DATELINE LOS ALAMOS

U . S . DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

AIR MONITOR INSTANTLY DETECTS BERYLLIUM

NEW MONITOR WILL REDUCE RISK OF WORKER EXPOSURES TO HAZARDOUS MATERIALS

Researchers have developed a portable, ultrasensitive air particulate monitor that instantly and continuously identifies virtually all known constituent elements in the periodic table and their relative concentrations. The instrument will greatly reduce, and in some cases eliminate, the risk of worker exposure to hazardous materials.

The inexpensive device, which can be used indoors or out, takes advantage of the fact that all elements in the periodic table have well-characterized atomic energy levels. A miniature microwave plasma source in the device excites the atoms, permitting quick, easy identification of air particulate samples based on the energy levels of those elements. With a minor modification, the device also can identify elements in solution.

The monitor is ideal for facilities that handle highly hazardous materials such as beryllium. Exposure of workers who are sensitized to beryllium can lead to chronic beryllium disease, which scars the lungs and can be fatal. There currently are more than 100 cases of chronic beryllium disease within the Department of Energy complex.

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A primary deficiency in protecting workers from exposure to airborne beryllium particulates has been that exposure levels were always determined after the fact through laboratory analyses. The new Los Alamos-designed instrument can provide real-time feedback to workers, allowing them to take prompt action and avoid overexposure.

DOE recently lowered the beryllium exposure action limit to one-tenth of its former level, from 2 micrograms per cubic meter to 0.2 micrograms per cubic meter.

At its current state of development, the new portable monitor can reach a detection limit for beryllium air samples of 0.12 micrograms per cubic meter. In solution, the monitor possesses a beryllium detection limit as low as nine-trillionths of a gram per milliliter.

The monitor is about 10 times more sensitive for air particulate monitoring than laser-based techniques, which are the only field technologies currently available. The new monitor also is easier to use and can detect and quantify multiple elements simultaneously.

The microwave plasma source-based monitor possesses several other advantages over inductively coupled plasma atomic emission instruments, which are used for analyzing air and solution samples. These include better tolerance to air particulate sampling, lower power and gas consumption, and smaller size.

DATELINE
LOS ALAMOS

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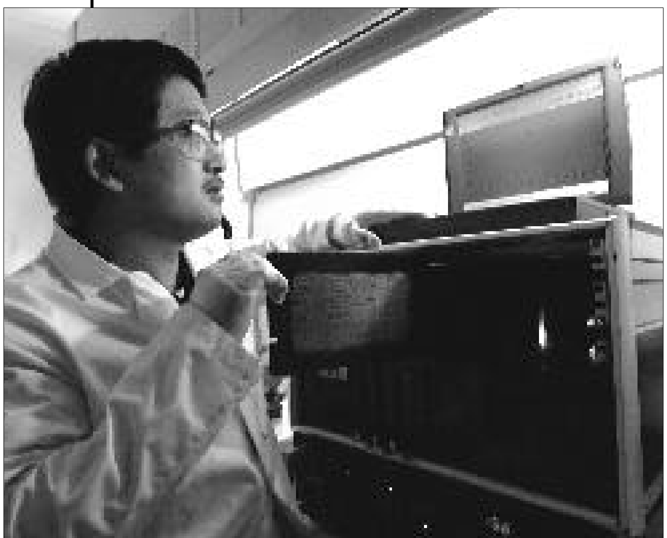

↑ Researcher Yixiang Duan reads experimental data on the notebook computer sitting on top of the beryllium air particulate monitor. The monitor normally is operated with the front panel in place. It has been removed for this photo to show the plasma source (the flame on the right inside the monitor).

Researchers pump an airborne sample through a tube into the heart of the microwave plasma source. Argon and helium are most frequently used as plasma gases for analyzing metal and nonmetal elements. A fiber-optic cable alongside the plasma source detects the optical emissions from the elements and feeds that information to a palm-sized spectrometer, which converts the information into a graph that shows each element's specific wavelengths and signal peaks on a laptop computer screen. The wavelengths identify the elements; the peak intensities reveal their concentrations.

Samples in solution are analyzed in the same way. The operator simply changes the initial air sampling pump to one suited for handling solution samples. Results are virtually instantaneous, requiring about 100 milliseconds.

The monitor weighs about 55 pounds and is about the size of a milk crate. The Los Alamos team currently is shrinking it further and making it easier to use. A patent is pending. Initial funding came from Los Alamos' Laboratory-Directed Research and Development (LDRD) Program. DOE's Defense Programs Office provided additional funds through its Advanced Design and Production Technology Initiative.

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MODELING ACCELERATORS OF THE FUTURE

BY COMBINING WORLD-CLASS CAPABILITIES IN ACCELERATOR PHYSICS AND COMPUTER SIMULATION, A LOS ALAMOS TEAM IS HELPING TO REVOLUTIONIZE THE DESIGN OF NEXT-GENERATION ACCELERATORS

The Department of Energy's Spallation Neutron Source currently is under construction at Oak Ridge National Laboratory. Once operational some time in 2004-2006, it promises to provide the scientific and industrial research communities with a much more intense source of pulsed neutrons than currently available anywhere in the world for conducting cutting-edge neutron scattering experiments in materials science, condensed matter, magnetism and many other fields.

This future capability is due in part to the work done by Los Alamos physicists Robert Ryne, Ji Qiang and Salman Habib; Los Alamos' Advanced Computing Laboratory; and others nationwide as part of DOE's Grand Challenge in Computational Accelerator Physics. Los Alamos' Spallation Neutron Source Linac Team designed the linear accelerator to be constructed at Oak Ridge and provided detailed design information to Ryne and his colleagues.

The more protons simulated that better reflect a real-world accelerator environment, the greater the researchers' confidence in that computer model. Ryne and his colleagues recently developed a model in which the number of simulated protons is nearly equal to the number of actual protons that travel through high-average power linear accelerators such as the one envisioned at the SNS.

This latest achievement and future work will help researchers not only design and fabricate future accelerators such as the SNS, but also upgrade, improve and maintain current accelerators as well.

The goal of the grand challenge, run out of DOE's Office of Science, is to develop and apply next-generation accelerator modeling tools based on high-performance computing and communications technologies.

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These simulation tools will help researchers design more efficient, next-generation accelerators — at less cost.

There are two components to the challenge: beam dynamics and electromagnetics. The electromagnetics effort is aimed at using computer modeling to solve a wide range of electromagnetic problems that arise in accelerator design and analysis. The Stanford Linear Accelerator Center is spearheading that component.

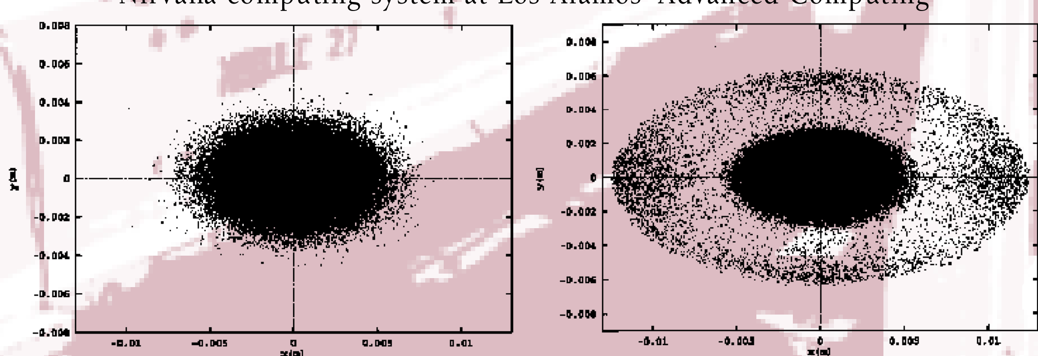
Los Alamos has the lead on the beam dynamics component; the goal is to develop a high-resolution particle simulation capability that will enable researchers to quantitatively predict the beam's evolution and behavior as it travels through the accelerator.

The biggest challenge for researchers is knowing how to predict and avoid the conditions for "beam halo," a diffuse region of charge that sometimes forms far from the beam core as accelerated particles move down the pipe, causing beam loss and making accelerator components radioactive.

Building an accelerator with a large beam pipe aperture could eliminate beam halo/loss. However, the larger the aperture, the higher the construction costs — ranging from a few million to hundreds of millions of dollars.

The SNS linear accelerator will possess neutron-producing beam power two to four times greater than the linear accelerator currently at Los Alamos (the more beam power, the more neutrons available for experiments) and will send a beam down the pipe in "bunches" of just under 1 billion negatively charged hydrogen ions. Physicists must control beam loss resulting from beam halo to about 10 particles per billion.

Ryne and his colleagues used the 2,048-processor, massively parallel Nirvana computing system at Los Alamos' Advanced Computing



The figure on the right is of a mismatched beam, which exhibits a beam halo. The figure on the left is a matched beam properly injected into an accelerator.

Laboratory — capable of performing trillions of calculations per second — and specially developed software to create three-dimensional computer simulations of about 800 million particles.

This increase in beam modeling resolution and speed is at least three orders of magnitude better than previously possible prior to the inception of the grand challenge. Los Alamos now boasts the most advanced beam dynamics computer modeling capability in the world and currently is working to share this capability with other institutions nationwide.

The Los Alamos researchers developed two software packages designed specifically to simulate beam halo phenomena. HALO3D provides researchers with a better understanding of the physics involved in beam halo formation.

Integrated Map and Particle Accelerator Tracking Code, or IMPACT, performs beam dynamics simulations under “real-world,” complex accelerator system conditions. Called the “flagship code” for large-scale beam dynamics simulation by Ryne, IMPACT already has been used in support of the SNS and Los Alamos’ Accelerator Production of Tritium Project.

Ryne stressed that the researchers’ latest accomplishments could not have been possible without strong collaborations among physicists, computer scientists and software engineers. For example, their ongoing collaborations have led to HALO3D and IMPACT currently being at least 20 times more powerful than when they first were created three years ago.

Los Alamos first began performing accelerator computer simulations in the early 1990s through funding provided by the ACL and later under Los Alamos’ Laboratory-Directed Research and Development Program (see the August 1999 issue of Dateline: Los Alamos for more information on LDRD). The DOE Grand Challenge in Computational Accelerator Physics is a continuation of that work and is in its third and final year.

The Stanford Linear Accelerator Center; Stanford University; University of California, Los Angeles; and the National Energy Research Scientific Computing Center also are collaborating with Los Alamos on this grand challenge, one of several supported by DOE.

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SOLAR DOLDRUMS

THE DISAPPEARING SOLAR WIND BAFFLES SPACE SCIENTISTS

For three days last May, space scientists at Los Alamos watched as the solar wind, which normally buffets Earth at speeds close to a million miles per hour, all but disappeared. This astonishing decrease in both the speed and density of the wind led to profound, but temporary, changes in Earth's magnetosphere. The discovery once again emphasized the Laboratory's valuable role in the fledgling, yet critically important, field of space weather studies.

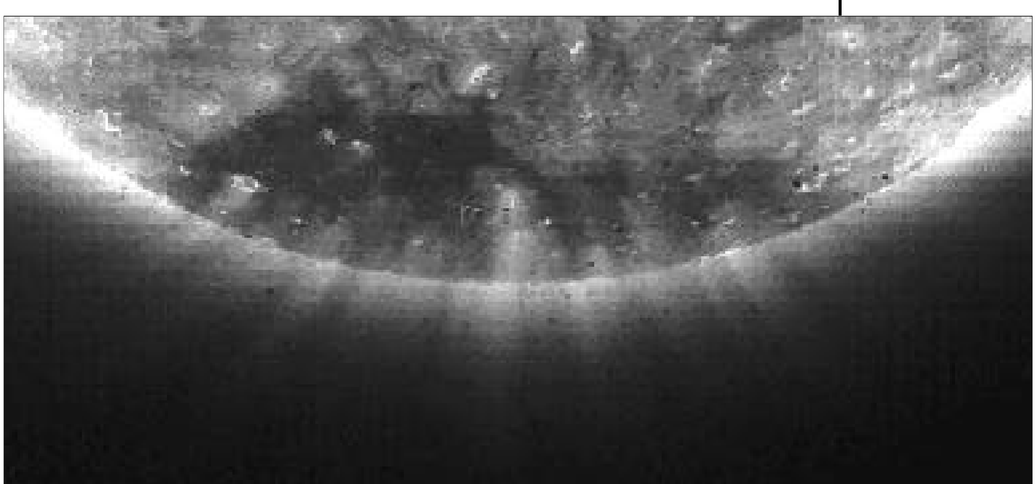
The solar wind is the stream of plasma, principally ionized helium and hydrogen particles, that is constantly being thrown off from the sun's corona in all directions. The wind is formed when the corona's million-degree temperature heats the gases and causes gas atoms to collide.

During these collisions, the atoms lose their electrons and become the electrically charged particles, or ions, that make up much of the solar wind. Occasional coronal mass ejections add to the solar wind as the sun burps supersonic bubbles of gas containing billions of tons of matter.

Beginning on May 10, 1999, and continuing for several days, the solar wind decreased in velocity to roughly 626,000 miles per hour. At about the same time the solar wind decreased, the particle density of the wind

Plumes of flowing hot gas in the sun's atmosphere cause the solar winds.

Image taken March 7, 1996, by the SOHO



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Above and on the page at right: stills from an animation "The Day the Solar Wind Disappeared." As the solar wind decreases (shown by fewer particles streaming from the sun), the magnetosphere and the bow shock around Earth expand to five times their normal size.

NASA and Allied Signal, MaxQ Digital Group

decreased from its typical 82 particles per cubic inch of space to fewer than 4 particles per cubic inch. Neither density amounts to very much physical matter per cubic inch, but the total decrease in the sheer volume carried by the wind was immense. It was the difference between a truckload and a tablespoon.

The May disappearing solar wind event, as it is being called, baffled scientists simply because it is so extremely rare for the density of the solar wind to drop so low for such a relatively long period of time. The mystery was further compounded by the low speed of the wind during the event.

Days later, when the wind finally kicked back in, riding in the wind were some of the largest solar wind waves that space scientists had ever seen. These waves in the wind caused the wind speed to fluctuate wildly over a matter of a few hours on the day following the event. Only in the ensuing days did the density and speed of the wind return to typical pre-event levels.

Basing their discovery on data gathered by the Solar Wind Electron Proton Alpha Monitor, an instrument flying aboard NASA's Advanced Composition Explorer satellite, and the Solar Wind Experiment aboard the WIND satellite, Los Alamos scientists believe the decrease in the solar wind may have been caused by an unusual coronal mass ejection from the sun.

Coronal mass ejections are most often violent discharges of matter from the corona — an irregular envelope of highly ionized gas that surrounds the sun. However, if this is indeed the case, this was not the garden-variety coronal mass ejection seen in the solar wind. Since the particle density of the solar wind typically drops below 50 particles per cubic inch only 5 percent of the time, for it to drop to 4 particles is really quite unusual at anytime, including within a coronal mass ejection.

The coronal mass ejection theory is also supported by other attributes that have, in the past, been associated with coronal mass ejections.

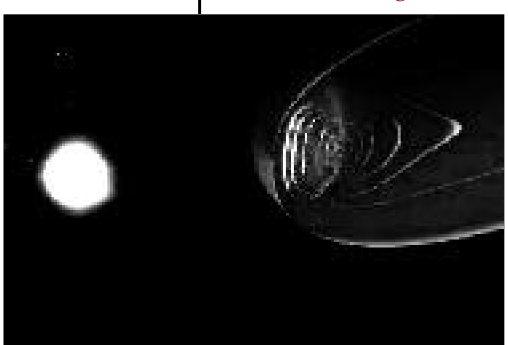
Other possible explanations have also been proposed, but the exact cause of the May event remains, at least for the present, one of the newest mysteries of space weather studies.

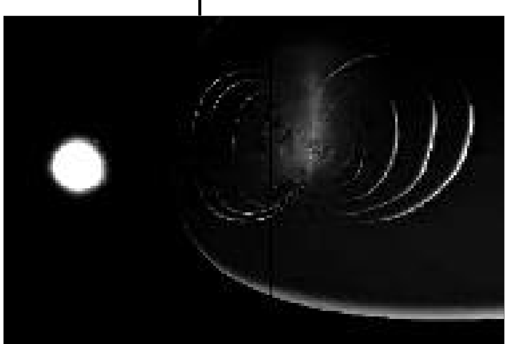
It was only in 1959 that the Soviet Luna 2 spacecraft confirmed the existence of the solar wind and therefore much of the existing knowledge about the solar wind and, in particular, its effect on Earth's magnetosphere has come in the past few decades.

While earlier studies focused on characterizing the average composition, density and speed of the solar wind, more recently scientists have been drawn to studying the variability of those solar wind properties.

These fluctuations in solar wind properties can be used to study the temporal and spatial variability of the sun and provide scientists with a remote probe for studying the solar atmosphere. Extreme variations (such as when the solar wind almost disappears) offer important opportunities to look for unique solar events and to study the range of effects that the sun can have on Earth's magnetosphere.

Because the solar wind is an ionized gas — that is, all the particles carry an electric charge — the wind sees Earth's magnetic field as an object to flow around. In doing so a bow shock forms when the solar wind runs into Earth's magnetic field.





The region of space inside this bow shock, where Earth's magnetic field dominates, is called the magnetosphere.

The bow shock normally forms about 50,000 miles sunward from Earth, but the May event provided geophysicists with a rare opportunity to examine solar-terrestrial interactions at a time when the magnetosphere was extremely inflated.

During the event, Earth's magnetosphere ballooned to more than four times its normal size. The IMP 8, Interball 1, Geotail and WIND satellites measured the bow shock at distances out to 200,000 miles, or roughly the same as the average distance from Earth to the moon.

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This was one of the few times known to scientists that the bow shock extended all the way out to the moon and possibly beyond.

The absence of the wind also gave the magnetosphere less of a cometlike shape by shortening the tail of charged particles that normally extends out from Earth's night side. The event gave Earth's magnetic field a shape analogous to the more familiar rounded field created by a dipole bar magnet.

The interaction between Earth's magnetosphere and the solar wind is responsible for a variety of phenomena. For example, when the charged particles of the solar wind reach Earth's magnetic field, some protons and electrons are trapped.

These trapped particles then spiral along a system of imaginary lines in the magnetic field, called field lines, between Earth's south and north magnetic poles. As the charged particles strike certain molecules in the upper atmosphere, energy is released to create the beautiful aurora that often light the skies of the far northern and southern hemispheres.

Los Alamos' long-standing participation in space weather research has been enduring and rewarding. The Solar Wind Electron Proton Alpha Monitor instrument built by Los Alamos and launched in 1997 as part of the Advanced Composition Explorer (ACE) orbits at a distance of roughly a million miles from Earth to provide scientists worldwide with information about the solar wind.

Data from ACE provides elemental and isotopic composition measurements of the solar wind and cosmic rays as well as warnings of potential geomagnetic storms caused by coronal mass ejections that can destroy satellites and disrupt electronic communications and electrical power grids.

In addition, important and valuable partnerships with institutions like the Massachusetts Institute of Technology, which participated extensively in the analysis of the data from May event, have and will continue to lead to significant advances in knowledge.

Los Alamos also works in close collaboration with researchers from NASA Goddard Space Flight Center and the Bartol Research Center at the University of Delaware to learn more about space weather and the enigmas to be discovered while studying the solar wind.

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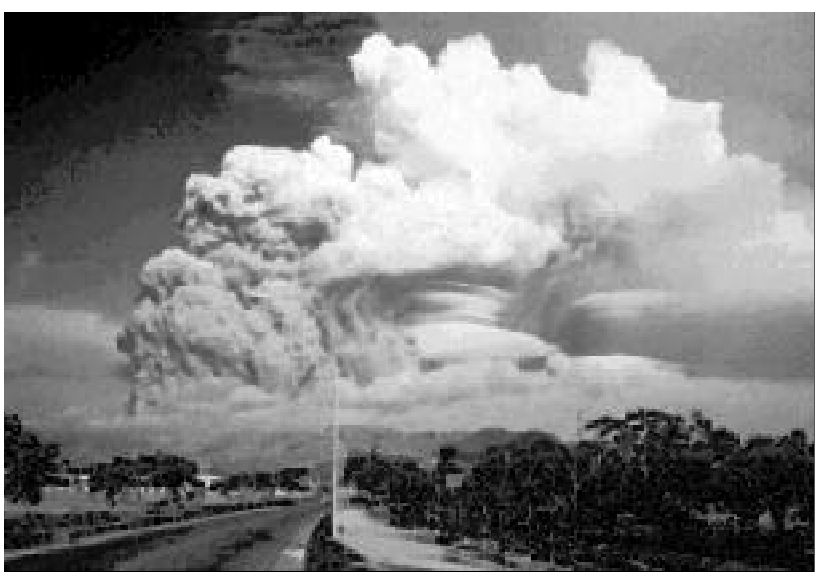
IT'S A WARM WORLD AFTER ALL

NEW OBSERVATIONS MAY ELIMINATE A PRIME OBJECTION TO GLOBAL-WARMING THEORY

In the late 1950s, scientists at universities and within the ranks of the U.S. federal government began participating in scientific workshops and international conferences on the nature of Earth's climate system. At issue was the role of carbon dioxide and other greenhouse gases and how they modified the global climate. From these meetings, and the research that followed, the scientific underpinnings of the human contributions to global warming were established.

From the beginning, however, the theory was rife with incongruities. If global warming were actually occurring, some scientists said, then observers should be able to document warming trends in the middle atmosphere as well as near the surface.

In particular, since satellite records over the past 20 years have recorded less warming in the troposphere, the lowest layer of the atmosphere, than at the surface, critics of global-warming theory used this to discount the idea that Earth is slowly heating due to a buildup of anthropogenic, or human-generated, greenhouse gases.



The huge quantities of ash and aerosols spewed out by the Mount Pinatubo eruption in the Philippines in 1991 caused cooling at Earth's surface, as well as in the lowest layer of the atmosphere.

Photo by David Harlow, USGS

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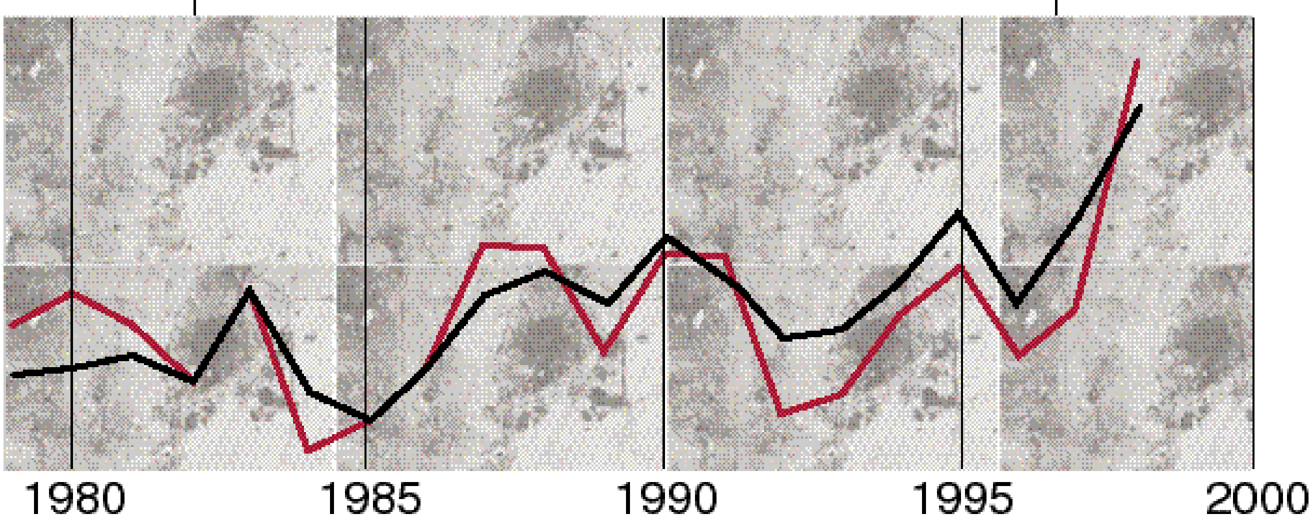
Researchers at Los Alamos now believe they have found a way to dislodge this obstacle to the global-warming theory.

They noticed that the satellite record was best treated in two pieces. Looking at the first 13 years, from 1978 to 1991, they saw rather consistent agreement with the surface records, but from 1992 to 1997 they saw a stepwise drop in satellite temperatures relative to the surface record. This drop began shortly after the June 15, 1991, eruption of Mount Pinatubo in the Philippines.

Pinatubo had spewed huge quantities of ash and aerosols into the stratosphere — the atmospheric layer above the troposphere that contains the ozone layer — scattering sunlight back into space and causing large cooling both at the surface and in the troposphere.

The eruption also led to a wholesale depletion of Earth's protective ozone layer in the stratosphere. Because ozone absorbs the sun's ultraviolet rays, the layer normally heats the stratosphere; but with depletion of ozone from the volcanic blast, the stratosphere cooled. Scientists surmised that this very cold stratosphere might have had a cooling effect on the troposphere.

Comparison of yearly temperature anomalies between satellite (red) and surface (black) measurements. Note the dramatic difference after 1991.



In their investigation, Los Alamos researchers divided the troposphere into an upper part and a lower part, which allowed them to compare temperature anomalies in these two regions with those at the surface. What they discovered was intriguing. Prior to the 1991 eruption of Mt. Pinatubo, the relative amounts of warming and cooling in these layers were well correlated with the occurrence of El Niños and La Niñas.

As a general rule, during El Niño years, the upper and lower troposphere sees greater warming than the surface, and see greater cooling than the surface during La Niña years. However, this was not the case after Mount Pinatubo erupted.

Even though there were three El Niños in the 1992 to 1997 period, the tropospheric temperature structure looked as it normally does during La Niñas, indicating that a cold stratosphere nestled directly above may have affected the troposphere.

Bolstering the Los Alamos theory is research from the Max Planck Institute for Meteorology where researchers had used a computer simulation with a crude approximation of ozone depletion to look at atmospheric temperatures. The simulation showed that the upper troposphere did indeed cool more than the surface during the aftermath of Pinatubo.

The next round of research will use Los Alamos computer models of oceans and sea ice coupled with computer models of the atmosphere and land surface developed by the National Center for Atmospheric Research to tackle the problem.

The research team will feed 20 years of accurate stratospheric ozone concentration measurements into the Laboratory's supercomputers and see whether the models will produce the actual level of atmospheric cooling measured during the 1992 to 1997 time frame.

The theory of an enhanced greenhouse effect due to human emissions of carbon dioxide and other gases is now more than a hundred years old, yet this new research could eliminate one of the primary objections to global-warming theory.

Los Alamos researchers believe that further studies will show that stratospheric ozone depletion retards the expected warming due to increases in greenhouse gases alone, which is what has been seen in the satellite temperature data. Perhaps it is a warm world after all.

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NUCLEAR ROCKETS

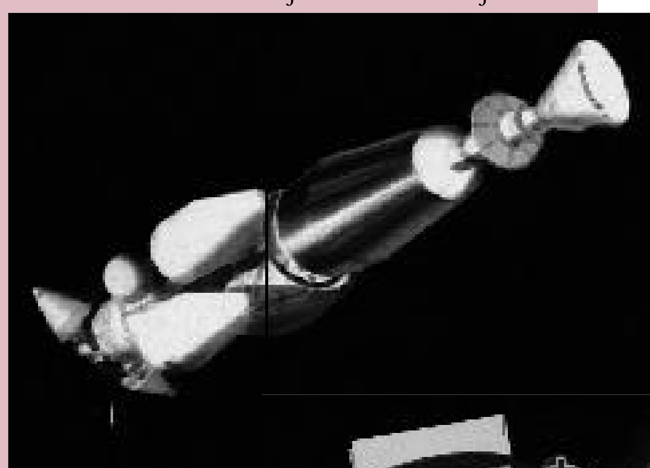
CONTINUING RESEARCH INTO PROPULSION FOR SPACE VEHICLES

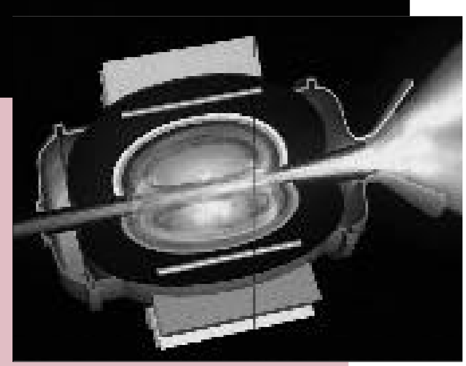
Los Alamos has played an active role in the U.S. manned space program — which reached its zenith with the Apollo 11 moon landing in 1969 — since its formative years. Future space missions, manned or unmanned, will require new technologies that can propel rockets and their payloads to other planets in the solar system or even other stars.

Research and development for space travel was a major scientific thrust at Los Alamos from the mid 1950s until about 1972. Project Rover — a joint effort between Los Alamos, the former Atomic Energy Commission and the National Aeronautics and Space Administration's Space Nuclear Propulsion Office — sought to build a nuclear reactor to power a rocket in space. Between 1959 and 1972, 23 reactors were built and tested by Los Alamos scientists.

The advantage of a nuclear rocket is its high exhaust velocity, which is more than two times greater than that of the engines on Space Shuttle rockets. The higher velocity translates into lower fuel mass of the ship in orbit and faster trip times to planets.

Today, Los Alamos scientists are engaged in several efforts to develop new ways to test





Stills from an animation of a gas core nuclear rocket and a cutaway of the inside of the engine. The inset shows cold hydrogen being pumped in from the left, which creates a recirculation vortex into which uranium particles are injected. When the uranium reaches critical mass and temperatures near 100,000 degrees Fahrenheit, it radiates energy to the surrounding hydrogen, which exits through a nozzle on the right, providing thrust.

Eric Vigil

and build nuclear rockets. SAFE, or Subsurface Active Filtering of Exhaust, builds on technology developed in the nuclear weapons program. With SAFE, gases emitted from nuclear rockets are diffused underground into permeable subsurface rock. Los Alamos has requested $10 million from NASA to test the SAFE process using a chemical rocket.

Because environmental regulations prohibit release into the atmosphere of gaseous byproducts from nuclear rockets, SAFE would be far cheaper than the estimated $500 million it would cost to build a scrubbing facility for emissions from nuclear rockets.

Los Alamos also collaborated with NASA's Marshall Space Flight Center in Huntsville, Ala., on a three-dimensional fluid dynamics computer model for a gas core nuclear rocket. If proven feasible, a gas core nuclear rocket would perform three times better than the solid core nuclear rocket developed during the Project Rover era. A gas core nuclear rocket still remains to be built and tested.

In a gas core nuclear rocket, cold hydrogen is pumped into the main axis of the rocket's engine. The hydrogen circulates, creating a recirculation vortex in the chamber. Uranium particles are injected into the center of the vortex until the uranium accumulates to near-critical mass. After the chamber is stabilized, control drums in reflector walls rotate, driving the uranium to criticality. The now-hot uranium gas — temperatures approach 100,000 degrees Fahrenheit — radiates energy to the surrounding hydrogen, which exits through a nozzle to provide thrust.

Because of the extreme operating conditions in a gas core engine, design issues in fluid mechanics, materials, thermal load and radiation transport are at the state of the art or beyond. The gas core rocket development is a grand challenge commensurate with the capabilities of a national laboratory.

Scientists now must test and verify that the vortices in the gas core rocket can be formed and stabilized.

If the technology proves successful, a manned mission to Mars — some 200 times farther than the moon — could be completed in nine months, versus an estimated three years using chemical rockets. Astronauts on such a mission would receive far less exposure to space radiation.

Development of a high performance nuclear rocket will enable humankind to finally break the bonds of Earth and gaze at undiscovered vistas throughout the solar system.

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BRIEFLY ...

LOS ALAMOS SCIENTISTS ARE WORKING WITH MOTOROLA, THE WORLD'S SECOND LARGEST WIRELESS PHONE MAKER, TO DEVELOP MINIATURE FUEL CELLS. While the miniature fuel cells are several years away from landing on store shelves, the powerful power sources are likely to someday replace traditional batteries in laptop computers, cellular phones and other devices. The cells, which last up to 10 times longer than conventional rechargeable batteries and measure only about one inch square and less than one-tenth of an inch thick, use methanol, or wood alcohol, to generate electricity. The "air breathing" fuel cell was developed at Los Alamos, and Motorola plans to assign a research and development team to Los Alamos to form a center of excellence and bring the product to market.

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