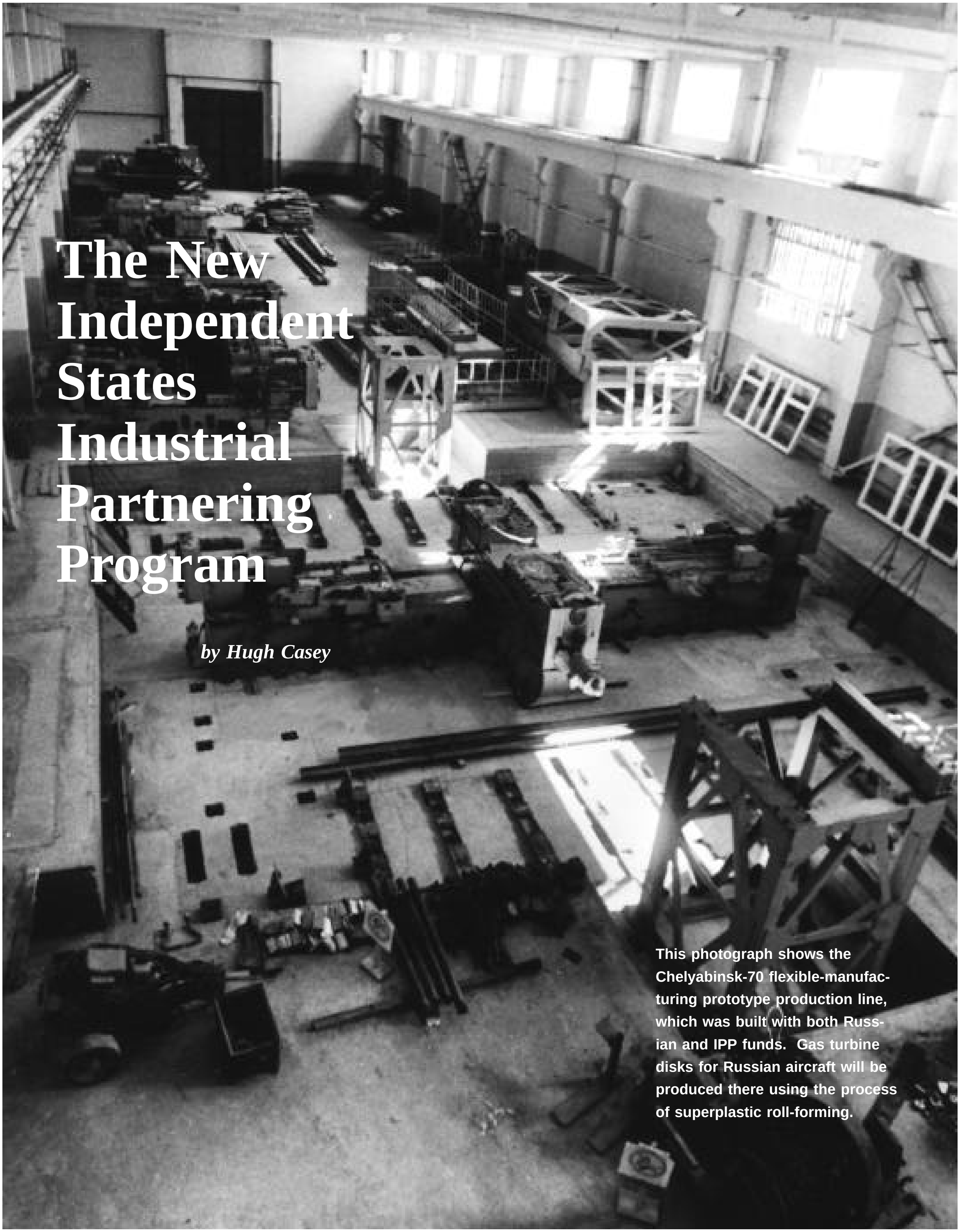
# The New Independent States Industrial Partnering Program

*by Hugh Casey*



**This photograph shows the Chelyabinsk-70 flexible-manufacturing prototype production line, which was built with both Russian and IPP funds. Gas turbine disks for Russian aircraft will be produced there using the process of superplastic roll-forming.**

During the Cold War, the Soviet Union developed a vast infrastructure of science and technology to support its defense needs. In contrast with the United States, however, the Soviet Union had no civilian research and development supporting a private sector. Consequently, thousands of scientists skilled in the various aspects of weapons development, including weapons of mass destruction, have found themselves ill-equipped to deal with the economic crisis that accompanied the Soviet Union's collapse. There are few alternative employment opportunities for those highly skilled specialists, and the possibility exists for defection of personnel or sales of sensitive information to rogue nations.

**Figure 1. The New Independent States**

**On December 25, 1991, the Soviet Union broke up into the 15 New Independent States (NIS) shown above. All members of the NIS are eligible to participate in the Industrial Partnering Program; however, as a nonproliferation program, IPP focuses on the four "nuclear successor states"—Russia, Belarus, Kazakhstan, and Ukraine.**

The Industrial Partnering Program (IPP) addresses the threat of "brain drain" by engaging weapons scientists from the New Independent States (NIS) (Figure 1) in cooperative research and development projects. The projects are specifically directed toward the development of non-military applications for the scientists' skills and technologies. The Department of Energy (DOE) laboratories identify and evaluate the technologies and facilitate the involvement of U.S. industry, which, in turn, shares the cost of the research and development effort and supports the commercialization phase of successful ventures.

The foundations of IPP date back to the late 1980s and President Gorbachev's policy of *glasnost*, or "openness," when the Soviet Union began overt attempts to market defense-based technology in eastern and western Europe. In 1988, the Soviets sponsored their first MATec conference in Helsinki, Finland, featuring advanced materials and manufacturing technologies from the Soviet defense institutes. Tony Rollett, 'Krik' Krikorian, and I, all from Los Alamos, were among the few Americans who attended.

I was specifically interested in the high-powered Soviet gyrotrons, which produce ultrahigh-frequency collimated microwave beams because at Los Alamos we had been experimenting with microwave sintering of ceramics. Our low-power industrial equipment was inadequate, and we were unable to obtain funding to build a more appropriate microwave source. During my conversations with Soviet scientists at MATec, I became convinced of the value of the Soviet gyrotron technology, not only for defense but for industry at large.

Our research on microwave technology continued, but it was not until several years later, following the collapse of the Soviet Union, that we had the opportunity to acquire the Soviet gyrotron technology. John Hnatio, who is the program manager for technology transfer at DOE, and I arranged a partnership between Los Alamos and the National Center for Manufacturing Sciences (NCMS), the United States largest consortium of manufacturing industries. With Hnatio's help, Los Alamos secured DOE funds from the Advanced Manufacturing Initiative (later called the Technology Transfer Initiative) to evaluate the equipment for NCMS applications. We acquired three gyrotron tubes and associated equipment from the Paton Institute in Kiev, Ukraine. With the help of Ukrainian and Russian engineers, we established a "user facility" at Los Alamos where the experimental work could be performed. Hnatio had also been instrumental in setting up an industrial consortium at Sandia Laboratory, and some of the member companies were interested in acquiring Russian technology.

When Senator Domenici expressed interest in involving U.S. industry in laboratory partnerships with the Russians, the labs held a series of three meetings to assess the level of interest and commitment on the part of U.S. industry to that concept. With positive response from industry, the Senator moved forward with legislation to provide funding for a program of technology transfer from NIS defense institutes to U.S. industry.

As a result, 35 million dollars were included in the fiscal year 1994 Foreign Operations Act to establish a "program of cooperation between scientific and engineering institutes in the New Independent States of the former Soviet Union and national laboratories and other qualified academic institutes in the United States" that was "designed to stabilize the technology base in the cooperating states" and to "prevent and reduce proliferation of weapons of mass destruction." More specifically, the U.S. national laboratories were to help NIS scientists convert their defense technologies into commercially viable products and to facilitate the transfer of those technologies to U.S. industry.

The Interlaboratory Board was formed between six U.S. national laboratories who prepared the original program plan for IPP. Since then, the board has grown to include all ten DOE multi-program laboratories. Following a long series of interagency negotiations, funds were received at the laboratories in July 1994. Shortly after receipt of funds, we helped establish the U.S. Industrial Coalition, a consortium of private companies with interests in investing in NIS technology.

In April 1994, confident that the funds would come through, I made my first trip to Russia accompanied by John Shaner. We visited Arzamas-16 and Chelyabinsk-70 as well as a number of institutes in the Moscow region, including the Institute for High Pressure Physics, the Bochvar Institute, and the Institute of Solid State Physics in Chernolgolovka. We collected a number of proposals, which we circulated to the technical divisions at Los Alamos. John Shaner and I headed up a committee of technical experts to select proposals for Los Alamos projects. Los Alamos received approximately 4.5 million of the 20 million dollars that were allocated for lab-to-institute projects. Our target was an average of 100,000 dollars per project, at least half of which had to be spent abroad at the Russian institutes. In August 1994, Los Alamos signed its first IPP contract with Arzamas-16, to be followed shortly thereafter by multiple contracts for twenty-four projects with twenty NIS institutes.

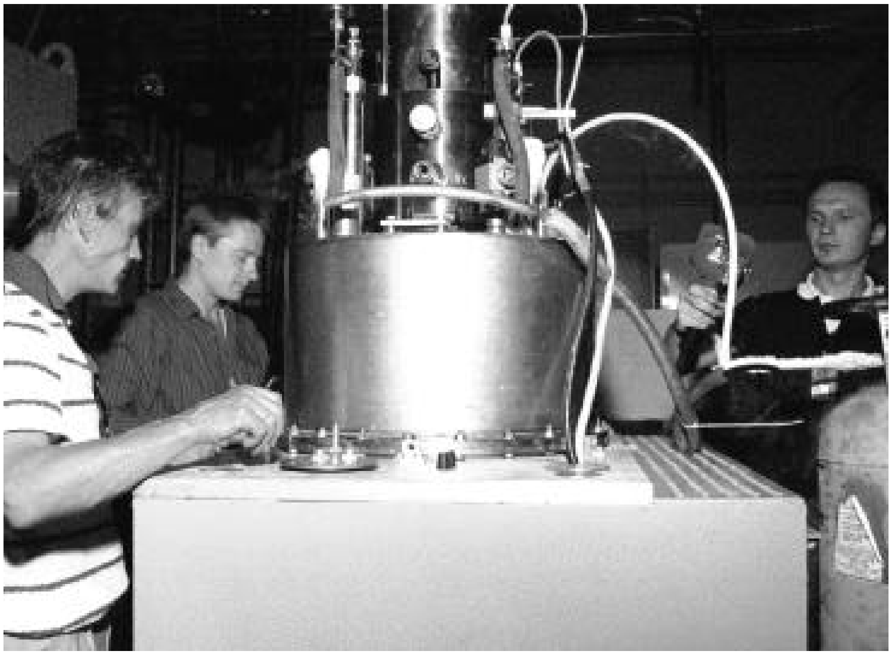


**Figure 2. The Gyrotron**

**Peter Alekseevich Syrovets and Andrey Ivanovich Bunenko from the Paton Institute in Kiev, Ukraine, and Vladimir Ivanovich Irkhin from Gycom in Nizhny-Novogorod, Russia, are shown working on the gyrotron in the Los Alamos "user facility."**

IPP projects cover a broad range of technologies that reflect the core competencies of the NIS institutes. The similarity of the NIS institutes' technical base with our own labs is not coincidental. Materials, manufacturing sciences, theory and modeling, lasers and particle beams, and sensors and diagnostics are all represented in the IPP project portfolio. We have a few fairly basic scientific projects, but most of our activities are in the areas of applied science and engineering. There are no military projects, and we have avoided technologies covered by other government programs. The following brief descriptions will illustrate the nature of the project work.

## The Gyrotron

Since the days of the Advanced Manufacturing Initiative, the gyrotron project has matured and grown to capture the interest of the automotive, oil, electronics, communications, manufacturing, and aerospace industries. Individual companies participating include Ford Motor Company, AT&T, General Atomics, Tycom, Continental Electronics, Baxter Health Care, and Ferro, a list that indicates the diversity of applications as well as the level of industrial interest. The gyrotron (Figure 2) is being investigated for use in numerous operations, including heat treating auto windshields, sintering ceramic and plastic appliance hardware, coating tool bits, separating and recycling plastics, vitrifying radioactive sludge, and other fascinating applications. At Los Alamos and the Paton Institute, we investigate the interaction of the millimeter-wave radiation produced by the gyrotron with different materials. We then optimize the gyrotron to specific applications.

The first gyrotron-based "production machine" will be installed at Ford Motor Company this year, and we are assisting the scientists at the Paton Institute to set up user facilities in Kiev.

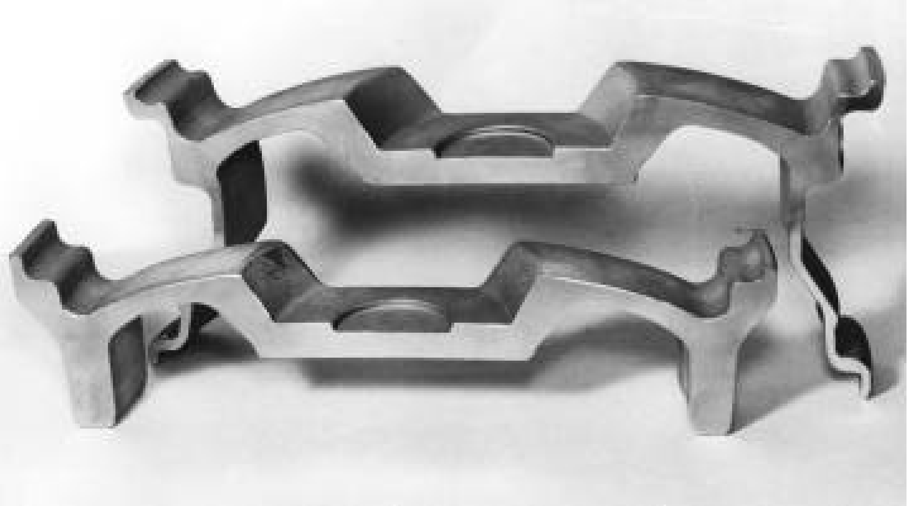


**Figure 3. Superplastic Forming**

**The photograph above shows two cross sections of automobile wheel rims that were produced at the Russian Federal Nuclear Center at Chelyabinsk-70. They were made of ultrafine aluminum which, like most ultrafine and nano materials, exhibits "superplastic" behavior at certain temperatures and certain rates of strain. Under those conditions, superplastic materials are as pliable as paste and can be formed into complicated shapes, such as automobile wheel rims, simply by pushing on them.**

## Ultrafine and Nano Materials

The size of the grains, or "crystallites," in metals and alloys has a pronounced effect on their physical and mechanical properties. The grain size in engineered materials, such as steels or aluminum alloys, is determined by the manner in which the materials are prepared. Historically, manufacturers of metals and alloys have obtained specific properties by controlling alloy composition or the thermomechanical processing steps used in the production of the material. For most conventional processing methods, grain sizes are typically in the range of tens to hundreds of micrometers.

Recent research in the United States, Russia, and Ukraine has shown that many materials exhibit remarkable properties when their grain-size is refined. Ultrafine materials have grains a few tenths of a micrometer in diameter and exhibit strengths as much as a factor of five times that of their unrefined counterparts while retaining excellent ductility and resistance to fracture. They also show improved corrosion resistance and, in many instances, "superplastic" properties—that is, they can be deformed without any "localized yielding" in a manner similar to heated plastics and glass (Figure 3).

Nano materials have grains as small as hundredths of a micrometer and have the same advantages as ultrafine materials but to an even greater extent. In addition, nano materials have a multitude of unique characteristics, such as their magnetic properties, that are not yet fully understood.

Early efforts to produce ultrafine and nano materials employed conventional methods of powder compaction in which solid shapes were formed by compressing finely ground powders, usually at high temperature. However, that process produced materials with relatively high levels of impurities and numerous defects. Under the IPP project headed by Terry Lowe of Los Alamos, we use the Russian-developed technique called "severe plastic deformation" in which a material is put under severe stresses that breakdown, or "refine," the material's grains. Although there remains considerable work to optimize that process, the Russian technique is the first to produce solid shapes of high enough quality to be considered useful in load-bearing engineered structures.

The Ufa State Aviation Technical University in Ufa, Russia produces all of the ultrafine and nano materials used in this IPP project. Three other Russian institutes in Ekaterinberg and Tomsk study and test those materials for practical applications, and Los Alamos and Northwestern University use them to test theoretical models of material behavior.

Recently, the researchers in Ufa began to produce superplastically formed ultrafine titanium plates for endoprosthetic applications (Figure 4). We expect to establish a U.S. Industrial Coalition partnership before the end of the year that will expand this application to other areas of traumatic medicine and biomedical engineering. Another partnership would apply nano materials to the construction of permanent magnets with "structural integrity"—that is, magnets that can be formed into complex shapes and still retain their strength and resistance to fracture.

IPP also funds two projects related to

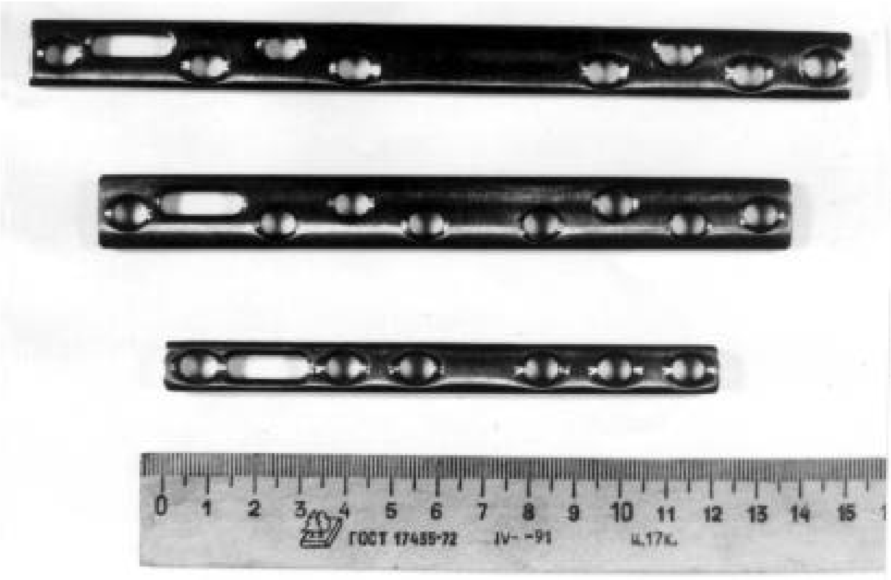


**Figure 4. An Application of Ultrafine Materials**

**The photograph above (taken at the Ufa State Aviation Technical University) shows endoprosthetic appliances produced from ultrafine-grain titanium. The "plates" in the picture are between 1.5 and 2 times stronger than conventional titanium alloys engineered for traumatic medicine applications. Even more importantly, these pure titanium devices will not react with the body's chemistry. They will be undergoing medical certification at the Research Center of the Republic Clinical Hospital in Ufa, Russia.**

nano and ultrafine materials. One is geared toward the production of nanocrystalline powders that are commonly used in cosmetics and paints as ultraviolet absorbers. In the other, Los Alamos is helping Russian scientists to convert a weapons facility at Chelyabinsk-70 into a manufacturing facility for superplastic roll-forming of turbine discs (see opening photograph). Industrial partners in that venture include Rockwell International Science Center, United Technologies Research Center, and several members of the U.S. Industrial Coalition.

## The Optical Microresonator

About twenty-five years ago, physicists conducting high-precision experiments approached the so-called "standard quantum limit," a theoretical bound on the accuracy of measurements on single objects (for example, a macroscopic oscillator or an electromagnetic wave) imposed by the fundamental principles of quantum mechanics.

Going back to thought experiments due originally to Bohr and Einstein, Vladimir Braginsky developed a theory of measurement called quantum non-demolition (QND) that outlined ways to overcome the standard quantum limit in different kinds of elementary measurements. Not only did QND eliminate any a priori limit on the accuracy of certain measurements, it also provided experimental recipes on how to make measurements without perturbing the quantity to be measured. For example, it indicated how the energy of a photon might be measured without destroying the photon. QND provided the capability to make repeated and predictable measurements on a single quantum system.

During the past decade, the principles of QND, as applied to electromagnetic waves in the optical band, have been demonstrated by researchers at NTT Basic Research Lab (Japan), Institute of Optics (France), and Cal Tech (U.S.). Despite those fine efforts, QND measurements have yet to reach the level of a practical technology because of the expense and labor associated with those experimental techniques.

Vladimir Braginsky and Vladimir Ilchenko of Moscow State University and Salman Habib and Wojciech Zurek of Los Alamos believe that simpler, inexpensive, and higher-resolution QND measurements are not only feasible but can also be the basis for useful applications. They are directing an IPP project to do just that.

A scheme has been proposed to measure the energy of a small number of photons in a resonator. The first and hardest step is to find a way to store photons in isolation for relatively long periods of time. One of the experimental schemes being explored under the IPP program is a new technology invented by the Moscow group called an "optical microsphere resonator." That device is a tiny sphere (30 to 300 micrometers in diameter) made out of very high-purity fused silica, or glass. The microsphere operates as a "photon trap," allowing only photons of very precise energy to enter. Due to total internal reflection, the photons glide continuously along the walls. They circulate inside the microsphere for a few microseconds—

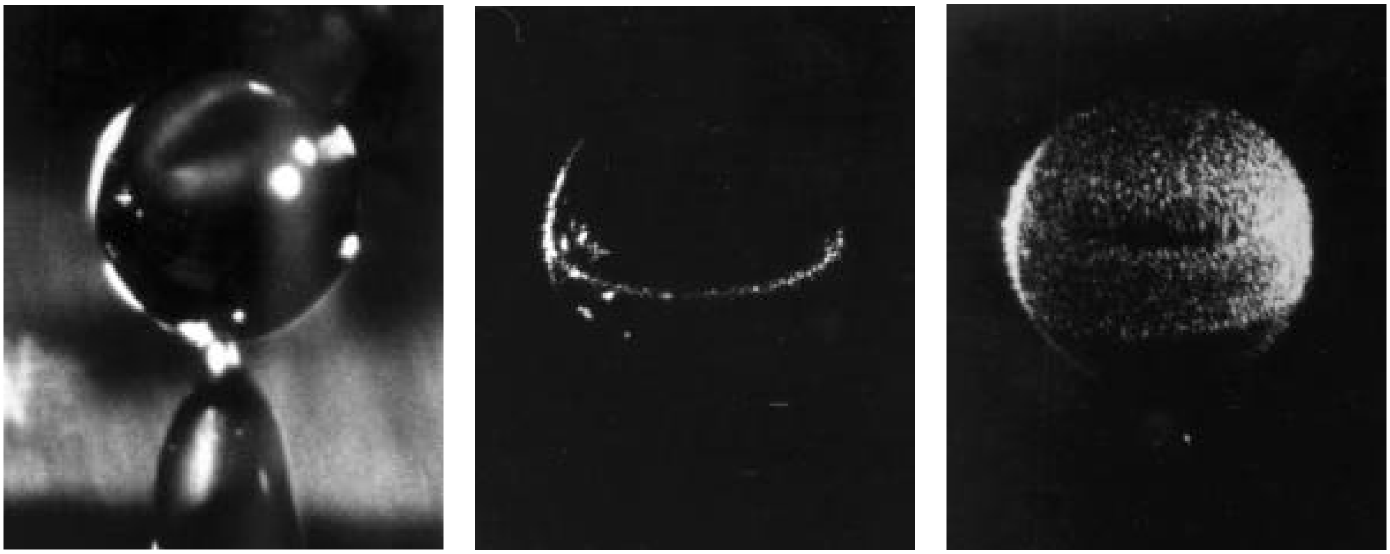


**Figure 5. The Optical Microresonator**

**The black and white photograph on the left shows the optical microresonator under external illumination. The photographs in the middle and on the right show photons trapped in two different modes of the microresonator. (The photons are from a helium-neon laser and are at a wavelength of 633 nanometers (red visible light.) The resonant modes are defined by the difference between two of the photons' quantum numbers, $l$ and $m$. The middle photograph shows the mode satisfying the relationship $l - m = 0$, and the photograph on the right shows the mode $l - m \approx 70$.**

long enough to perform successive measurements on the photons.

The photons occupy a "field mode" (such as the thin annular belt in the equatorial region of the microresonator shown in the middle photograph in Figure 5) of hardly any volume (down to $10^{-10}$ cubic centimeters). This allows very large electric fields to be established, even with only a small number of photons occupying the mode. For a single photon circulating in the microsphere, the field is larger than 100 volts per centimeter.

The index of refraction of the glass microsphere has a nonlinear component. Large fields produced by a relatively small number of photons in the "signal" mode change the refraction index in the mode area. That change can be monitored by the resulting shift of the resonance frequency of another "probe" mode that overlaps the signal mode. Absolute energy resolution in such a scheme can be made several orders of magnitude better than has been achieved in earlier QND experiments.

Successful QND experiments would allow attainment of the highest possible sensitivity permitted by quantum mechanics. On the way to that ultimate goal, the microsphere QND concept promises a host of less fundamental, yet important, technological spin-offs. The most obvious ones follow naturally from the microsphere's ability to choose photons of very precise wavelength. Relevant applications include high-resolution spectroscopy, investigation of fundamental loss mechanisms in transparent solids and liquids, and frequency stabilization of widely used semiconductor lasers (for which proof-of-principle experiments have already been conducted at Moscow State University).

The realization of QND measurements opens up another set of applications, wholly quantum mechanical, that arise from this new and intriguing ability to manipulate and non-destructively control an object's quantum states. The presently embryonic, but very exciting, areas of quantum computing and quantum communications are two areas where QND measurements will eventually find their natural niche.

## The IPP Information System

Early in the development of IPP, we realized that we would need an effective means of communication and a method for storing, tracking, and exchanging technical data. To meet those needs, Molly Cernicek of Los Alamos designed the IPP Information System, a secure and convenient computer-based system that provides information in near real-time to all the participants in the program. The Information System was built using "Lotus Notes Groupware"

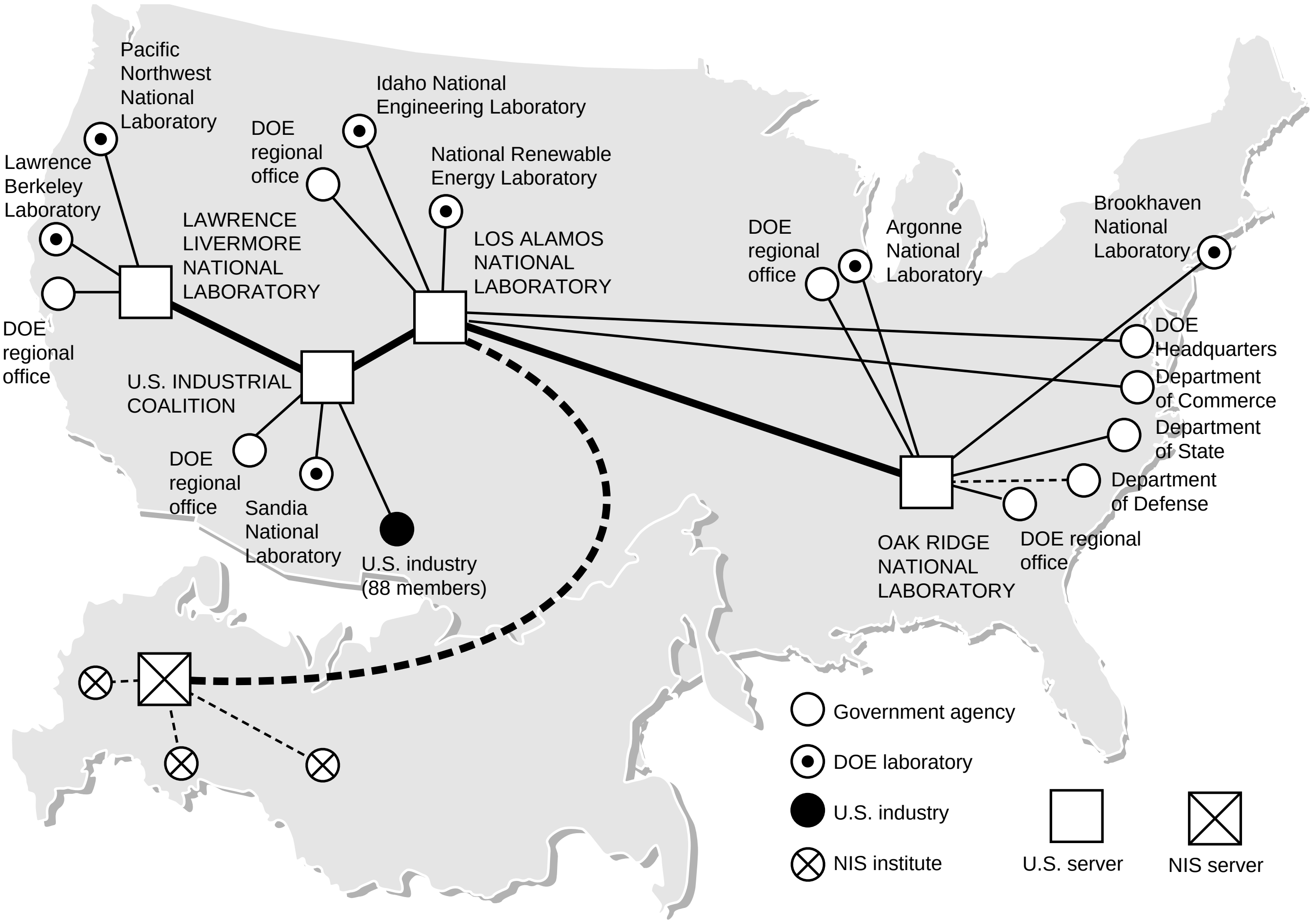


**Figure 6. The Net**

**The IPP Information System is a secure and convenient network of computers that provides effective communication of technical information between the participants in IPP. The current configuration (shown in solid lines) includes the Department of Energy and five of its regional offices, the Department of State, the ten participating DOE laboratories, and over 80 companies from the U.S. Industrial Coalition. Future servers and clients (shown in dashed lines) include the Department of Commerce, the Department of Defense, and most importantly, several nuclear institutes in Russia and other New Independent States.**

software. All information exchanged within the network is encrypted to provide security—that is, information can only be decoded by the computer to which it is sent. Furthermore, because the system is based on a single, comprehensive software program, it provides complete compatibility.

By October 1995, the IPP Information System had developed into the nation-wide network shown in solid lines in Figure 6. With few exceptions, the network relies upon existing Internet connections. The five servers in the network (the U.S. Industrial Coalition has two servers) house and share all the databases, which are "replicated," or copied onto one another, every hour. That way, all IPP participants have access to current IPP information in near real-time. In addition, the system holds dozens of clients representing DOE headquarters and regional offices, the ten participating DOE laboratories, the Department of State, and more than 80 members of the U.S. Industrial Coalition. Future clients in the United States include the Department of Commerce and the Department of Defense as well as both the government-to-government and the lab-to-lab MPC&A programs.

During the summer of 1996, we plan to connect several weapons institutes in Russia (see the inset in Figure 6) to the IPP Information System. Then NIS scientists will be able to use the Information System to electronically submit their own proposals for IPP projects and to rapidly establish relevant contacts with U.S. scientists and engineers. Because the IPP Information System facilitates the movement of NIS scientists from defense to paying peacetime work, it helps keep those scientists in their own countries and serves as a tool against nuclear proliferation.

Lastly, the Information System is used to track the progress of each project in terms of both the general goals of IPP and financial expenditures.

The IPP Information System enables IPP participants to collaborate with one another and to share knowledge and expertise unbounded by factors such as time and distance. Molly Cernicek, Mike Wyman, and their team of students, who put together this system, have introduced us all to what appears to be an interstate on the "information superhighway."

## Conclusion

The Industrial Partnering Program has funded nearly 200 projects involving over 70 NIS institutes and approximately 2000 NIS scientists and technicians since the program began in July 1994.

U.S. industry has shown great enthusiasm for IPP. For every dollar invested by the federal government in NIS-IPP collaborations, two dollars have been invested by members of the U.S. Industrial Coalition. We have received encouraging reviews from many sources, including the John F. Kennedy School of Government at Harvard.

Lastly, IPP has spontaneously integrated with the International Science and Technology Center (ISTC) in Moscow and its equivalent Center in Kiev (see "The International Science and Technology Centers in the Former Soviet Union"). IPP and ISTC are coordinated to avoid redundancy and to promote synergetic interactions among the participants. Several large projects, such as the superplastic forming facility at Chelyabinsk-70, are being funded by both programs, and because of that larger integrated effort, our projects have a greater chance of success.

IPP is a nonproliferation initiative with the added benefit that technology flows back to the United States as a result of the program's cooperative research and development activities. Programs like IPP have the opportunity to demonstrate the delicate balance between defense and industrial applications of advanced technology as well as promote and facilitate the transfer of NIS defense scientists to peacetime work. ■

## Acknowledgements

From a personal point of view, this has been a tremendously exciting and rewarding experience. I would like to take this opportunity to thank all of my Los Alamos colleagues who have provided support and encouragement for this program. Also, I would like to acknowledge the cooperation and support of my colleagues in the Departments of Energy and State who have become members of the team responsible for implementation of this program.

## Further Reading

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**Hugh Casey** is the project leader for IPP. Hugh earned his masters degrees in science and engineering from the University of Glasgow and the University of Strathclyde, Scotland. Upon moving to the United States, he worked in corporate research in the aerospace industry. While employed by United Aircraft corporation (now United Technologies), Hugh's research and development work with high-energy electron beams and industrial scale lasers included contract research work for Los Alamos and Lawrence Livermore labs. He joined the Chemistry and Materials Division at Los Alamos in 1972.

At Los Alamos, Hugh has worked on translating conceptual designs into engineered systems and developing advanced materials processing and fabrication facilities, particularly electron-beam, plasma, laser, and microwave systems. In his current assignment, Hugh is Chairman of the Interlaboratory Board, which consists of the ten DOE multi-program national laboratories responsible for implementing the cooperative projects with the weapons institutes in the former Soviet Union.

Hugh has numerous personal interests but is best known locally for his association with the Los Alamos Ski School, where he has taught as a certified PSIA instructor since 1978.