JULY ISSUE 2001

DATELINE LOS ALAMOS

U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

RADIATION BYSTANDER EFFECTS

An important discovery about the effects of low-level radiation on cells is altering long-held beliefs about risk assessment in radiation exposure.

Los Alamos National Laboratory biologist Bruce Lehnert's study of the effects of extracellular mediators, including proteins, from irradiated human cells on non-irradiated cells has confirmed the existence of the so-called "bystander effect," which essentially refers to radiation-induced effects in unirradiated cells.

The effect induces a response that could hold the key to the causes of gene instability that underly cancer, as well as other phenomena such as increases in cell growth that have been observed with low doses of ionizing radiation, radio-adaptive responses to low doses of radiation provide protection against the killing effects of subsequent high-dose exposure.

"We are studying cancer mechanisms at their most basic level, looking for pathways that may underlie genomic instability," Lehnert said. "Finding those pathways may show us how we can deal therapeutically with the health effects of radiation exposure."

According to Lehnert, mounting evidence suggests that many important effects of radiation can occur in the absence of direct irradiation of cell nuclei. Results from recent experiments show that at least some cancer-associated effects of ionizing radiation, including the

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Laboratory Director
John Browne

MESSAGE FROM THE DIRECTOR

July marks the 56th anniversary of the Trinity test near Alamogodo, N.M. No one knows why J. Robert Oppenheimer, the Laboratory's first director, chose the name "Trinity" for the test, but it signifies the dawn of the atomic age, the completion of the Manhattan Project and the first of many achievements for the Lab.

When Oppenheimer recruited employees for the Manhattan Project, he knew he would need a synergy of skills. He needed engineers, machinists, chemists, physicists and theorticians, along with many others.

That synergy and diversity of skills is still important today as we continue our work for the nation. As you will read in this month's Dateline, there are many Los Alamos research projects, ranging from biology to space science, that have recently celebrated success and demonstrate our range of scientific and technical expertise. I hope that you will enjoy this month's Dateline, which highlights some of the great science the Laboratory conducts.

What began as a crash effort 58 years ago has grown into a world-class laboratory whose great science, flexibility and resilience continue to respond to national needs and make valuable contributions to the foundations of science.

LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE
LOS ALAMOS

A MONTHLY PUBLICATION OF THE PUBLIC AFFAIRS OFFICE OF LOS ALAMOS NATIONAL LABORATORY

LOS ALAMOS NATIONAL LABORATORY, AN AFFIRMATIVE ACTION / EQUAL OPPORTUNITY EMPLOYER, IS OPERATED BY THE UNIVERSITY OF CALIFORNIA FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. W-7405-ENG-36

EDITOR
Kathy DeLucas

MANAGING EDITOR
Judith Goldie

SENIOR SCIENCE WRITER
Todd Hanson

E-Mail the Dateline staff at *dateline@lanl.gov*

CONTRIBUTING WRITERS
Nancy Ambrosiano • Kevin Roark
Kay Roybal • Shelley Thompson

CONTRIBUTING PHOTOGRAPHERS & ILLUSTRATORS
LeRoy N. Sanchez • Edwin Vigil
Shelley Thompson

PRINTING COORDINATOR
G.D. Archuleta

LOS ALAMOS NATIONAL LABORATORY
PUBLIC AFFAIRS OFFICE IN THE COMMUNICATIONS & EXTERNAL RELATIONS DIVISION
MS C177
LOS ALAMOS, NM 87545

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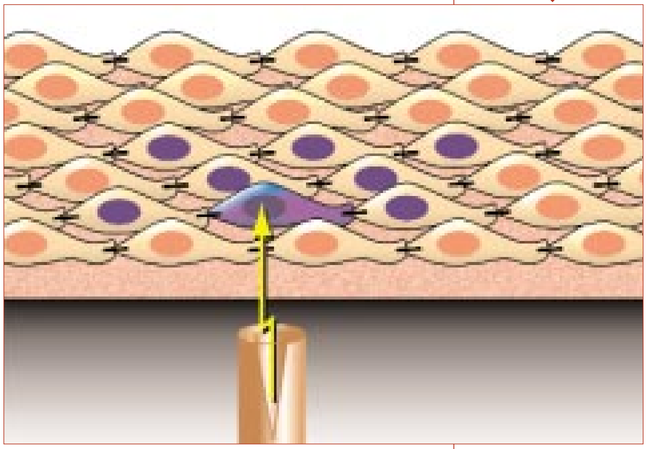
induction of genetic mutations, **can occur in cells that** have not been directly exposed to radiation. These results have profound implications for assessing cancer risk and other collateral effects of environmental, diagnostic or therapeutic exposure to ionizing radiation.

When Lehnert first came to Los Alamos nearly 20 years ago, he worked on the effects of toxic gases on the lungs and lung defense mechanisms. On the lookout for interesting problems in radiation biology, Lehnert was intrigued by papers on genomic instability that suggested a far-reaching phenomenon activates something in cells making them susceptible to damage even when their nuclei are not directly irradiated.

Recent advances in charged-particle micro-beam technology have provided a means to directly assess the consequences of irradiating cell nuclei as opposed to irradiating extranuclear regions. With these approaches, the nucleus and the cell's body, or cytoplasm, are differentially stained with compounds that fluoresce with different emission spectra when illuminated by ultraviolet light. This allows visualization of the subcellular regions so that the subcompartments can be preferentially targeted for irradiation by charged particles and the results observed. Such studies have confirmed that the irradiation of parts of cells aside from their nuclei can cause numerous effects.

Lehnert and his group obtained evidence that alpha particles like those emitted by radon, radon progeny and plutonium 238 can cause increases in sister chromatid exchanges – an indicator of DNA damage that involves symmetrical transfers of DNA fragments between two chromatids of the same chromosome – in normal human cells without direct nuclear traversals. They also found that these increases were maximally induced over a low-dose range in an "all or none" manner. They concluded that the excessive chromatid exchange response could have been induced by an effect of alpha particles in some region outside the nucleus and theoretically even outside the cell itself.

Radiation effects may be transmitted to unirradiated or "bystander" cells via gap junctions, shown below as bars between the cells. Studies of cells that are in direct contact with one another and that form these gap junctions, reveal that levels of proteins involved in cell cycle regulation are increased in more cells than experience radiation.



In further investigations, Lehnert's group found unequivocal evidence that this and several other cellular effects are mediated by the production of extracellular factors that transmit signals that produce responses in unirradiated cells to the same extent as those observed when cells are directly irradiated to low doses of radiation.

Definitively demonstrating that radiation can produce bystander effects on neighboring cells has introduced a new variable in risk assessment. Under some experimental conditions, DNA, or even whole cells, can no longer be viewed as the only relevant target for the actions of ionizing radiation, or even necessarily the most important target for eliciting at least some of the detrimental effects of ionizing radiation.

The Department of Energy has long been interested in individualized risk assessment for radiation exposure. Scientists are seeking to identify genes that play crucial roles in determining an individual's susceptibility to the effects of ionizing radiation and are looking for the mechanism that causes genes to become unstable. What is clear from Lehnert's work is that one important bystander effect is an increase in intracellular reactive oxygen species, which potentially can cause several types of DNA damage. A second important bystander effect is that the growth of cells is enhanced, and cells showing this response fail to stop growing when subsequently exposed to radiation.

"All of these features of bystander responses readily fit into current models of carcinogenesis," Lehnert said. "This makes this new area of radiobiological research so interesting and important. The bystander effect may or may not contribute to cancer, as yet we simply don't know its full health implications. The confirmation of its existence and newly available information about its causes, at least in cell culture systems, are already changing how we think about risk assessment."

CONTACT:
BRUCE LEHNERT
BIOSCIENCE DIVISION
505-667-2753 • LEHNERT@LANL.GOV

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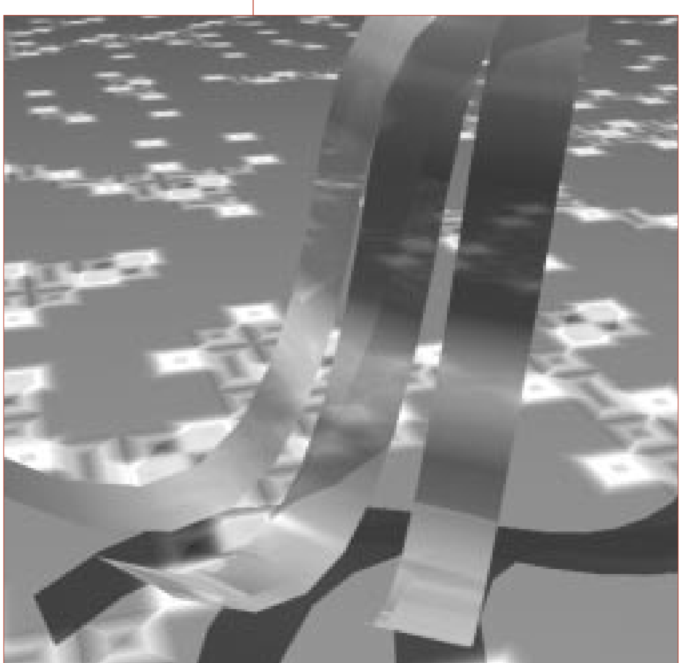
DATELINE FOLLOW UP

HIGH-TEMPERATURE SUPERCONDUCTING TAPE LICENSED

Los Alamos National Laboratory has licensed patents and applications related to its technology for manufacturing high-temperature superconducting tape to IGC-SuperPower of Latham, N.Y., a wholly owned subsidiary of Intermagnetics General Corp.

The Lab technology allows superconducting materials to be deposited onto a flat-formed tape that serves as a wire that can be made into cables and coils. Those can be used in motors, generators, transformers, transmission lines, fault current controllers that prevent lightning strikes from burning out controllers and energy-storage devices that allow energy to be stored when demand is low and used when demand goes up.

The tape, one-tenth the thickness of a human hair, can carry more than 100 amperes per centimeter width, which is 100 times the amount of current, or electric power, that can be carried through an equivalent area of copper wire.



Lab scientists have demonstrated the high-temperature superconducting tape works in short lengths – up to one-meter long. IGC-SuperPower intends to manufacture kilometer-long HTS tapes with the same superconducting properties and make this technology commercially available.

The technology licensed to IGC-SuperPower is the second generation of HTS tape and has superior superconducting properties – it will carry more current as compared to the first generation of HTS tape that is already commercially available.

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High-temperature superconductor materials carry electrical currents without any resistance, or loss of energy, when cooled with liquid nitrogen. Since the discovery of these materials' superconducting properties in the late 1980s, researchers have sought ways to produce flexible wires or tapes from the normally brittle substances for use in electric motors, transformers and magnetically levitated trains. In 1995, a Los Alamos team developed a method of depositing a superconducting ceramic known as yttrium barium copper oxide, or YBCO, on inexpensive nickel-alloy tape by first applying a buffer layer of cubic zirconia. This layer of zirconia imposes the crystalline alignment necessary for the YBCO to maintain superconductivity.

Researchers deposit the zirconia layer using two ion beams in a process known as ion-beam-assisted deposition. The first beam removes material from a zirconia target and deposits it on the nickel tape. The second ion beam, aimed at the tape, orients the zirconia grains as they are deposited. A subsequent pulsed-laser deposition of YBCO film – a mere one millionth of a meter thick – on top of the aligned zirconia allows the YBCO grains to mimic the crystalline alignment of the zirconia buffer, which improves the tape's superconducting properties.

CONTACTS:

DEAN PETERSON

MATERALS SCIENCE AND TECHNOLOGY –
SUPERCONDUCTIVITY TECHNOLOGY CENTER

505-665-3030 • DPETERSON@LANL.GOV

BRIAN NEWNAM

MATERALS SCIENCE AND TECHNOLOGY –
SUPERCONDUCTIVITY TECHNOLOGY CENTER

505-667-7979 • BNEWNAM@LANL.GOV

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A NEW LOOK AT OLD FISSION MYSTERIES

When theoretical physicist Peter Möller worked on his thesis at Los Alamos National Laboratory in 1973, his calculation of the nuclear potential energy for 175 different nuclear shapes, or grid points, pushed the limits of existing computational power. Using one IBM computer punch card to define each grid point, Möller's total input data card deck for the calculation was about one inch thick.

Much has changed in the field of high-performance computing and modeling since Möller did that calculation. Punched cards are obsolete, computing has become ubiquitous and Laboratory physicists like Möller now use computers to explore their theoretical models in previously unimaginable detail. Faster, more powerful computers mean that the number of grid points or data sets (in this case the number of nuclear shapes) that can be investigated can now run in the hundreds of thousands or even millions.

Recently Möller, together with David Madland and Arnold Sierk at Los Alamos and Akira Iwamoto of the Japan Atomic Energy Research Institute, had yet another chance to push the limits of computational power at Los Alamos and at the same time help to further unravel one of the great mysteries in nuclear science – the process of nuclear fission.

Theoretical physicist Peter Möller shuffles a deck of computer punch cards made obsolete by modern computers. The Avalon cluster of 144 interconnected computers, in the background, greatly expands the scientist's ability to define different nuclear shapes.

Since its discovery in 1938, the phenomenon of fission has frequently been explained in terms of a liquid drop. In such a depiction, when a nucleus starts to deform the energy increases, caused by the surface tension of the drop. If the nucleus deforms, but is stopped early in the deformation process, it snaps back to its original shape just like a rubber band that is pulled out and released. But if the nucleus is deformed beyond a certain configuration – beyond a point of no return – it snaps, and like the rubber band, the two fragments fly apart.

Möller's computer model is based upon a similar analogy of a ball being pushed up toward a mountain pass. The pass itself represents the point of no return: after being crossed the ball will roll down into another mountain valley. The height of the mountain pass corresponds to the threshold energy of the fissioning nucleus. Since a five-dimensional energy landscape cannot be visualized on a two-dimensional sheet of paper, unlike that of a geographical map, a challenge in the group's research was to establish which of the many passes in the five-dimensional energy landscape represented the relevant fission threshold. This problem was solved by considering, in the computer model, imaginary water flowing in five dimensions.

Möller's model used nearly three million physical grid points to define critical shape coordinates related to various aspects of elongation, neck diameter, emerging fragment deformation and mass division in the fission of radium and fermium. Because several million grid points and five shape dimensions are required to reach a sufficient level of physical detail to adequately describe fission, structures such as those revealed in the calculation by Möller and his collaborators had never before been seen or identified in nuclear structure calculations.

The results of this groundbreaking research have allowed a number of fundamental conclusions to be drawn about the fission process. First, there are several fission paths possible for most heavier nuclei, which means the fission process is more complex than is accounted for in most existing models. Second, for lighter actinide elements like radium and thorium, two paths dominate: one mass-asymmetric, with division into unequal fragment masses, and another mass-symmetric with equal fragment masses. Finally, the calculations are in agreement with experimental observations that for elements lighter than fermium – that agreement being that the average kinetic energy is higher for the asymmetric mode than for the symmetric mode. The calculations also reproduce, for the first

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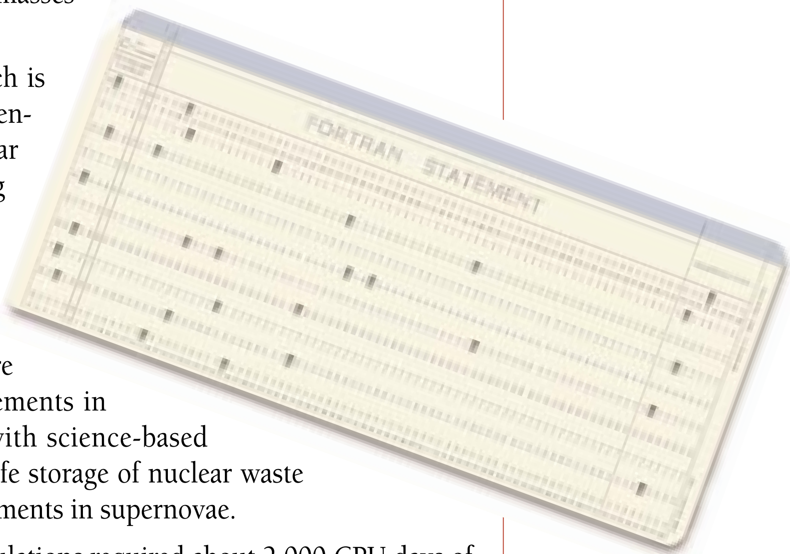
time, the average fragment masses observed in fission.



The net result of this research is a greater and more comprehensive understanding of nuclear structure and the underlying mechanisms behind nuclear fission. The new insight into fission obtained from the computer studies by Möller and his colleagues are expected to lead to improvements in related models associated with science-based stockpile stewardship, the safe storage of nuclear waste and even the synthesis of elements in supernovae.

The group's most recent calculations required about 2,000 CPU days of computer time to process and were performed on the Avalon cluster at Los Alamos – a group of 144 interconnected computers running at 500-MHz each. Funding from the Department of Energy's Offices of Defense Programs and Science supported Möller's work.

A relic of computations past, punch card technology would have been prohibitively slow.

Contact:
PETER MÖLLER
NUCLEAR PHYSICS
505-665-2210 • MOLLER@LANL.GOV

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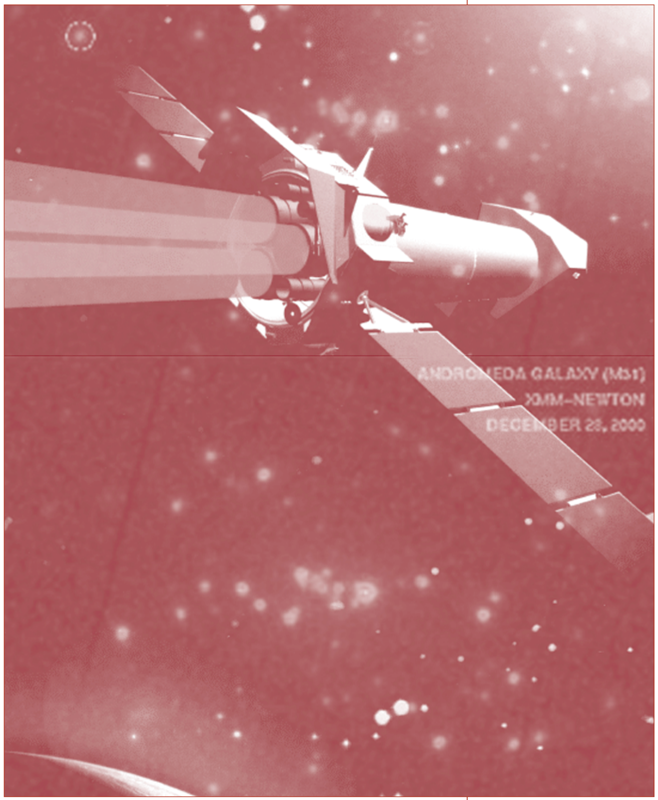
XMM-NEWTON MAKES UNUSUAL DISCOVERIES IN ANDROMEDA GALAXY

In its first look at the Andromeda Galaxy, known as M31, the X-ray multi-mirror satellite observatory has revealed several unusual X-ray sources. In examining new satellite data, an international team of scientists, including researchers at Los Alamos National Laboratory, discovered an unusually bright spot created by an enormous X-ray nova outburst. Another mysterious object has been found as well: One of the "coolest" sources of the central region appears to be a luminous white dwarf with an extremely soft energy spectrum and the shortest X-ray pulsation period seen to date.

XMM-Newton carries three very advanced X-ray telescopes, each containing 58 high-precision concentric mirrors, nested to offer the largest collecting area possible to catch the passing X-rays. These mirror modules allow XMM-Newton to detect millions of sources, far greater than any previous X-ray mission.



The report on these and other results was presented recently by Sergey Trudolyubov of Space and Remote Sensing Sciences at the 198th American Astronomical Society meeting.

The Andromeda Galaxy, the closest spiral galaxy to our own – 2.6 million light years away – is a unique object for the study of X-ray astronomy. M31 is in many respects similar to the Milky Way and even called its "twin sister." The Andromeda Galaxy hosts hundreds of X-ray sources, which are observed at a nearly uniform distance, because of the favorable orientation of the M31, they are less obscured by interstellar gas and dust than those in the our galaxy.

"Because the solar system is situated in the galactic disk, we have a somewhat distorted view of our own galaxy, like that of a fly sitting on the elephant's ear," explained Konstantin Borozdin, also of NIS-2. "But we are in a good position to study the Andromeda Galaxy, which is very much like our own Milky Way."

XMM-Newton, the most powerful X-ray observatory ever placed in orbit, observed the central region of M31 in June and December 2000 during the performance verification phase of the mission. The international team of researchers detected more than a hundred discrete-point X-ray sources, some of them previously unknown. Most of the detected sources were identified with X-ray binaries, accreting systems containing either a white dwarf, a neutron star or a black hole fed by gas flow coming from a companion star.

One of the new sources, X-ray nova XMMU J004234.1+411808, was extremely bright in June but was not detected at all half a year later. In a previous 30 years, only two dozen similar outbursts have been detected in our galaxy. Scientists still argue on the physical origin of these events. However, it is recognized that they are usually caused by the sudden release of a huge amount of emitting matter spiraling into a black hole.

The observations of X-ray novae provide unique information on the processes in the immediate vicinity of the compact objects, which is why each outburst attracts a great deal of interest. Novae are bright not only in X-rays, but also in other parts of the spectrum. Thus, the simultaneous observations in the X-ray, optical and UV bands are of special importance to understanding of the structure of these objects.

Realizing the importance of the coordinated observations of the X-ray novae with different instruments, the XMM-Newton group at the Laboratory and the Chandra team at the

Harvard-Smithsonian Center for Astrophysics have agreed to inform each other immediately of new sources within M31. In addition, another valuable space observatory resource, the Hubble Space Telescope, will follow up the nova imagery in a visible light and UV band.

The unprecedented sensitivity of XMM-Newton allowed a detailed study of spectral and temporal properties of several dozen X-ray objects. As a result, several main classes of sources were found. “This is the first time we are really able to study the individual properties of the binary systems in M31 millions of light years away and compare them with that of our own galaxy,” said Trudolyubov.

One class includes relatively bright objects with extremely soft energy spectra, implying the temperature of accreting gas lower than 1 million degrees Kelvin, 10 or even a 100 times lower than in the other sources detected in M31. It is likely that most of the emission of such “cool” sources is created by steady thermonuclear burning of enormous amounts of matter falling onto the surface of a white dwarf. Most exciting is that one of these sources, first detected by XMM-Newton, demonstrates X-ray pulsations with a period of nearly 900 seconds, the shortest ever observed in such systems.

The remaining classes of objects may be associated with either transient or persistent X-ray sources containing a neutron star or a black hole. Several bright objects are associated with globular clusters, compact spherical concentrations of tens or even hundreds of thousands of stars. The spectral properties of these objects are strikingly similar to the globular cluster sources observed in our own galaxy, proven to be the systems with neutron star primaries.

The identification of the discrete X-ray sources in M31 with various types of compact objects, which is based mainly on their spectral properties, needs further work. To finally resolve a debate on the mysterious nature of these systems, a greater number of X-ray instruments is needed (for example, to detect short thermonuclear bursts from the neutron star sources).

Several more XMM-Newton observations of the Andromeda Galaxy are scheduled as well. It is expected that they will bring important insights into the nature of the X-ray sources in M31.

The European Space Agency's XMM-Newton was launched from Kourou, French Guiana, on Dec. 10, 1999.

For more information on the satellite and its mission, see http://sci.esa.int/xmm/ on the Internet. High-resolution digital versions of the X-ray images and other information associated with this release are available at http://nis-www.lanl.gov/~tsp/pressrelease.html online.

CONTACT:
SERGEY P. TRUDOLYUBOV
SPACE AND REMOTE SENSING SCIENCES
505-665-0019 • TSP@LANL.GOV

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NEWNET STATIONS BOUND FOR BILBINO

A network of United States-based environmental monitoring stations will eventually expand to include a Siberian nuclear plant, thanks to a multilab multinational effort.

NEWNET, the Neighborhood Environmental Watch Network based at Los Alamos National Laboratory, consists of stations that have sensors for monitoring wind speed and direction, ambient air temperature, barometric pressure, relative humidity and ionizing gamma radiation. The heart of the system, usually mounted on tall, slender metal stands with antenna built in, is the software and computers that transmit the data to a meteorological satellite and thus to the laboratories and to the public via the Internet.

The NEWNET staff at Los Alamos has partnered with the International Center for Environmental Safety, an organization with directors in Moscow and at the Idaho National Environmental and Engineering Laboratory, to pursue the goal of establishing monitoring stations around the Bilibino community of northeastern Siberia. Key partners also include Pacific Northwest National Laboratory and Sandia National Laboratories, whose staff has been instrumental in coordinating the effort. “This isn’t something that just happens, you have all these players to coordinate,”said Los ALamos researcher Larry Sanders. “None of us could have done this without the other.” The project is funded by the Department of Engery’s Office of Nonproliferation and National Security.

The plan, still in its early stages, is to find a way to install NEWNET stations in the vicinity of the Bilibino power plant, the first Russian nuclear power station built above the Arctic Circle. The town is in the central part of the Chukotka peninsula, closer to Nome, Alaska, than to Moscow, and the plant provides electricity for the regional mining industries. It has four small graphite-moderated reactors, used for electricity production and to heat water for the city's central heating installation. The power plant, producing 48 megawatts, is not far from the Bering Strait.

For the Bilibino project, the station locations will be selected on the basis of likely dispersion patterns and prevailing winds around the nuclear plant. Now retired Los Alamos researcher Cheryl Rofer notes that siting decisions will also take into account information relating to terrain, conversations with local residents, precipitation data and similar information. The equipment will be Russian wherever possible, both for ease of access and repair, and one challenge will be to make the U.S. and Russian systems compatible.

NEWNET was started in 1993 with stations in Nevada, California, Utah and New Mexico. It is based on concepts developed by DOE for the Community Monitoring Program at the Nevada Test Site Nuclear Testing Facility.

Current NEWNET units, placed across New Mexico and in several locations in Alaska, are solar powered but with some battery/electrical backup for dark winter days. For Bilibino, some may be close to the plant and have access to the electrical power. Others may need other sources of energy such as wind-energizing storage batteries in anticipation of dark or cloudy days. If the Russian power station staff has developed ideas for improving cold weather performance challenges, existing stations in Alaska may benefit from the new information as well.

CONTACT:
LARRY SANDERS
INTEGRATED INFORMATION MANAGEMENT
505-667-3492 • LSANDERS@LANL.GOV

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BRIEFLY . . .

For the fifth year, Los Alamos hosted the Earthwatch Student Challenge Awards Program. Eight high school students from across the country came to Los Alamos to explore the world of transient phenomena in astrophysics at Fenton Hill Observatory west of Los Alamos.

The Earthwatch students became familiar with the Fenton Hill Observatory site and learned to use various telescopes for both visual observations and electronic imaging. The goals of the expedition were to identify new transient sources and locate a list of double stars – stars that are very close together. Several modest radio telescope components also were in place at the observatory for the students to observe galactic radio sources.

Earthwatch Institute's goal is to educate the public about science and technology to create a more informed populace. Earthwatch works toward this goal by sponsoring awards expeditions for talented students.

A MONTHLY PUBLICATION OF LOS ALAMOS NATIONAL LABORATORY

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DATELINE LOS ALAMOS

A Monthly Publication of the Public Affairs Office of Los Alamos National Laboratory

Nonprofit Organization
U.S. Postage Paid
Albuquerque, NM
Permit No.532

LALP 01-1-7

Los Alamos National Laboratory

NNSA National Nuclear Security Administration