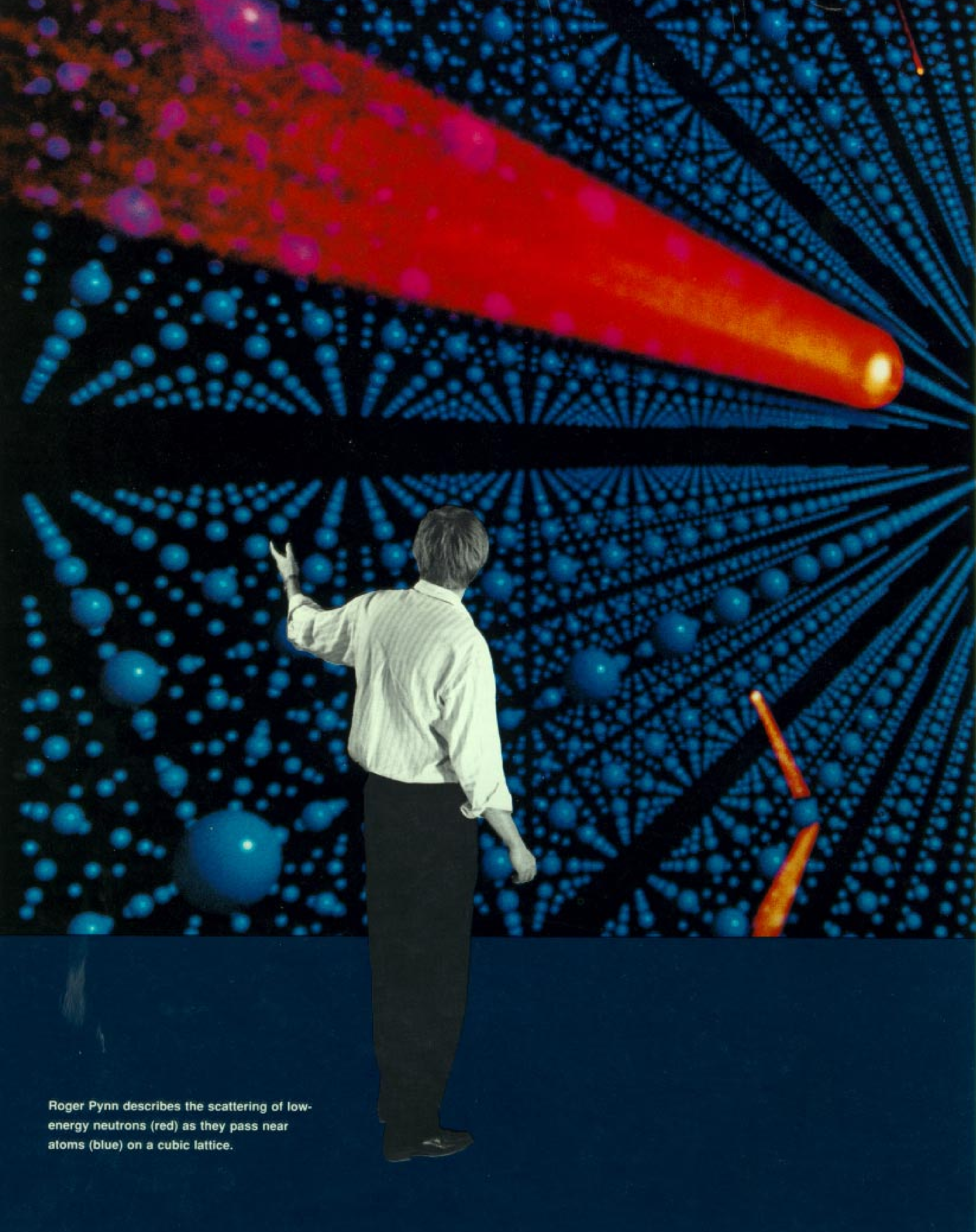
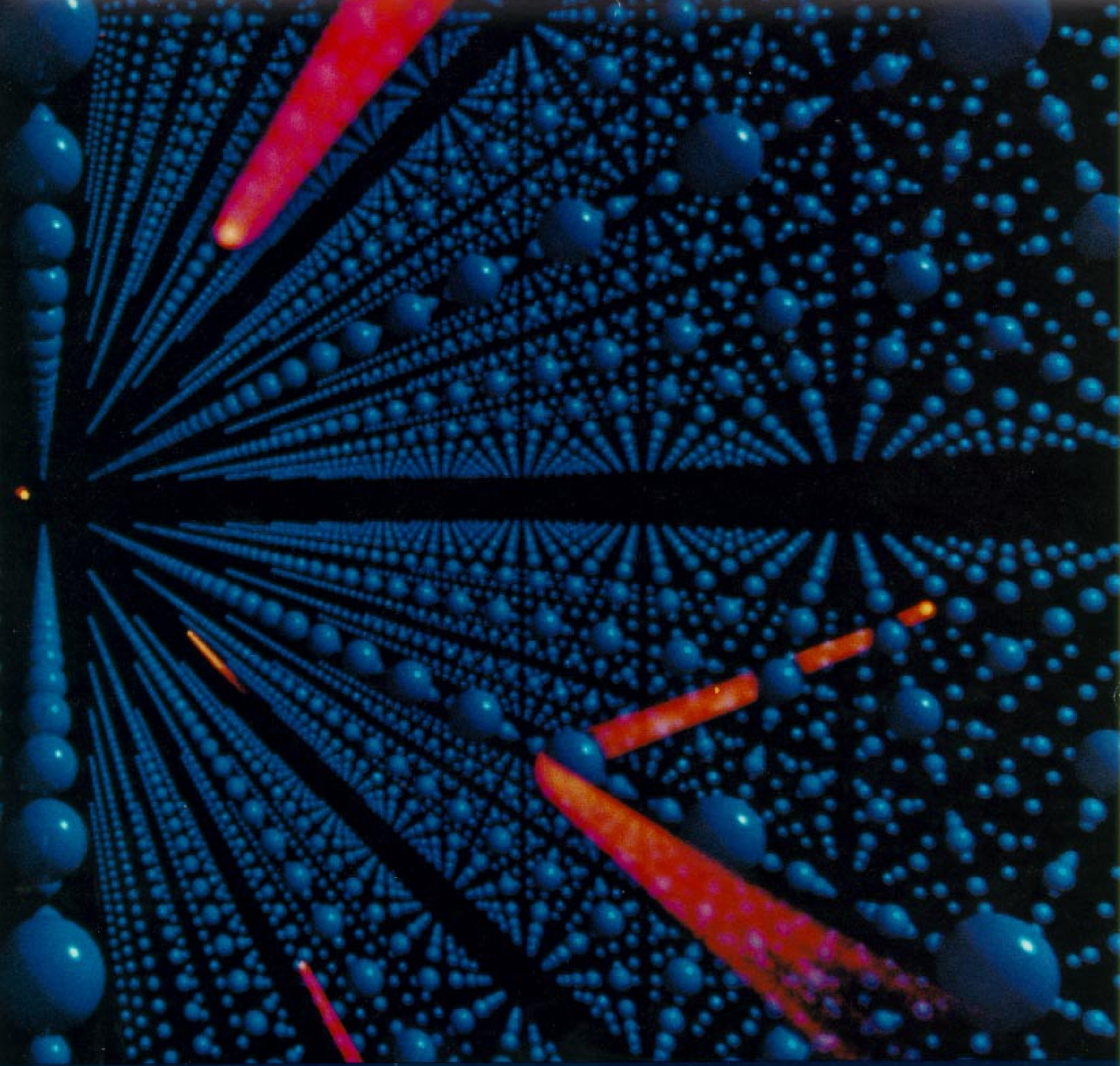


Roger Pynn describes the scattering of low-energy neutrons (red) as they pass near atoms (blue) on a cubic lattice.



Putting Neutrons in Perspective

An Interview with Roger Pynn

Imagine alchemists struggling in the dark with materials they do not understand; see modern industrialists trying to control the properties of polymers, colloids, and gels; think of a theorist grasping for the essentials of complicated nonlinear phenomena. Do you feel you need some solid ground? Neutrons traveling through mutter see mostly empty space, but their few interactions with nuclei begin to show us the structures of materials-concrete information that can crystallize our questions and theories into a framework of future discovery, Relating the basic properties of materials to their structures transforms alchemy to technology and binds industrial research to basic science. This is the world of neutron scattering.

As director of the Los Alamos Neutron Scattering Center, Roger Pynn is caught up in every aspect of this world. When the user rooms at LANSCE are jammed with biologists, chemists, physicists, and industrial researchers, he jumps from question to question and field to field in only the time it takes him to hurry through the halls. (There were times when we thought he might write all the articles for this issue instead of only three.) Even his own ongoing research projects range from phase transitions and surface phenomena to instrument design and data analysis.

Given the present state of neutron scattering in the United States, however, Roger's most important work may be as LANSCE's ambassador to the larger, more political world. In the last weeks of 1989, one hundred participants in a condensed- matter physics conference petitioned Presidential Science Adviser Allan Bromley for a new commitment to funding for neutron-scattering research. Citing aging facilities and a lack of young scientists entering the field, these researchers warned that the United States neutron-scattering effort may lose irretrievable ground to the thriving community in Europe. We inter-

viewed Roger to find out where LANSCE fits in this picture, and he gave us a unique perspective on neutron scattering's history and on the most pressing problems facing the field today.

Science: Last winter, a petition to secure funding for neutron scattering's future was sent to Presidential Science Adviser Allan Bromley. Can you explain why?

Pynn: The petition actually relates to the present as much as the future. Right now, the two most powerful nuclear reactors used for neutron scattering in this country are closed to address safety concerns. Brookhaven has been closed for nearly a year, and Oak Ridge has been closed for over three years. In addition, the National Institute of Standards and Technology reactor was closed during 1989 while neutron guides were being added. It is bad enough that these facilities haven't been available for research, but a larger and larger share of the neutron-scattering budget has also been spent on their safety studies and repairs—and that drains the budgets of the remaining facilities. For example, this year at LANSCE we'll be able to run our beam less than half the year, which means we won't accommodate nearly as many experiments as we'd like.

Science: Is the situation likely to improve in the near future?

Pynn: Well to make matters worse, these reactors are all around twenty years old, and their neutron-scattering instruments are antiquated. If funds were available, we could improve experiments at these facilities by a factor of five to ten simply by modernizing equipment. For a while, we wouldn't even need to worry about getting higher beam fluxes. I should say, however, that the future of this field depends on building facilities with higher beam fluxes. If the U.S. wants to keep pace with Europe and Japan, it is critical that we build a next-generation neutron source.

Science: Why is it so critical to keep pace? The petition to Bromley mentioned economic growth.

Pynn: As far as that goes, neutron scattering has all sorts of technological applications. We can use neutron diffraction to do nondestructive testing of residual stresses and strains in a wide variety of industrial products. Small-angle scattering can examine the structures of polymers and colloids, which are the basic ingredients of many modern materials. Neutron reflectometry can look at the structures of protective coatings and lubricants. Look what came across my desk today: "A Neutron Scattering Study of Diffusion and Permeation Processes through Pores in Clay." You can imagine applying that to underground waste disposal or oil mining. Really, the industrial uses of neutron scattering are endless.

> *The future of this field depends on building facilities with higher beam fluxes. If the U.S. wants to keep pace with Europe and Japan, it is critical that we build a next-generation neutron source.*

Science: So you argue that we should fund neutron scattering because it is crucial to the industrial future of the United States?

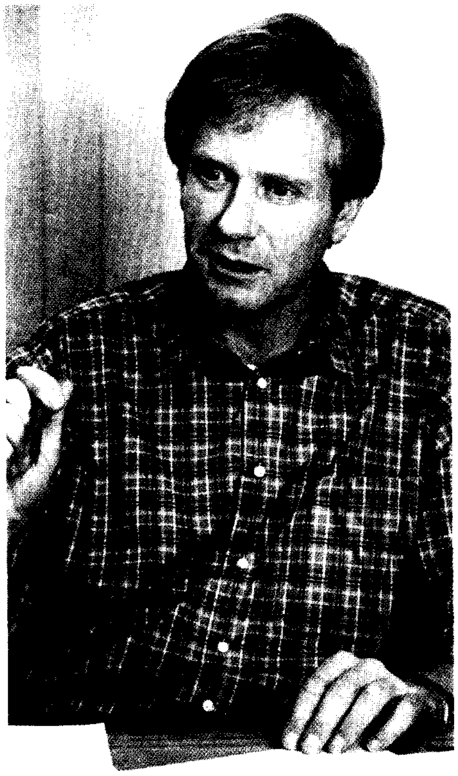
Pynn: Partly. I am very interested in promoting industrial uses of neutron scattering, but that's not the only reason to promote the technique. We should develop materials-research techniques and do science with them whether their applications are instantly apparent or not. For example, when new materials like high-temperature superconductors come along, you want to understand them and you use every resource you have--electron microscopy, nuclear magnetic resonance, neutron scattering, x rays, or whatever. In the case of high-temperature superconductors, neutron scattering gives unique information about structure because it can locate light elements and also look at magnetic properties. Researchers at Brookhaven were doing valuable experiments of this kind when the reactor was closed down. For other problems, other methods might be more valuable, but it is impossible to predict which ones. So we should maintain a capability in each technique if we want to have an effective materials research program. Furthermore, techniques need to be explored because they open new areas of basic interest. As a matter of fact, the development of neutron scattering illustrates this point quite well. Back in the forties, scientists shot neutrons into samples because they wanted to find out about the fundamental properties of this new elementary particle. Today, neutron scattering provides useful information about the samples themselves to physicists, chemists, and biologists in addition to all the industries I mentioned.

Science: Go back and tell us a little more of the early history.

Pynn: Soon after Chadwick's discovery of neutrons in 1932, researchers began trying to understand the properties of these particles by sending them through various materials. Theorists knew from quantum mechanics that neutrons would behave like waves, and that low-energy neutrons would produce interference or diffraction patterns much like x rays. But there were many theories and disagreements about specifics. For example, people wondered what details of the interaction between a neutron and a nucleus could be determined from a scattering experiment, and they wondered whether the neutron's expected magnetic field would resemble that of a bar magnet, a current loop. or something in between. Fermi resolved the first problem in 1936 by proving theoretically that the neutron-nucleus interaction is described by only one meaningful parameter—what we call today the scattering length. The second problem grew into a fertile debate between Bloch and Schwinger. In 1939, Halpem and Johnson suggested experiments to settle this argument and to test a number of other theories. But of course in the early forties, pressure from the Manhattan Project for critical neutron data was dictating most of the neutron research.

Science: Were these early neutron-scattering experiments much the same as those done today?

Pynn: Until the first reactors were built, researchers couldn't generate enough flux for anything but transmission experiments, but after the war Fermi and Marshall began experiments comparable to ours today. They measured neutron diffraction from a crystal whose structure was known from x-ray experiments-some simple thing like rock salt—and then they drew conclusions about the interaction of neutrons with different nuclei by comparing the neutron data with the x-ray data. At the same time, Wollan and Shun were using a similar method to study neutron diffraction from crystalline powders and getting some very important results. In 1947 they demonstrated that neutrons can see hydrogen atoms in a crystal, and that unique ability has become neutron scattering's great contribution to the study of biological systems. Another seminal experiment was Hughes and Burgy's verification of Schwinger's current-loop hypothesis. They produced the first fully polarized neutron beam by using magnetic mirrors—precursors to the reflection technique that we use today in neutron guide tubes. I should say that in all these experiments people were still primarily interested in understanding the neutron.



The great breakthrough for neutron scattering came in 1952 with the first [measurements of] the internal dynamics of condensed-matter samples.

It was the opposite of most research today, where we assume we know about the neutron and draw conclusions about the sample from the scattering.

Science: Even so, it sounds like the early researchers conceived of most of the techniques in use today.

Pynn: To a large extent that is true. Most of the gains made in neutron scattering have been technological. For example, if you want to make guide tubes that transport neutrons with minimum losses, you have to make glass which is optically flat enough and you have to learn how to vapor-deposit nickel. We have made many improvements like that. The neutron spin-echo technique that came along in the early seventies was a genuinely new method of getting high resolution without losing much intensity. but for the most part the basic experimental concepts go way back to the beginning.

Science: When did researchers start using neutrons to probe materials?

Pynn: Once the properties of the neutron were understood, it was natural to turn scattering experiments into a means of studying static crystalline structures—a change which occurred in the early to mid fifties. This wasn't a completely new research field, however; essentially it extended the x-ray crystallography work that had been going on for some forty years. The great breakthrough for neutron scattering came in 1952 with the first inelastic-scattering experiments, which investigated the internal dynamics of condensed-matter samples.

In an inelastic-scattering experiment, you measure the energy and momentum a neutron transfers to the atoms of a solid-energy which can then vibrate throughout the sample as a collective excitation called a phonon. Theorists had already described phonons as vibrational waves whose frequencies relate to the interatomic forces in solids, but neutron scattering was the first way to make measurements in real samples. Groups in France and the U.S. began measuring phonons using time-of-flight spectrometers, and in Canada Blockhouse began using what he called a constant-Q scan on his triple-axis spectrometer. Such a machine measures only at well-defined scattering angles and energy transfers, which makes for very precise, very focussed inelastic-scattering data. Blockhouse used to say something like you never get more data than you need from a triple-axis spectrometer, and you always get it at a rate that lets you figure out exactly what to measure next. As I said, many people were working to develop instruments for measuring inelastic scattering processes, but the three-axis spectrometer became the prevalent tool. For whatever reason, Blockhouse was able to apply it to a wider range of materials and problems than anyone else. Given the technology at the time, he made some spectacular measurements of phonons in semiconductors, and metals, and ionic crystals, and everything you can think of. He just knocked them off one after another.

The study of phonons in all sorts of materials became a major focus of neutron-scattering research throughout much of the sixties. As the experimental part of my doctoral thesis, for example, I studied the phonon spectrum of magnesium. I had this huge single crystal of magnesium—four inches long and an inch and a half across—and I measured phonons in the damn thing. Today people would say, "So what? Why would you bother to measure phonons in a single crystal of magnesium?" The answer is that we were just beginning to learn how to calculate phonon frequencies in metals from first principles, People would propose models of the different bonding forces in metals, calculate what the phonon frequencies should be, and then compare them with neutron-scattering measurements. If they didn't see agreement, they would go back and fool around with their models or come up with better ones. Efforts like those gave us a much better qualitative and quantitative understanding of what holds metals together.

Science: What were some other major discoveries from the fifties and sixties?

Pynn: Perhaps the most striking was Van Hove's elegant formulation of the neutron-scattering law in 1954. Before Van Hove people used neutrons to study structure and dynamics in a variety of ways, but they didn't understand how these different techniques related to each other. Van Hove's analysis unified the whole field of research. It brought together in one simple equation the static structure factor, which we measure in diffraction experiments, and the collective excitations, which we measure in inelastic-scattering experiments. Before Van Hove no one had really demonstrated the simplicity and power of neutron scattering as a research tool.

There were also neutron-scattering results which affected materials physics as a whole. In 1951 Cliff Shun used neutron diffraction to verify Neel's theory of antiferromagnetic structure, which said that in certain materials the magnetic moments of electrons line up in alternating sequences. There had been no way of proving the existence of such antiferromagnets until neutron scattering came along. Once this structure had been verified, people used inelastic neutron scattering to discover the collective excitations in these antiferromagnets and then developed theories to explain them. In 1961 neutron scattering was also used to observe rotons, a type of collective excitation in superfluid helium which Landau had predicted on the basis of God knows what genius.

Science: It sounds like neutron scattering research was beginning to broaden its scope. How did that happen?

Pynn: After a while it becomes tiresome to measure a sample of tedium boride for the seventy-fourth time just to find out what the interatomic forces are at some other temperature. In the mid sixties people gradually started to do experiments that involved some special physical phenomena; for example, if a material went through a ferroelectric transition, they would use neutron scattering to see whether the phonons had played a role in this transition. The motivation became, "Well, here is this phenomenon called a phase transition. What can we learn about it with neutrons?" rather than, "Here we have this piece of solid garbage on the shelf. Let's measure it."

Science: What is a phase transition?

Pynn: A phase transition is a disappearance of order in a sample of matter, brought on by a change in some external factor like temperature or pressure. Everyone is familiar with ice changing to water or water to steam, transitions in which the structural order as well as the bulk properties of the mat-

[Van Hove] brought together in one simple equation the static structure factor, which we measure in diffraction experiments, and the collective excitations, which we measure in inelastic-scattering experiments. Before [that], no one had really demonstrated the simplicity and power of neutron scattering as a research tool.

When I look at the theory of critical phenomena, it seems clear that the universality classes could not have been identified without the clues provided by [neutron scattering] experiments.

ter change suddenly; but there are also phase transitions in which order changes gradually. The order can be structural, or magnetic, or ferroelectric, or whatever. Since the early sixties, there has been a huge intellectual effort to describe the gradual changes in order as different systems approach the so-called critical point where order disappears altogether. By the early seventies, theorists succeeded in organizing these continuous phase transitions into universality classes defined by the way the order changes. They discovered that the symmetries of the system. and not the particular details of the forces responsible for creating the order, determine the universality class of the phase transition. Some very high-powered people have worked on this theory of critical phenomena, and a Nobel prize was given a few years ago for work in this field.

Science: How did neutron scattering contribute to this study?

Pynn: Let's take the specific example of' a magnetic phase transition. As you heat a magnetic sample, its spatially averaged magnetism will decrease continuously until you reach the Curie temperature [critical point] where the magnetism disappears completely. This might seem very simple, but it is not. Although the average magnetism goes through a smooth decrease, the magnetism at any point in the sample fluctuates more and more about the average as the sample nears its critical point. In addition, the fluctuations in magnetization at one point in the sample are correlated with fluctuations at a new-by point. As the Curie temperature is approached, the spatial extent of these correlations becomes very large and the fluctuations slow down. The way in which the correlation length increases and the fluctuations slow down-that is, the dependence on temperature—characterizes the universality class of the transition. Neutrons can measure both of these quantities, as well as the average magnetic order. Without all the neutron scattering experiments. I don't think theorists would have been able to understand these immensely complicated phenomena. Now when I look at the theory of critical phenomena, it seems clear that the universality classes could not have been identified without the clues provided by the experiments. So neutron scattering had a large role in that development.

Science: Was neutron scattering a well-recognized research field at that time?

Pynn: It was beginning to become one. Until the early seventies. the people doing neutron scattering were actually condensed-matter physicists who had become interested in the technique. More important than that. however, was the lack of dedicated research facilities. In the fifties and much of the sixties, neutron scattering was just a parasitic operation at research reactors that had been built to study things like isotope production and radiation damage. Those experiments had first priority at all the facilities because the people doing neutron scattering didn't decide the politics of reactor use. Instead, they hung around the edges, borrowing beam lines and setting up spectrometers when they could. The first reactor built exclusively for neutron scattering was the Brookhaven High Flux Reactor, which came on line in the mid sixties.

Science: Did the Brookhaven reactor begin the field as we know it today?

Pynn: I'm not sure I can define a beginning. Certainly the advent of the Brookhaven reactor gave neutron scattering a dedicated tool. but it didn't change things that drastically. Even though this new reactor was dedicated to neutron scattering, it was also dedicated. in a sense, to the few people who were employed at Brookhaven. Essentially, you still had a small neutron-scattering group working by themselves. The field as we know it today-with scientists from all over doing their re-


LANSCE operations manager Richard Woods with Roger Pynn and Dianne Hyer

search at large central facilities—started during the early seventies in Europe.

Science: Was there a definable beginning to this change’?

Pynn: The first real user facility—and incidentally still the pre-eminent neutron scattering facility in the world today—is the Institut Laue-Langevin in Grenoble, France. Sometime after the war, a German professor of physics by the name of Maier-Leibnitz proposed building a large research reactor as part of the France-German cooperative effort, and this reactor became the ILL. It was born of politics, not because people said. “We have to do neutron scattering.” It was born because the Germans and the French wanted to get together for scientific and cultural exchanges. As the rumor goes, it was born because Maier-Leibnitz had a relative who was close to Adenauer, but that may not be true, At any rate, Maier-Leibnitz persuaded the politicians that a reactor dedicated to neutron scattering was something they needed as well as a scientific need. Next, he toured the United States and Canada, which were strong in neutron scattering at that time, asking for advice about designing a first-rate research program. The advice was, “Well, first you build your three-axis spectrometers and get a program established, and then you think about doing something else.” Triple-axis machines were very popular at that time, especially in the United States, and many of the questions asked in inelastic neutron scattering were dictated by the machine’s characteristics. Even today that is true to a certain extent. Anyway, Maier-Leibnitz said, “Thank you very much, but I will not build a single three-axis machine at my institute.” And at first he didn’t. Instead, he hired a bunch of young people, many of whom knew nothing whatsoever about neutron scattering, and set them working on some of his own bright ideas. They were happy to try anything because they didn’t know what was impossible. They invented things and incorporated ideas from prototypical instruments at smaller reactors in France and Germany, and they wound up with all sorts of novel instrumentation-and only one three-axis machine when the institute became operational.

Science: What were some of Maier-Leibnitz’s bright ideas’?

Pynn: There were several. One of the great successes at the ILL has been the use of long-wavelength neutrons—what we call cold neutrons. There were other cold-neutron sources in operation at the time the ILL was built, but they were created by putting moderators on existing beams, Maier-Leibnitz proposed building the moderator in next to the reactor core so cold neutrons would be generated in copious quantities whenever the reactor was running, At the time, many people said the ILL people were crazy to tie the operation of the reactor and the cold source together in this way, Next, Maier-Leibnitz decided to use hundreds of meters of optically flat, nickel-coated glass tubes to transport neutrons away from the reactor and into a huge new guide hall where the background radiation would be low.

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This was an incredibly courageous decision given that guide tubes of that type had only been benchtop tested and cost several thousand dollars a meter. The ILL researchers also improved the angular resolution of small-angle scattering experiments by putting their detector 40 meters away from the sample—a distance that had never been tried before. There is still not an instrument in the world that comes close to the resolution of that machine.

Maier-Leibnitz also had some wild ideas that didn't work. For example. he wanted to replace triple-axis spectrometers with three separate remotely controlled units that could be moved around on air pads. So the ILL people laid down enormous, smooth marble floors called tanzboden, or dance floors, and built these air-levitated units—sort of nineteen seventies R2D2 units. Those things never worked as planned. In the end someone clamped them together into a traditional three-axis spectrometer that moved on air pads instead of on the naval gun mounts used in the sixties. That technology has now spread almost everywhere.

Science: Were these developments in instrumentation motivated by specific scientific questions'?

Pynn: Not really. Maier-Leibnitz had specific ideas about improving the measurement techniques themselves, and he knew this would lead to new and exciting science—an obvious idea that seems to have been largely misunderstood in the United States. Remember, neutron scattering is a signal-limited technique. You can't measure a particular effect unless enough neutrons reach the detector. Let's take a simple example. The original triple-axis spectrometers used big, flat monochromator and analyzer crystals. usually aluminum or copper or something else that grew well in single crystal form. That is analogous to doing optics with rather poor flat mirrors, and it is very inefficient. To maximize the intensity of a light beam, you usually use good-quality reflecting surfaces and focus the beam with curved mirrors or lenses. People tried all sorts of things to make single crystals more efficient at transmitting neutrons, for instance laying them on a table and beating them with a hammer. That helped a little bit but it wasn't very controlled.

Maier-Leibnitz and his co-workers thought they knew how to improve the flat crystals, and they approached this problem in a systematic way-tailoring new materials and using multiple crystals to achieve a focusing effect. Spectrometers today deliver much better intensity and resolution than the original instruments, mostly due to improvements in individual components rather than to increases in neutron fluxes.

Science: How do you increase the scattering efficiency of crystals?

Pynn: It is a very sophisticated technique that involves well-defined distortions of' the crystal. You start with a crystal that has less than a certain density of' dislocations, then you cut it to a specific shape, then you squeeze it along a specific direction usually while heating it to a certain temperature. This technique has really only been pursued at the ILL. which fits with their history of developing instrumentation. Let me say right now that one-third of the initial budget of the ILL was for instrumemt and spectrometer design and construction. By comparison. the plan for a next-generation source in the U.S. allots only one-fifteenth of the budget to instrumentation, and you know exactly what that will produce—nothing new.

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Science: How important has instrument development been to the field?

Pynn: Initially people used diffractometers and triple-axis machines, which limited experiments to a small range of' phenomena. Now we use small-angle-scattering instruments, backscattering instruments, diffuse-scattering instruments. time-of-flight instruments, spin-echo instruments. reflectomcters, and all sorts of' other things—and this variety is very important. Basically, you can imagine that any experiment you want to do exists in a space whose dimensions arc momentum transfer, energy transfer. and resolution. Because neutron scattering is limited by the flux of' neutrons you have in your beam, you must develop special types of instruments to get you into different corners of that space. A generic instrument simply won't take you everywhere. So people have built special new instruments to study phenomena involving high momentum transfer. or very high resolution, or low energies, or whatever specific problem they were interested in. The ILL has done a great deal to expand the momentum-energy space to which we have access. and spallation sources like LANSCE also expand it. I should point out that future experiments could fall anywhere in this space at random; so it is difficult to overemphasize instrument development.

Science: When did the ILL people begin inviting outside researchers to come and do experiments'?

Pynn: I suppose they must have realized the enormous potential of' the place once they began building all the spectrometers and opening all the beam lines. Mossbauer, who succeeded Maier-Leibnitz as director of' the ILL, really initiated the user system by encouraging proposals from universities and by setting up a committee to evaluate these proposals and decide who should get beam time. By attracting a variety of users, this system made a great contribution to the expansion of the field. The ILL uses it today, and we are copying it here at LANSCE.

Science: Say more about how neutron scattering came to be used for the widely varying research we see today.

Pynn: For the most part, the ideas came from outside the field, not from the professional neutron scatterers. I know that a very strong group from Oxford drove much of' the expansion of chemistry research at ILL, and the push toward uses in polymer science and biology also came from the outside.

Science: How did these outsiders find out that neutron scattering was such a useful tool?

Pynn: I can at least answer that question for the Oxford chemists. Sometime back in the late fifties, Cockcroft, who had been the director of the Atomic Energy Research Establishment at the Harwelt reactor, was made chairman of a committee to get university researchers involved in work at government labs. So be gave the people at the Harwell reactor the equivalent of $3 million in today's money to develop neutron scattering, and they drove up the road to Oxford and started trying to interest people. Among others, they talked to a chemist named John White, a real dynamo, and he started to figure out the experiments you could do with neutron scattering in chemistry. He later became one of the directors of the ILL. establishing strong connections with the chemistry group at Oxford.

Some physicists who began with neutron scattering also helped widen the field. for example Bernard Jacrot. He had been doing scattering experiments since the fifties, studying magnetism and magnetic properties-he did some of the early time-of-flight experiments. Anyway, the story goes that sometime during his stay at the ILL, Jacrot put a dump truck outside his office window, threw everything into it, and started doing biology instead. He was one of the people who showed the power of the contrast-matching technique. which is now almost second nature to biologists.

All these people came together at the ILL, So neutron scattering got a large facility where it could grow with influences from other fields, and Europe got a centralized facility where other fields could use neutron scattering. Today, for example, the U.K. sees the ILL as a training ground for Ph.D.'s in methods of research. No such movement happened in the United States. In the United States. small groups working around their own reactors never really got together, and that is as true today as it was twenty years ago.

Science: Why did that happen'?

Pynn: Perhaps it has something to do with the way things are funded here. I'm not a great fan of the peer-review system as it works in the U.S. because

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International Workshop on Cold Neutron Sources, March 1990

it doesn’t encourage cooperation or synthesis of ideas. Anyway, the sociology of neutron scattering in the United States has centered the work in small, parochial groups that are very defensive of what they have acquired over the years. In contrast, the ILL became a user facility-people from universities and laboratories came to do science there. Until quite recently the idea of a facility catering to outside users didn’t exist in the DOE. Isolated groups of professional neutron scatterers ran every one of the U.S. facilities.

Science: Did outside researchers come and ask to do experiments?

Pynn: The doors to the U.S. facilities certainly weren’t wide open. In the scientific sense, the neutron professionals determined everything that happened in neutron scattering. I’m not saying they didn’t do good science—they did—but the field was inbred and cut off from new ideas and influences.

Also, because researchers from different facilities did not cooperate and because there was no user group to ask for more facilities, the field got no money beyond what was necessary to keep the small groups going. In fact, the U.S. is missing two generations of scientists in neutron scattering. Almost all the people who were trained as postdocs at Brookhaven or Oak Ridge in the sixties and seventies couldn’t get a permanent job in neutron scattering and went on to something else. Despite my air of venerability, I‘m young in the American neutron-scattering scene. The number of twenty-five- to thirty-year-olds is essentially zero.

Science: Did your coming here coincide with the DOE’s idea of encouraging user groups?

Pynn: I think the idea of a designated user facility came earlier—near the beginning of this decade. A number of DOE panels have looked into neutron scattering. The first one asked what would happen to neutron scattering in the United States if its budget remained constant. They concluded that neutron scattering in the United States was very healthy, thank you. It was doing better than everybody thought because Americans were smarter and didn‘t need expensive, modern facilities. This mistake was eventually recognized when sufficient people managed to get out of’ the United States and see for themselves. After that, various committees were set up to look into the field, and they said, “We have to do better. The Europeans are way ahead of us, and [he Japanese are coming.” I remember sitting in front of one of these committees during a visit to Brookhaven during 1980. when I was still at the ILL. Various other labs had testified during that hearing, and the Oak Ridge people, for example, had said, “We had one hundred sixty visitors last year.” That was a nice introduction to my pie chart showing how all the ILL users broke out into different subjects. There were sixteen hundred of them—an order-of-magnitude difference!

Science: Has neutron scattering in the United States changed in response to these findings?

Pynn: It is not obvious to me that the sociology of the field has changed much here. There is just no coordinated leadership anywhere in this country. As a small beginning, LANSCE and the pulsed source at Argonne now have the same advisory board passing judgment on experimental proposals, but any talk of a national committee seems to fall on deaf ears. It is very hard to get people from the various facilities to work together at this, but we have to try and collaborate as we can. 1 don’t think the field will move ahead in the United States unless we do.

Science: Is that why you left the ILL and came here?

Pynn: Not really. You have to realize that the ILL has set the standard in neutron scattering for the last decade and will probably do so for the next, but I had basically done everything I wanted to do there. I had built a polarized-neutron spectrometer; I had participated in many exciting experiments; and I had worked throughout the ILL organization in various capacities. 1 could have stayed and done my own research there. but LANSCE was a challenge to me. After coming here as a consultant, I began to wonder if it could be made better than its European competition. I think we have succeeded in some ways, but we could do a lot better with only 20 percent more money.

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Science: Is LANSCE now a state-of-the-art neutron **source’?**

Pynn: Before answering that question we should ask if LANSCE is a state-of-the art spallation source. Most neutron-scattering facilities, and most of the ones I've mentioned today, use beams of neutrons produced by reactors. Spallation sources, on the other hand, direct a beam of accelerated particles onto a target, which then emits bursts of high energy neutrons. With that said, one way to answer my question is in terms of the reliability of the beam-delivery system.

In 1988, we had an awful time; on average, we had neutrons on the samples in our spectrometers during only 50 percent of the time we scheduled. Since we run a user program with people coming in from out of town, that is just a complete disaster. It really is. Suppose you have some guy come in with samples that last a few hours or days, and the beam is down. There goes $10,000 worth of samples to the wastebasket because they couldn't be run on the machine. So we made reliability our highest priority this year and finished with the beam operating 74 percent of the time. That is an acceptable level for a user program, because a lot of the 26-percent loss is an hour here and an hour there. In fact, that is almost as high a reliability as you can expect from a state-of-the-art accelerator source because they are incredibly complicated beasts. The accelerator itself has all sorts of power supplies and magnets. You need to tune beams to get them into closed orbits-all sorts of complicated things like that. If an accelerator has very high reliability—and some do-its design and performance are probably not at the forefront of technology.

Another way to ask if we're state-of-the-art involves the intensity of the neutron beams on our spectrometers. By the end of the 1989 run cycles, we had a higher peak neutron flux than any other spallation source in the world—and when the proton-storage ring is operating at full capacity, our neutron fluxes will be even higher.

Science: How does LANSCE compare with the best reactor sources?

IPNS/LANSCE External Program Advisory Committee

Pynn: I like to use our small-angle-scattering machine, the Low-Q Diffractometer, as an example, because many people thought spallation sources would not be suited to small-angle-scattering experiments. As always, the standard for any comparison in neutron scattering is the similar machine at the ILL. We have optimized the LQD at LANSCE so that our results are as good or better than the ILL's when we probe length scales up to 500 angstroms or so. At larger length scales the ILL instrument wins, but most experiments fall in the range I just mentioned. In that sense we are competitive. However, I have always taken the view that reactor and spallation sources are complementary—that you need both types if you want a complete neutron-scattering program. You can do a lot of things with each one that you can't do with the other. For example, spallation sources are better for powder diffraction, but a simple three-axis spectrometer at a reactor source still produces inelastic-scattering data that we cannot duplicate.

Science: Are you also competitive with the ILL in the number of users?

Pynn: In 1989, one hundred and eighty-six scientists were involved in experiments at LANSCE, and one hundred and twenty of them actually came and worked. In addition, about three thousand people are now on our mailing list. The IPNS at Argonne, which was the first neutron-scattering facility in this country to have a user program. has done a tremendous job of bringing in users and expanding the user community. We are gradually attracting more and more people from universities and

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industry, but it is a long uphill battle.

Science: In what sense is it uphill? Do people have to be very brave to try a neutron-scattering experiment?

Pynn: If you think of going to a facility to do something that you have never done before, just wanting to get the answer to your scientific question and not knowing exactly what is involved, you realize it must be quite daunting. Even going to the lab next door and borrowing a simple piece of equipment can be extremely difficult, and might even keep you from an important discovery.

Science: That's human nature isn't it?

Pynn: I guess, but the adventurous people who overcome these barriers can be extremely successful. Lots of people in Europe now use neutron scattering and no other technique. They may be at a university and have no lab of their own, but they can rely on doing neutron-scattering experiments at user facilities.

Science: They get hooked on the field?

Pynn: Perhaps they get hooked on going to Grenoble and skiing, either that or on French wine and cuisine! But I do think it is very important to overcome the barriers that prevent scientists from coming to user facilities, and we work very hard at it. In some sense the ILL succeeded because they required only a one-page experiment proposal and would pay travel fare and living expenses if they accepted it. So people had nothing to lose. The ILL is very unusual in paying those expenses; we don't have that kind of budget at LANSCE. Including the proton-storage ring, our budget in 1988 was between $14 million and $15 million dollars per year, whereas the ILL's was over $50 million.

Science: How do the committees determine who gets to do experiments?

Pynn: My answer to that depends on which hat I wear, my user's hat or my **LANSCE** director's hat. Recently I got the results from four proposals I submitted to the ILL. In that case I'm the user, so I sometimes think the ILL committees toss a coin and don't consider scientific merit at all. I had one proposal out of four turned down, you see, so I argue that the committee just didn't understand that proposal. I'm sure all users have that attitude, but we try, in principle, to get together a group of people who can judge. That is extremely hard to do. It comes back to the question whether theory should lead experiment or not. If I propose to you an experiment to look for Landau's roton, you will probably give me beam time, provided you understand the theory of the roton and understand that neutrons can find it. It is an essential experiment; I could end up verifying Landau's theory or demolishing it. But suppose I said to you, "There is an extremely good theory of magnetic excitations in a material called TMMC. Among other things it predicts four modes, and I want to see whether there really are four." You would probably tell me to do something rude, right? In fact, I took part in that experiment, and we happened to identify five modes instead of four. We got beam time only because we had proposed something else.

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Science: Do you think the committees are too conservative?

Pynn: Quite often, yes. That is one of the great disadvantages of the user system, and I assume it must be the same for a grant system unless you get somebody who says, "Let's risk it. This looks like wild stuff but it just may pay off." Even so, I'm sure an open system of proposals and reviews is better than a private party where a few people control and use the beam time.

Science: Who at your facility chooses the experiments?

Pynn: I mentioned that we have a joint program advisory committee with the facility at Argonne National Lab. People submit proposals to both facilities, and the committee breaks up into three subcommittees: one that looks at diffraction, one that looks at small-angle scattering and reflectometry, and a third that looks at inelastic scattering. Unfortunately, these are technique-oriented groups, so there may be only one person in each group who is an expert on a particular type of science. It is hard to be sure that you always get the best decisions out of a committee like that. But to have a wider scientific debate in each subcommittee, you need more members, and that costs money. The way to solve the problem, in my view, is to involve other scattering centers in the same committee and share the costs.

Science: Is there a collaborative arrangement for the people who come here to do science?

Pynn: Users aren't required to have any experience with neutron scattering to come do an experiment at LANSCE. Instead, we generally set it up so each user has a local contact, some card-carrying member of the neutron Mafia who doesn't mind what he shoots his neutrons at.

Science: Let's talk about your connection with the rest of the Laboratory.

Pynn: Well, we have a number of people from different divisions who work more or less permanently at LANSCE. We have people from the Life Sciences Division, someone from Materials Science and Technology, and someone from Chemical and Laser Sciences as well. That's about the extent of it right now. Even here inside the Lab there are still a lot of people who don't realize the useful information they can get with neutron scattering. I know this because I sat on a committee which reviewed proposals for internally supported research [ISRD], and last year a number of them could have used neutrons but didn’t propose to do so. They were not intentionally ignoring neutron scattering; they just didn’t think of it because they didn’t know it was available or what it could do. To a large extent that is our fault—we have to get the information out there. With that in mind, we have been trying to set up a committee with representatives from lots of different divisions to try and acquaint people with the neutron-scattering facility, and to teach them which experiments in their work can use neutrons. We hope they will eventually become advocates of neutron scattering in the Lab. In particular, I think we haven’t done a good job of selling to the weapons community. There is a communications problem because we are in an open area, and there are a number of us, including me, who can ‘t hear classified information.

Science: That’s right. You’re an alien.

Pynn: I’m an alien and if I’m going to discuss weapons-related neutron scattering with people, it has to be in a very generic sense—but that is often good enough. It is only when you are planning the details of the experiments that you need to know details of materials and composition or of shapes and forms and sizes, So I can usually tell someone whether their experiment makes sense without knowing classified details.

The problems I have as an alien are not technical; they're bureaucratic. One thing which seems to have changed since I came to work in Los Alamos is the thicket of rules about foreign nationals at DOE facilities. I can understand the need for security and I respect it, but some of the new rules aren’t well considered or in the national interest. For example, there was a draft regulation which would have prevented foreign nationals from using almost any computer at a DOE facility-including PCs—for any kind of work, classified or not. That’s not very smart. The U.S. needs its scientific contacts with the rest of the world-perhaps now more than in the past. So a sensible compromise has to be found which encourages international science and preserves national security. I have to say, though, I have never experienced any discrimination towards me here at Los Alamos. The people here are always very thoughtful and hospitable, even though the bureaucracy can sometimes give real meaning to the word “alien”-a green thing with horns that spies or worse.

Science: What do you see as the future of neutron scattering?

Pynn: I talked before about the need for a next-generation source. Ideally, we should build both a reactor source and a spallation source—and also keep the older facilities for more patient development of the field. That way we could do the science which needs high-intensity sources, and people would also have places to think, work, try new ideas, and train students without too much pressure. 1 don’t think you can have a very healthy program without such places. However, on a more realistic level, we need to expand our user base in order to generate support for at least one new source. If basic researchers and people from industry combined their support, their voice would be difficult to ignore. So we have to contribute as we can to technological and industrial problems, as well as to basic research. Finally, neutron scatterers need to speak with a unified voice and work together to produce a coherent national policy. At the moment, some of us are trying to create a national steering committee. If we can accomplish that and maintain the present fragile unity, I think the field will be poised 10 move ahead, ■

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