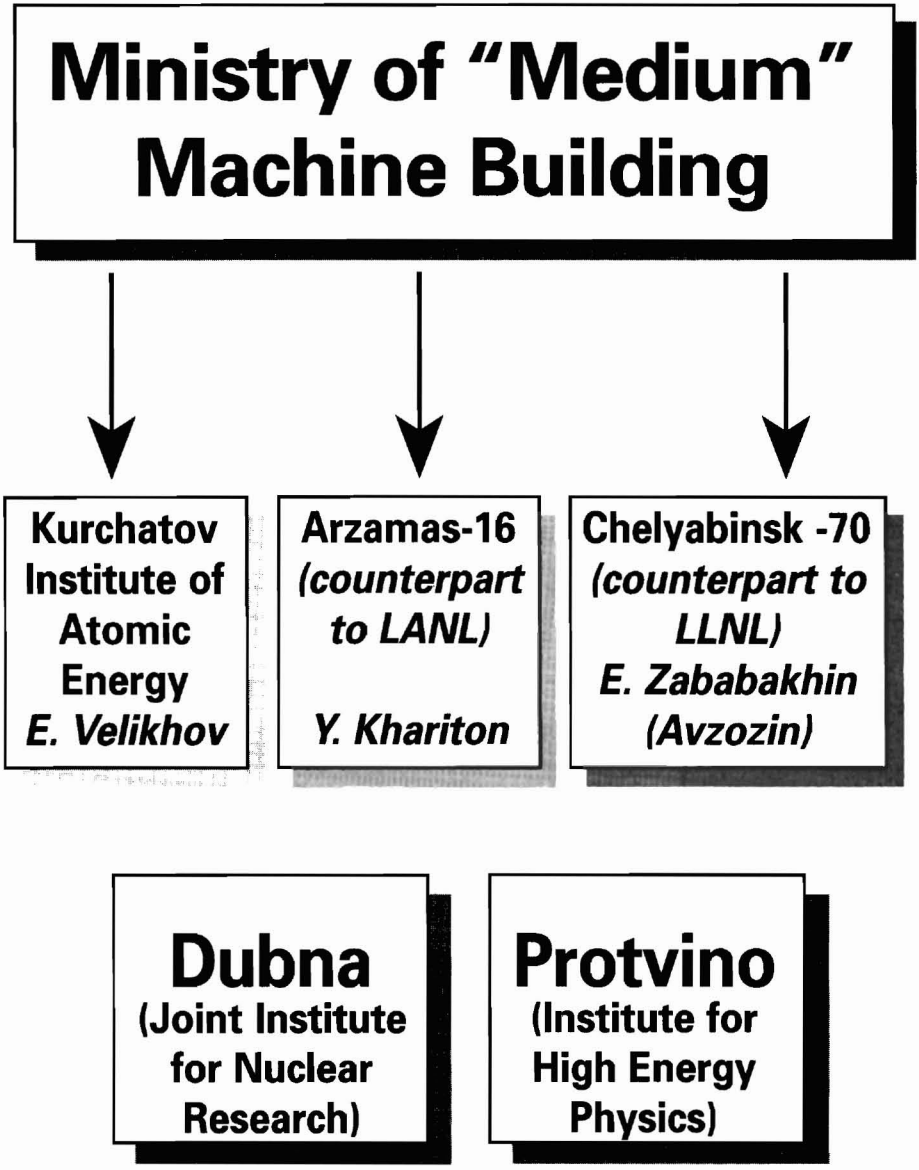
What we have now is no longer called the Military Industrial Commission. Yeltsin has instituted a new board, called the Committee on Defense Industries. It has many familiar faces, but of course their influence and budget is much smaller. The primary task of this board now is not so much to contract 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.



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"
"Scientific Leader"
Design Bureau of...
(Mail Box N=...)
Research Institute
(.....)
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. ❖