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Goddard Technologist Wins Lunar Sortie Mission Study

Attributes Success to IRAD Funding

Goddard technologist Daniel Glavin has won NASA funding to carry out a 9-month study to define and test a suitcase-size instrument that could answer whether the high concentrations of hydrogen detected in the permanently shadowed areas of the Moon's polar regions indicate the presence of water ice and organics delivered possibly by comets.

Of the 77 proposals submitted under the Agency's Lunar Sortie Science Opportunity (LSSO) program, NASA Headquaters selected only seven, two from Goddard. In addition to funding Glavin's Volatile Analysis by Pyrolysis of Regolith (VAPoR) instrument concept, NASA also selected Pat Taylor and Paul Lowman, both with Goddard's Planetary Geodynamics Laboratory, to continue work on a proposal called "Seismology and Heat Flow Instrument Package for Lunar Science and Hazards."

Glavin attributed his win to the fact that he had received Goddard Internal Research and Development (IRAD) funding to advance his idea, assemble a talented group of Goddard scientists and engineers, and begin building a laboratory instrument that he and his team will use to run experiments on cometary ice analog samples and actual lunar soil samples gathered during the Apollo 16 mission. From the testing, he hopes to get baseline scientific data and develop mission requirements in the event that NASA funds a future robotic lunar lander or human sortie mission.

"Everyone on my team is excited about the award," said Glavin, an astrobiologist by training. "The selection of our VAPoR proposal demonstrates the success of Goddard's investment in key technologies and underscores why Goddard needs to continue investing in R&D."

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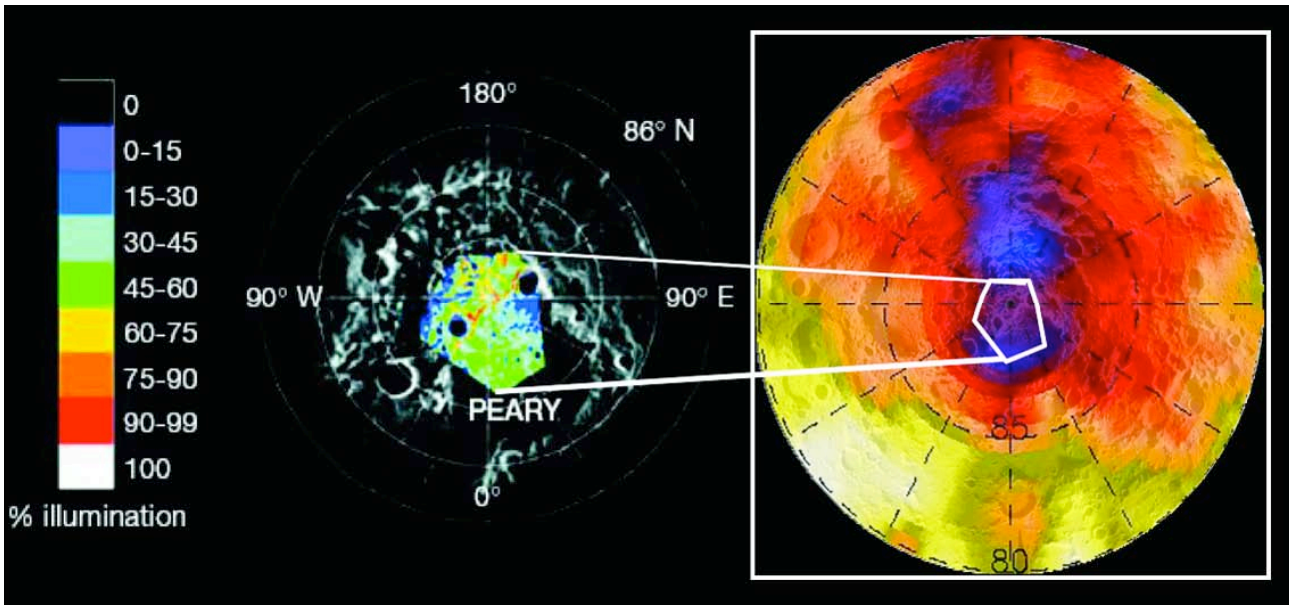

The Clementine solar illumination (left) and Lunar Prospector hydrogen (right) maps of the Moon's north pole reveal constantly illuminated areas and permanently shadowed craters that contain higher levels of hydrogen. VAPoR's in situ analyses of these areas could determine the origin and abundance of water and other volatiles.

On The Cover:

Principal Investigator Daniel Glavin and his team have won a NASA concept study to develop a breadboard instrument that could answer whether the high concentrations of hydrogen detected in the permanently shadowed areas of the Moon's polar regions indicate the presence of water ice and organics delivered possibly by comets. Ed Patrick, Kirsten Fristad, and Inge ten Kate are helping Glavin build the breadboard instrument. Glavin attributed his win to receiving Goddard Internal Research and Development funding to advance his idea.

Photo Credit: Chris Gunn

First X-Ray Communication System Demonstrated

Goddard Physicist Keith Gendreau, who initially set out to create an enabling technology for NASA's proposed next-generation Black Hole Imager, ended up developing along the way the world's first X-ray communication system.

Gendreau recently demonstrated voice communication using a modulated X-ray source he developed under Goddard R&D and Defense Advanced Research Projects Agency (DARPA) funding to a group of NASA Headquarters decision makers. He now plans to use a mid-term Internal Research and Development award to increase the system's data rate of about 50 kbps to 1 Mbps and integrate it with X-ray optics to demonstrate a full system-level concept. Testing at Goddard's X-ray Interferometry Testbed, using the facility's 600-meter vacuum beamline, is scheduled for September, Gendreau said.

The goal is to some day transmit gigabytes of data per second with minimal power, but it could take some time before that happens given the technological hurdles to overcome, Gendreau said. "With laser communications, you have to point really well. That's the problem," he said. "In X-rays, however, it's a thousand times harder. That's what will push it into the future."

Gendreau began work on the technology several years ago when attempting to come up with a technological solution for NASA's proposed Black Hole Imager, an ambitious mission aimed at directly imaging the event horizon of a super-massive black hole or the "point of no return" where nothing — neither particles nor photons — can escape. The idea was to establish a constellation of precisely aligned spacecraft that would in essence create an X-ray interferometer, he said. Making sure these spacecraft remained perfectly positioned was one of the challenges Gendreau tried to address.

He conceived the idea of using X-ray sources as beacons to enable highly precise relative navigation. He then thought of an idea to modulate the X-rays — where the X-ray source is turned off and on many times per second to change intensity — to create a communication system out of the navigational beacons. To do this, he used Goddard R&D funds to develop a Modulated X-Ray Source.

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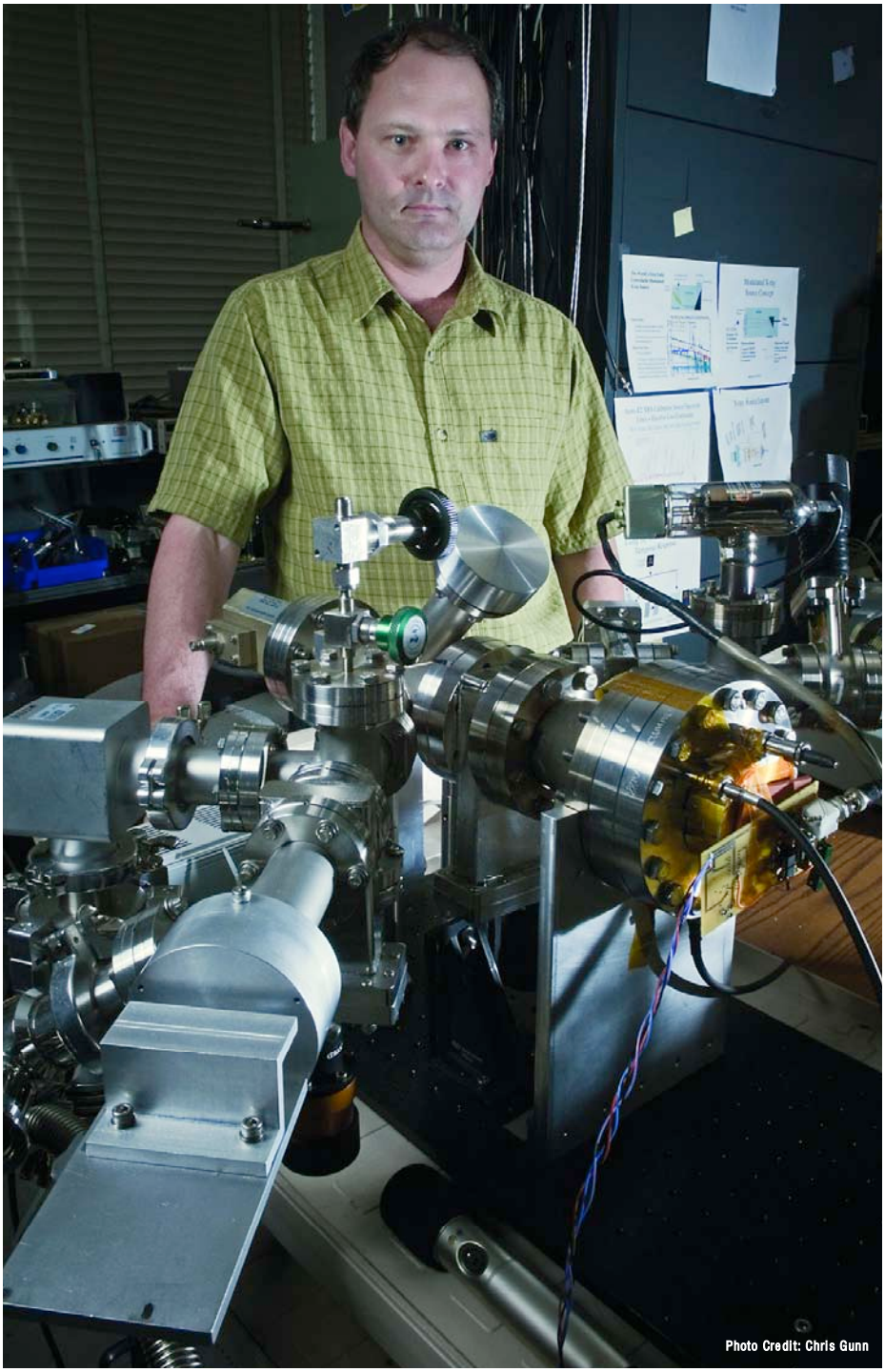


Goddard Physicist Keith Gendreau has created the world's first X-ray communication system. The laboratory instrument will undergo additional improvements under a mid-term Internal Research and Development award.

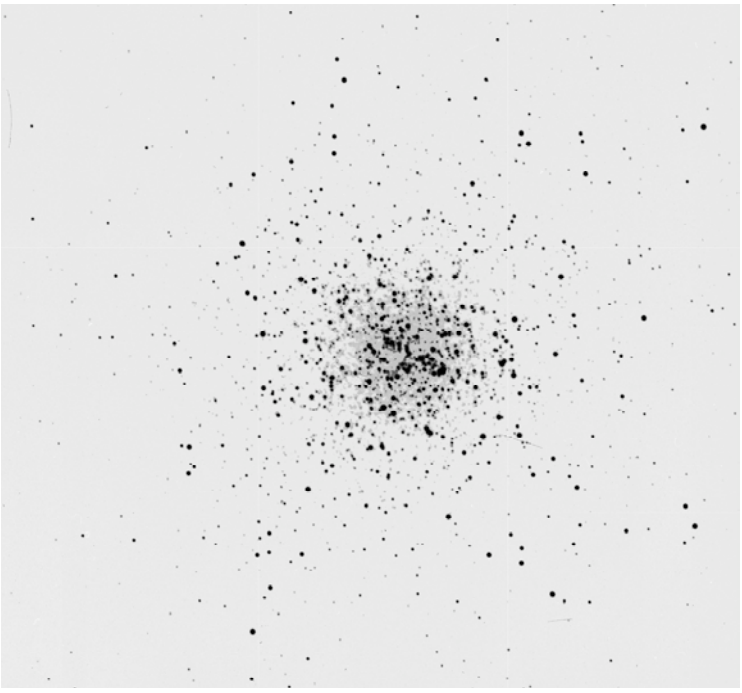
Large-Format, CMOS-Based Imager Produces 'First-Light' Image

Technology Offers Scientific and Exploration Applications

Two Goddard technologists who characterized the world's first large-format, CMOS-based visible imager as part of a 2-year-old partnership with the U.S. Naval Observatory (USNO) say they are "ecstatic" over the camera's performance and are confident that it will find widespread application with NASA's exploration initiative and future science missions.

Principal Investigator Peter Shu and his co-investigator, Laddawan Miko, delivered the 16-million-pixel prototype camera system to the USNO's facility in Flagstaff, Arizona, in late May and within a few weeks the observatory had taken its "first-light image" measuring highly precise positions of stars. "We were ecstatic because it worked," Miko said. "It assured our leadership role in building the best detectors in the world."

The CMOS image-sensing technology, developed in part with Goddard Internal Research and Development funding, is significant because it provides a large image area and returns data faster and at a higher resolution than other imaging technologies, Miko said.



This "first-light" image taken with the world's first large-format, CMOS-based visible imager shows highly precise positions of stars. The imager was installed in the U.S. Naval Observatory's Flagstaff facility.

In addition, it allows users to select a particular "window" in the sky from which to gather data. The ability to create a "window" can be electronically programmed. In other words, "you can target an area you want to see, program the window, and get the data quickly," Miko added.

Rendezvousing and Docking Potential

This capability makes the technology ideal for exploration, in addition to its obvious scientific applications, Shu said. One possible use is with rendezvousing and docking. Using the Shuttle and International Space Station as an example, the CMOS-based camera could image the Space Station from a distance. As the Shuttle moved closer, the system would zoom in on the docking port, providing a larger and more detailed image of where the Shuttle was supposed to attach itself.

The next step is to carry the technology to the next level and create an even larger format containing 64 million pixels, Miko said. In addition, the technology's flexibility allows it to be easily adapted to other wavelength regimes, in addition to visible light. ◆

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X-Ray... *Continued from page 3*

"But if you can modulate the X-rays, then you can communicate," he said. "I didn't start out interested in X-ray communication, but then I thought that such a system would have widespread application."

Military Applications

One potential user is the U.S. military. DARPA already has invested in the technology and Gendreau hopes to get additional DARPA support in upcoming solicitations.

NASA, too, could benefit from such a technology, Gendreau said. X-ray communication can rival its laser counterpart over long distances in space. It also permits communication with hypersonic vehicles and spacecraft during that short period when the build-up of heat prevents communication during reentry. Perhaps its most significant application, at least from a civilian space point of view, is its promise to carry large amounts of data with little power, Gendreau said.

Although Gendreau views the technology as his baby, his real motivation remains with the Black Hole Imager. "Making an X-ray imager is really the goal here." ◆

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MINI-ME to Advance Goddard's Lead in Neutral Atom Imaging

Instrument Could Address Many Scientific Questions

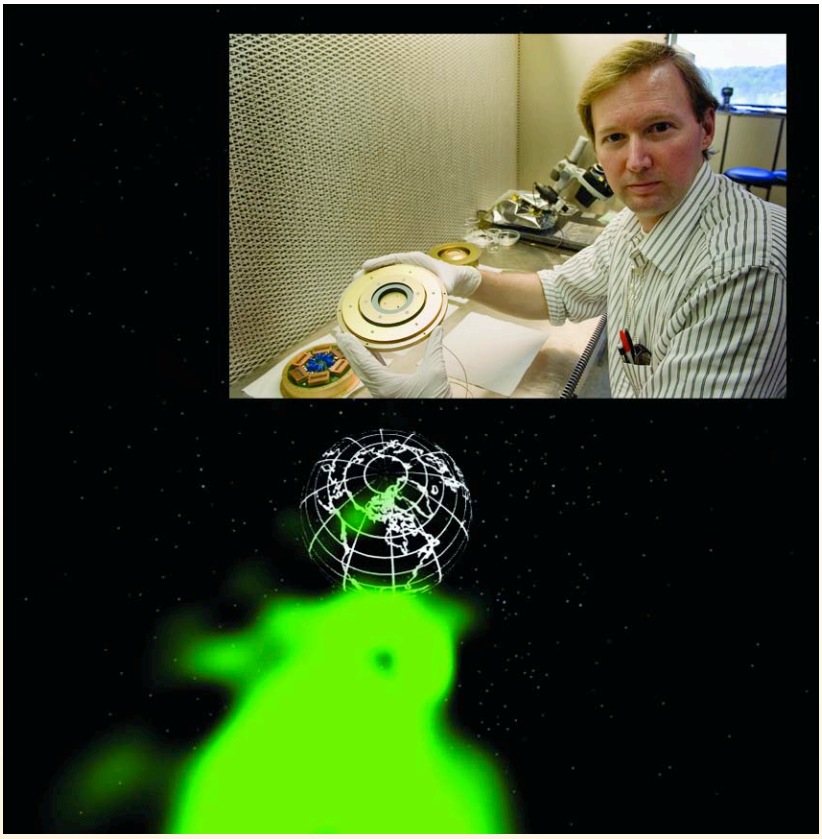
Other than for its diminutive size, Goddard's own MINI-ME bears no resemblance to the fictional character in the popular Austin Powers movies.

Now being developed under Goddard's Internal Research and Development (IRAD) program, the instrument will carry on a tradition established 7 years ago when NASA launched the Goddard-developed Low-Energy Neutral Atom (LENA) imager aboard the IMAGE spacecraft, the first time such an instrument had ever flown in space.

However, MINI-ME — which stands for Miniature Imager for Neutral Ionospheric atoms and Magnetospheric Electrons — takes the technology to the next level and offers several improvements over its forebear.

Measuring just 6 inches (15.24 cm) in diameter and 5 inches (12.7 cm) in height, the 6.6-lb (3-kg) MINI-ME is significantly smaller than the storage box-size, 44-lb. (20-kg) LENA. Its innovative design also will make it more capable, promising to offer 10 times greater energy resolution than LENA, said Michael Collier, MINI-ME principal investigator.

"In this current environment, Goddard must be able to produce instruments that have lower mass, consume less power, and are less expensive to build," he said. "With MINI-ME, we accomplish all three, plus we offer more performance."



The Goddard-developed Low-Energy Neutral Atom (LENA) imager captured the image above. It shows the low-energy ion outflow from the Earth's auroral region. Goddard technologist Michael Collier (inset) is building a flight instrument that takes LENA's capabilities to the next level. He has developed most prototype hardware for his next-generation neutral atom imager, which is slated to fly on an experimental satellite in 2011.

The Search for Neutral Atoms

Like LENA, MINI-ME will look for neutral atoms flowing up from Earth's ionosphere and into the magnetosphere, the magnetic field that envelops the planet and protects it from the harmful effects of solar wind. With this information, scientists hope to better understand the physics that influence the magnetosphere, which is particularly important because most space assets, including communications satellites, reside there and are sensitive to severe space weather caused by solar wind.

However, MINI-ME could be applied to other scientific questions, Collier believes. NASA could one day use the instrument to better understand the effects of solar wind on the Moon, determine whether Europa, one of Jupiter's moons, harbors a water ocean beneath its icy crust, and understand the influence of solar wind on the atmospheres of other planets, perhaps answering why Venus lost its water.

Flight Slated for 2011

MINI-ME and three other Goddard-developed instruments will fly in 2011 on a high-risk experimental satellite — MidSTAR-2 — now being developed by midshipmen at the U.S. Naval Academy. "Our collaboration with the Naval Academy is really a win-win," Collier said. "What Goddard gets is the ability to develop a high-quality instrument that will allow us to be more competitive in winning future space missions."

Since winning the IRAD award, Collier has developed most prototype hardware and is getting ready to test the instrument this summer to see if the concept works. "We're well on our way," he said. "The ultimate test is to put this in front of a neutral beam and get a signal." ◆

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In the late 1990s, a group of Goddard technologists proposed a new vision for NASA's Earth science enterprise. It promoted for the first time a more "holistic" approach to measuring naturally occurring and human-induced phenomena on Earth. Instead of today's stove-piped, passive measurement techniques, the group envisioned a "sensor web" of interconnected land- and space-based instruments that could take measurements, exchange information, and modify their own measurement strategies to get data in locations where scientists needed it.

In a recent research announcement, the NASA Earth Science Technology Office (ESTO) tied its Advanced Information Systems Technology solicitation to sensor webs and in 2006 awarded research money to 28 teams from industry, academia, and NASA centers, including three from Goddard. The award represented a key investment by ESTO in the sensor-web concept. The articles here describe some of the promising research projects awarded to the Goddard teams under their 3-year awards. ◆

Building A Better Weather Model

Enabling 14-Day Forecasts the Goal

How many times have emergency rescue personnel evacuated people living along the coastline only for the storm to hit hundreds of miles away? How many times have forecasters called for heavy snow, only to get flurries?

The problem lies with the computerized weather models used by forecasters to predict the weather and the actual data that feeds these models, says Goddard technologist Michael Seablom.

Under his ESTO award, Seablom and a team of researchers from academia, industry, and Goddard are attempting to build a "Sensor Web Simulator" aimed at improving the accuracy of the weather models. Under his concept, the simulator would evaluate forecasters' multiple weather models, specifically looking for discrepancies and predictability problems in the models' results.

Intelligent Observing System Sought

With that information, Seablom's system would then direct Earth-observing satellites and other ground-based sensors to make targeted observations in areas where forecasters need better measurements. "Under our current system, we get data whenever a satellite passes over, as opposed to where we need data," Seablom said. "If we can identify in our models where we have predictability problems, we can then say to the observing system, look here."

Currently, the Goddard Global Modeling and Assimilation Office is developing techniques to identify predictability problems. If scientists were then able to direct a sensor to gather information in a particular area, Seablom believes 14-day forecasts could become a reality. Currently, they aren't possible with existing technology.

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Satellites collect all types of data about weather and other events on Earth, including volcanoes and severe storms. A Goddard technologist hopes to create a way to direct Earth-observing satellites and other ground-based sensors to make targeted observations in areas where forecasters need better measurements. The aim is to improve weather modeling.

This image shows a wildfire in the Alpine region, east of San Diego. Goddard technologist Dan Mandl plans to demonstrate a sensor-web technology to monitor fires similar to this one.

Using the Internet to Cross-Link and Task Earth-Observing Sensors

Goddard Technologist Uses ESTO Award to Advance Architecture

At any given time, tens of thousands of space- and land-based sensors are gathering data about conditions on Earth. The problem is the systems are stove-piped. The data they gather cannot be easily accessed and cross-linked to make them responsive to transient events happening on Earth.

"This is equivalent to catching a fish with a fishing pole, versus casting a wide net to catch the same fish or perhaps the whole school of fish," says Goddard technologist Dan Mandl, who says he would like to assist in the changeover from fishing poles to wide nets.

As the principal investigator under an ESTO award, he is developing a modular sensor-web architecture that would give users access to both ground- and space-based sensors via the Internet.

Achieving Interoperability

"We want to wrap every sensor with a standard interface and then use the Internet to access and connect these assets. My goal is to come up with an easy way to then make these sensors interoperate," said Mandl, who also is the mission manager of NASA's Earth Observing-1 (EO-1) mission, a New Millennium Program technology-validation spacecraft. "When this happens, we will have enabled on-demand science, which allows anyone in the public to conduct customized, inexpensive science investigations that in the past were traditionally reserved for well-funded scientists," Mandl said.

Mandl, along with his multi-center team, gets a chance this summer to demonstrate his system under real-life conditions. Expanding on a sensor-web experiment he conducted in August 2003, Mandl plans to use EO-1, an unmanned aerial vehicle managed by the Ames Research Center, and several automated ground weather stations operated by the U.S. Forest Service to monitor wild fires burning in the western U.S.

The team plans to prototype the use of this Internet-based system to automatically gather data and task the various sensors to provide more detailed images and data to fire managers who would use this timely data to manage the conflagrations.

He also is working with other ESTO researchers to integrate the capabilities they're developing into this fire sensor-web demonstration. One example is an Internet search technique for finding sensors and algorithms needed to supply and process data related to the fire of interest. "This capability would be similar to how a user searches the Internet using Google," Mandl said.

Although other researchers worldwide are attempting to develop similar systems, Mandl says he has the advantage. "I'm one of the few people with access to a satellite," he said, referring to EO-1. ◆

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Legacy Technology Used

VAPoR is a miniaturized mass spectrometer similar in concept to the Goddard-developed Sample Analysis on Mars (SAM) instrument, one of 10 instruments flying on the 2009 Mars Science Laboratory rover. Like SAM, VAPoR is designed to analyze gases in the atmosphere as well as vapors that are produced when its onboard oven heats soil and rock samples to temperatures exceeding 2200ºF (1204ºC).

Such an instrument would help scientists determine whether the large concentrations of hydrogen are actually water ice deposited by cometary bombardments or simply hydrogen implanted by the Sun. It also could answer whether organic compounds exist on the Moon.

If the hydrogen turns out to be water ice, NASA could use the resource to sustain human astronauts living in lunar habitats and use pyrolysis or another technique to extract oxygen from water ice and lunar soils to produce breathable air.

As part of his study, Glavin has tasked another Goddard technologist, Eric Cardiff, to provide experimental data on the temperature required to release oxygen from the lunar regolith. Cardiff has been working with several lunar oxygen-production techniques for several years, including work on an IRAD to build a prototype system that used vacuum pyrolysis to incinerate regolith to release oxygen. Cardiff will be testing a variety of higher-temperature oven materials that VAPoR would require.

"We were looking at the science applications and Eric was looking at in situ resource utilization applications. The LSSO program wanted proposals that addressed both science and exploration needs," Glavin said. "It was a natural merge."

Should NASA choose Glavin's concept for a future lunar sortie mission, he said VAPoR could be deployed on a robotic lander with a suite of instruments or as a stand-alone instrument placed by astronauts. "After the Lunar Reconnaissance Orbiter (which flies in late 2008 to map the lunar surface), there's a good chance that NASA will want to send a robotic lander to the Moon to provide ground-truth measurements of the polar region before a human mission," Glavin said. "This definitely has a short-term strategic impact." ◆

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Weather Model... Continued from page 6

As part of his award, Seablom and his team plan to demonstrate his concept using simulated data from the proposed Global Wind Observing Sounder (GWOS), a polar-orbiting spacecraft that may fly early next decade. The objective is to investigate the potential benefits of using a predictive forecast model to drive targeted lidar measurements. "What we're trying to determine is whether targeted observations would really give us better science," he said. The demonstration is expected to take place in 2009.

Another significant piece of the challenge is creating a way to immediately task a satellite with a different observation. "This is where Dan Mandl can help," Seablom said. Mandl also received an ESTO award to develop the capability to task sensors configured in a sensor web using the Internet (see related story, page 7).

If Seablom succeeds, he said the benefits are enormous. It costs about a $1 million per mile to evacuate people who are threatened by hurricanes. "We can save millions of dollars with more skillful forecasts," Seablom said. "The applications of this technology are endless. What we're doing is letting the models drive the observations." ◆

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Goddard Tech Trends

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