National Aeronautics and Space Administration

goddard tech trends

Innovators of the Year

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An R&D Success Story

SXS Team Wins 'IRAD Innovator of the Year' Award

The Goddard team that NASA recently selected to build a next-generation spectrometer for Japan's Astro-H mission has won the 2008 "IRAD Innovator of the Year" award. The Office of the Chief Technologist bestows the award annually on technologists who exemplify the best in R&D.

The team, led by Principal Investigator Richard Kelley, was chosen because of its success leveraging Internal Research and Development (IRAD) funds to enhance instrument capabilities and ultimately being selected to build the $44 million Soft X-ray Spectrometer (SXS), which will probe the motion of matter in extreme environments, investigate the nature of dark matter on large scales, and explore how galaxies and clusters of galaxies form and evolve.

"We invest in technology primarily to become more competitive winning new work," said Chief Technologist Peter Hughes, who administers the IRAD program. "Richard's team effectively used those investments to significantly improve his instrument, which resulted in new business for Goddard. We're very pleased with his success and happy that our investments paid off."

In late June, NASA selected the instrument from among 17 proposals under the Agency's Explorer Program Mission of Opportunity solicitation. It is one of four slated to fly on Astro-H (formerly known as the New X-ray Telescope), which the Japan Aerospace Exploration Agency plans to launch in 2013.

Though similar in many respects to the X-Ray Spectrometer that flew on Japan's Suzaku Observatory in 2005, the new instrument will offer greater capabilities particularly in the areas of detector performance, cooling technologies, and collecting area — enhancements made possible in part by Goddard's R&D investment programs, said Kelley.

"Certainly, the support we received through Goddard's IRAD and other programs contributed to our proposal win and our ability to build an enhanced, higher-resolution instrument," he said.

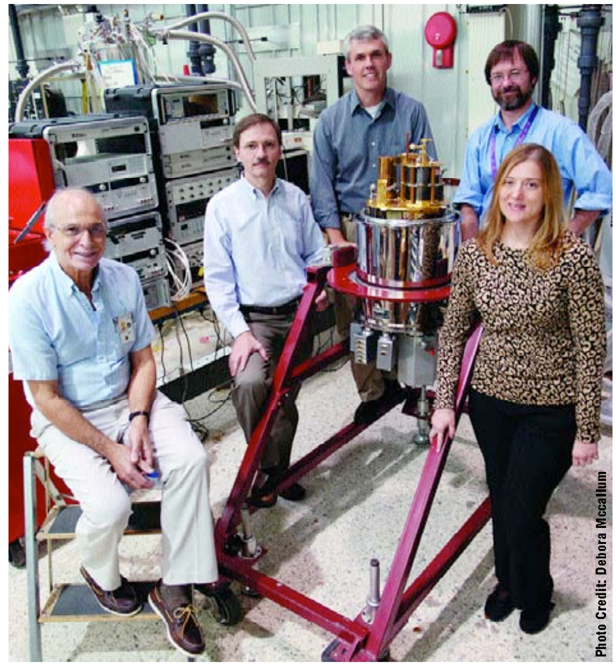

Photo Credit: Debora Mccallum

The SXS team includes (from left to right): Peter Serlemitsos, Richard Kelley, Peter Shirron, F. Scott Porter, and Caroline Kilbourne. Christine Jhabvala is not pictured.

Larger Microcalorimeter Array

Chief among the improvements is the instrument's microcalorimeter array — an IRAD-funded technology that first flew on Suzaku. With microcalorimetry, incoming X-ray photons strike the microcalorimeter's absorbers, where their energy is converted to heat and measured. The heat is directly proportional to the X-rays' energy, revealing much about the physical properties of the X-ray-emitting object.

To gather as many X-ray photons as possible, scientists place an array of microcalorimeters at the focus of a large X-ray telescope and cool the instrument to about one-tenth of a degree above absolute zero.

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About The Cover:

Each year, the Office of the Chief Technologist selects a technologist or team of technologists who exemplify the best in R&D. This year, the office has selected a team, led by Principal Investigator Richard Kelley (center), to receive the award for its work building a next-generation spectrometer for Japan's Astro-H mission. The team was chosen because of its success leveraging R&D funds to enhance instrument capabilities and ultimately winning the $44 million Soft X-ray Spectrometer (SXS) development effort. Kelley's SXS team will receive the award at the Annual IRAD Poster Session — "Collaboration + Innovation = Mission Success" — on November 6. Also pictured are Christine Jhabvala (left) and Peter Shirron (right).

Photo Credit: Chris Gunn

X-ray Astronomy... *Continued from page 2*

While Suzaku carried a spectrometer equipped with a 32-pixel microcalorimeter array, the SXS array is twice as large with 64 pixels, said detector developer Christine Jhabvala. More pixels mean a greater field of view, which will significantly improve measurements of the many extended sources that Astro-H will observe. Scaling up to the larger size was driven in part by a new technique for attaching large numbers of absorbers simultaneously, she said.

Two-Stage ADR

The cooling technology needed to measure X-ray photon heat represents another significant instrument advance. SXS will come equipped with a two-stage adiabatic demagnetization refrigerator (ADR), a mechanical cooling system that provides improved cooling capacity over the cryogenic dewars that NASA traditionally used to cool infrared and X-ray detectors. Suzaku had flown a one-stage model.

Further improvements are planned for the Goddard-developed technology, said Peter Shirron, who leads the Center's ADR development effort. With his R&D funding, Shirron is now developing a more advanced four-stage unit — the continuous ADR — that runs around-the-clock and is capable of 30 times more cooling capacity.

"Support we've received through IRAD and Goddard's Innovative Partnerships Program Office has really kept us going," Shirron said.

Mirrors

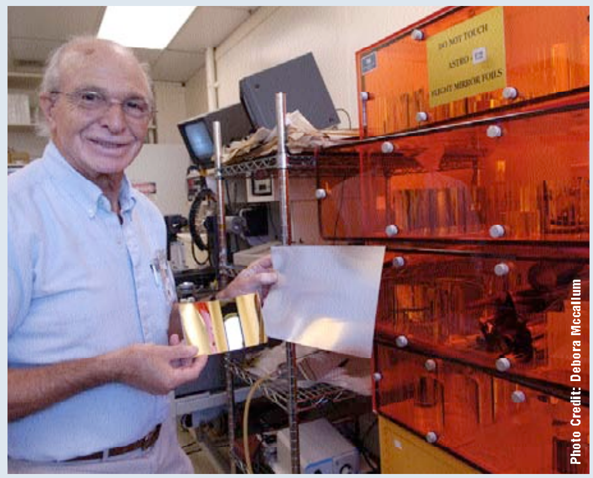
The instrument's mirror assembly also benefited from past R&D funding, Kelley said.

SXS's mirror assembly will include as many as 1,800 curved mirror segments, nested inside a canister-type assembly. Goddard scientist Peter Serlemitsos and his co-workers will make the mirror shells of a commercial aluminum alloy sheet, which is inexpensive and very lightweight — two very important considerations for space-borne instruments.

The challenge is in accurately shaping the aluminum, then making its surface smooth enough and coating it with gold to efficiently reflect X-rays. The smoothness requirement is considerably more stringent than it is for optical telescope mirrors, he said. Using Goddard R&D funding, Serlemitsos developed a technique to replicate the smoothness of PYREX glass using a sprayed epoxy buffer layer and a thin gold layer, acting as the release agent.

"With this technology, we were able to find a niche in the field of X-ray instrumentation. We were able to keep down instrument costs and weight, which are important drivers in the field," he said. ◆

SXS will fly a more capable adiabatic demagentization refrigerator to cool the instrument's microcalorimeter detectors. Peter Shirron is shown here with the technology.



Scientist Peter Serlemitsos holds a sheet of aluminum, which he used to ultimately create the gold-coated, curved mirror that he holds in his right hand.

To focus X-rays, scientists stack curved mirrors inside a canister-type optical assembly, such as the one shown here.

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SPECIAL REPORT: NEXT-GENERATION EARTH-OBSERVING MISSIONS

In 2007, the National Research Council urged NASA to rebuild its network of Earth-observing spacecraft. The first two missions begun as a result of those recommendations are the Soil Moisture Active Passive (SMAP), which will gather little-known data about soil-moisture levels, and the Ice, Cloud, and land Elevation Satellite (ICESat-II), which will measure ice sheet balance and cloud properties.

In starting the missions earlier this year, NASA directed the Jet Propulsion Laboratory (JPL) to lead SMAP, with significant inputs from Goddard, and Goddard to lead ICESat-II, with possible contributions from JPL. This article addresses the challenges Goddard scientists are overcoming to build SMAP's radiometer.

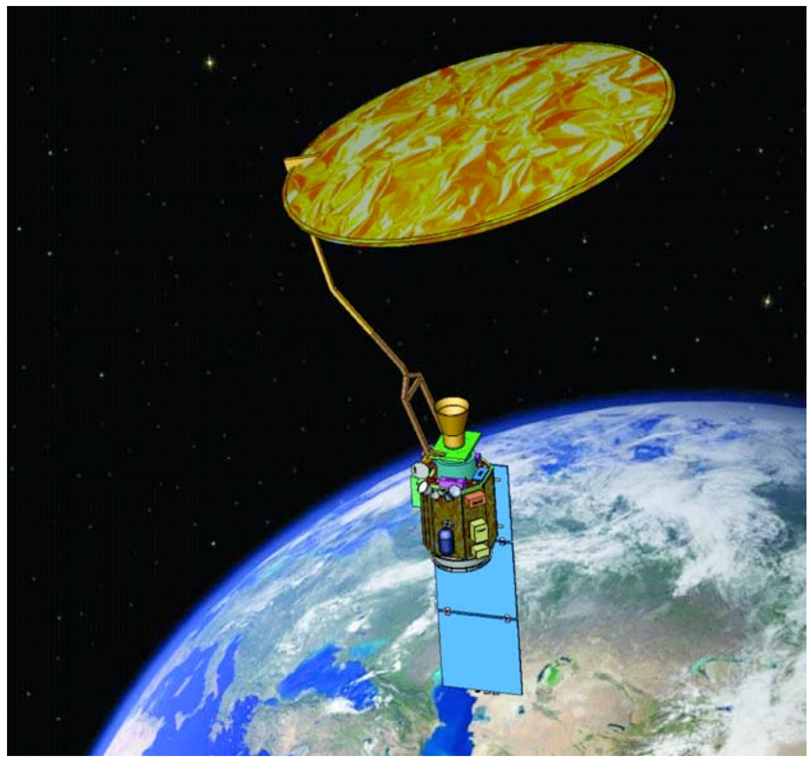
Running Interference

Radiometer Team to Test Algorithms to Enable Collection of Soil-Moisture Data

Before NASA launches a next-generation Earth-observing satellite dedicated to measuring how much moisture is bound up in the soil — a data point now largely missing in global change models — Goddard instrument designers will have to overcome one potentially tricky technological nuisance: radio interference from air-traffic control radars and even oil rigs.

The Soil Moisture Active Passive (SMAP) mission that NASA officially started earlier this year in response to the National Research Council's first-ever Decadal Survey for Earth science will globally map soil moisture and the freeze/thaw state with unprecedented accuracy, resolution, and coverage when it launches in 2013.

The NASA-directed mission will carry a high-resolution synthetic aperture radar and a Goddard-developed radiometer that thermally images heat at long wavelengths.



Goddard scientist Jeff Piepmeier will be building the radiometer for the Soil Moisture Active Passive mission, shown here in this artist's rendition. The mission is one of two that NASA began earlier this year.

Challenges to Overcome

However, building a radiometer and obtaining the type of global data scientists require are easier said than done.

To sense near-surface water, salinity, humidity, and other characteristics, instruments must penetrate vegetation and other barriers, which only can be accomplished using longer wavelengths either in the C- or L-band frequencies. Until recently, the L-band was off limits due to the prohibitively large antenna systems required to capture the long wavelengths. That left the C-band for these types of measurements — and in retrospect, not an ideal solution.

Overlap from active radio-service allocations has seriously affected remote-sensing products in the C-band. The radiometer on the Aqua spacecraft, for example, is plagued by interference, making it extremely difficult to use for soil-moisture remote sensing.

However, recent advances in antenna design now make L-band applications possible, which is why SMAP's instruments will operate in the L-band (1.4 GHz) — a frequency that is devoted to "passive" remote-sensing applications. In other words, users at these low-frequency bands are not allowed to transmit data. They only may listen to the "static" from which they can derive the moisture data.

However, even that band might encounter interference from neighboring spectrum users, particularly from air-traffic control radars, said Jeff Piepmeier, the instrument scientist for Goddard's radiometer.

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Measuring Dust Motes

Instrument Prototype Could Help Scientists Understand Dust Problem on the Moon and Mars

While chasing down the swirling towers of dust that frequently crop up in the deserts of the American Southwest, research physicist Brent Bos experienced an "ah-ha" moment.

Dust devils, like the one captured in this photo, are driven by the same physical mechanisms that form their cousins on Mars. Goddard Principal Investigator Brent Bos is now developing an instrument that would measure the count, shape, size, velocity, and trajectory of dust particles to better understand their characteristics on the Moon and Mars.

Although he could measure the dust particles that fell in and around the mini-cyclone he was tracking that summer day 5 years ago with a customized microscope attached to a camera, he couldn't measure the individual particles' characteristics and dynamics while they were entrained within the vortex. "That's when I started thinking about other optical techniques that would allow me to see the particles inside," he recently recalled.

For Bos and a team of other Goddard scientists, seeing the particles that make up these whirling plumes of dust and grit isn't just an academic question.

Dust devils also occur on Mars, apparently driven by the same physical mechanisms that form their cousins on Earth. Dust also presents a severe challenge on the Moon, where ultra-tiny particles levitate in all directions and at various speeds, adhering to everything with which they come into contact.

Dust Characterization Applications

Having an instrument that could measure dust particle sizes, concentrations, and velocities obviously would have practical applications for NASA's Exploration Systems Mission Directorate, Bos reasoned — especially since the sensors that obtain these measurements on Earth won't work in the low-pressure atmospheres found on the Moon and Mars. Current sensors don't monitor trajectories, either.

"What we need to know is what's going on at a particle level. We needed to see these particles in flight," Bos said.

And so began his effort to build an instrument — the Large Depth-of-Field Particle Image Velocimeter (PIV) — that would gather these measurements and give scientists needed insights into the lunar and Martian dust environments and how engineers might mitigate the dust problems before astronauts explore these worlds in the coming years.

The prototype instrument, funded in part with Goddard Internal Research and Development (IRAD) funding, features an "afocal" optical design that looks promising, Bos said. During a field campaign in Arizona 1 year ago, Bos was able to detect dust particles as small as 5-10 microns in size.

But Bos said his instrument concept is not ready for prime time — yet.

To obtain images needed to determine particle count, shape, size, velocity, and trajectory, the instrument generates about 4 gigabytes of data every 3-1/2 minutes of operation. Space-based operations, even those in the future, unlikely will be able to transmit such large datasets.

Consequently, Bos and Co-Investigator Scott Antonille are using IRAD funding to develop algorithms that can autonomously identify, measure, and track the dust-particle signals measured by the PIV. The aim is to significantly reduce the amount of data that a flight-ready PIV would downlink back to Earth.

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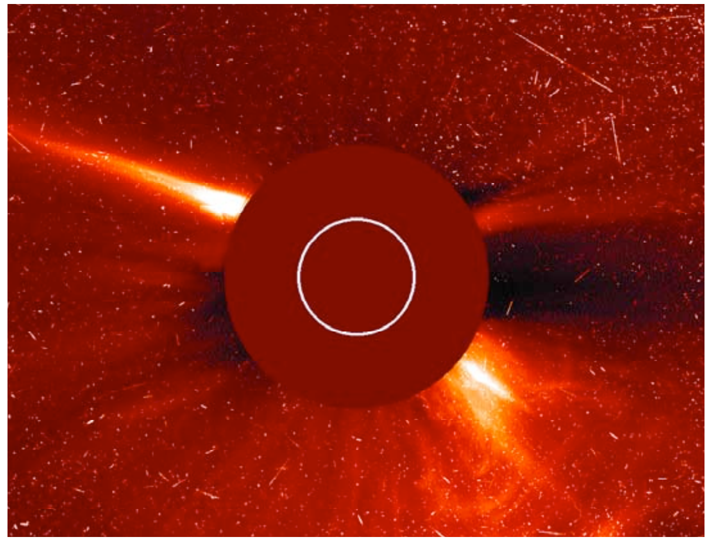
Chicken Little: The Sky Isn't Falling

New Instrument Could Improve Ability to Predict the Orbital Decline of Low-Earth Orbiting Satellites

In December 2006, a massive solar flare erupted on the Sun's surface, setting off a fast-moving stream of extreme-ultraviolet photons and atomic particles straight for Earth. The resulting bombardment heated Earth's uppermost atmospheric layer or thermosphere and caused it to expand, ultimately disrupting a handful of European-owned satellites and the attitude-control system on the International Space Station.



Two years ago, the Sun unleashed a large solar flare and coronal mass ejection (pictured above) that upset several spacecraft. Goddard scientist John Sigwarth is now developing an instrument to reveal how similar solar storms affect Earth's thermosphere, contributing to atmospheric drag on low-Earth-orbiting spacecraft.

Though ground controllers took steps to protect their respective assets, solar-induced disrupts, such as the one that occurred 2 years ago, haven't always had happy endings.

In the late 1970s, for example, Skylab plunged to the Earth earlier than expected after a storm-heated atmosphere expanded and exerted an aerodynamic drag on the low-flying laboratory. In 2001, Japan's Advanced Satellite for Cosmology and Astrophysics suffered an identical fate.

With so much at stake, Goddard scientist John Sigwarth is setting out to learn more about the thermosphere, which is 200-400 km (124-249 miles) above Earth's surface. The goal is to more accurately predict atmospheric drag on low-Earth-orbiting spacecraft.

Measuring Thermospheric Temperatures

With Goddard Internal Research and Development funding, Sigwarth is developing a prototype-demonstration instrument that is slated to fly on the U.S. Naval Academy's experimental MidSTAR-2 spacecraft in 2011. The Thermospheric Temperature Imager (TTI) will remotely sense the temperature of Earth's thermosphere and demonstrate key enabling technologies that could pave the way for a more robust flight opportunity in the future.

Such a measurement capability currently isn't available. These measurements are possible in-situ; that is, they only can be made at the location of the sensor. With TTI, however, direct measurements could be made near simultaneously around the globe.

The instrument works by imaging the spectral lines of atomic oxygen and molecular nitrogen in the far-ultraviolet wavelength bands — measurements that together reveal the temperature of the thermosphere. To see the width of these spectral lines, Sigwarth's team worked with an Oregon-based company, LightSmyth Technologies, under the Small Business Innovation Research program to develop a state-of-the-art diffraction grating that performs like a prism, separating the light into its constituent wavelengths or colors.

Gratings, like the one being developed for TTI, consist of equally spaced parallel grooves, etched on a silicon substrate and then coated with a reflective layer. A grating's resolution depends largely on the distance between adjacent grooves and the groove angle. At 7,200 grooves per millimeter on an 8-inch piece of silicon substrate, the TTI grating has the highest density and consequently the highest spectral resolution ever achieved in a flight instrument, Sigwarth said.

Good Timing

For Sigwarth's team, the flight opportunity couldn't come at a better time.

The MidSTAR-2 launch coincides with the 11-year solar maximum, a period when the Sun produces a higher number of sunspots and solar storms. When the Sun is active, it can double its extreme-ultraviolet photon output and hurl clouds of electrons, protons, and heavier ions toward Earth at nearly the speed of light. In addition to degrading the orbits of satellites, these solar storms knock out power grids, play havoc with radio communications, and expose astronauts to high dosages of radiation.

Having an instrument that demonstrates near real-time temperature-measuring capabilities at a time of high solar activity should give scientists much-needed data to understand the Sun's effects on Earth's atmosphere. "The point is we have to better predict where satellites will be. This mission will give us better data to better protect our space assets," Sigwarth said. ◆

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A Mystery Wrapped Up in An Enigma

Goddard-Developed Instrument Measures Heat from Unlikely Saturnian Moon

The Goddard-developed instrument that discovered heat escaping from prominent fractures near the south pole of Saturn's tiny moon, Enceladus, could one day have a successor.

Goddard investigators are now using Center and NASA R&D funding to advance technologies needed to develop a lightweight successor to the Cassini mission's Composite Infrared Spectrometer (CIRS), which can "see" in the dark and map surface temperatures. Such an instrument, dubbed CIRS-Lite, already has been baselined for the proposed Titan Orbiter mission, which would investigate the complex atmosphere and methane-driven hydrological cycle on Saturn's largest moon sometime in 2018.

To get a berth, however, scientists would have to reduce the instrument's mass by half, improve its spectral resolution, and equip the instrument with detector arrays capable of imaging.

A Good Role Model

The proposed instrument, however, couldn't have a better role model.

Among other discoveries, CIRS has found evidence for an isolated polar vortex around Titan's north pole, similar to the one that occurs on Earth. The observations suggest that strong, circulating winds isolate the atmosphere during the polar night. CIRS also has made some remarkable discoveries on Enceladus, one of Titan's much smaller sisters.

During flybys this year, CIRS measured remarkably high temperatures of at least 180 Kelvin (-135° Fahrenheit) along fissures or "tiger stripes" that cross Enceladus's south polar region. "The temperature is higher than what you'd think normal for a polar region," said Goddard scientist Mike Flasar. By way of comparison, surface temperatures elsewhere in the area are below 72 Kelvin (-330° Fahrenheit).

These thermal "hot spots" spew active plumes of water vapor, water particles, and other gases, and scientists do not know why or how such a relatively tiny moon can sport such an active geology.

Additional flybys are planned to further probe the mystery. In October, Cassini will fly past Enceladus twice, coming as close as 25 kilometers (16 miles) from the orb's surface. "We know almost nothing about these bodies," Flasar said. "We're just trying to make sense of this foreign outpost." ◆

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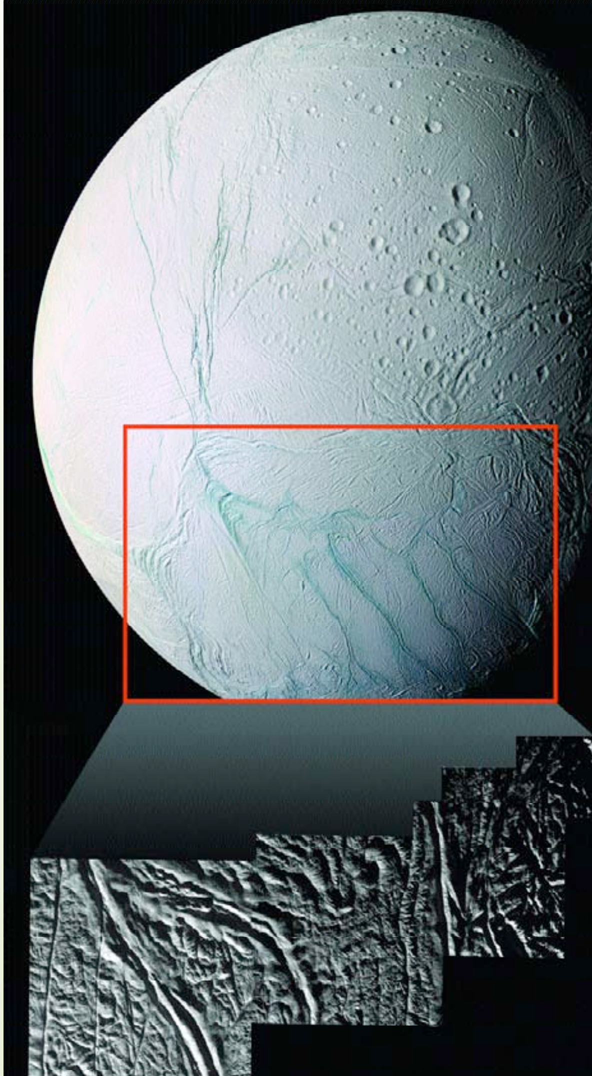
Cassini Fly-By

Enceladus

This mosaic was created from 21 false-color frames taken during the Cassini spacecraft's close approaches to Enceladus on March 9 and July 14, 2005. The fractures or tiger stripes — the area that has attracted considerable interest among scientists — are visible near the moon's south pole.



Cassini shot past the surface of Enceladus on Aug. 11 this year, acquiring a set of seven high-resolution images targeting known jet source locations on the moon's "tiger stripe" fractures, or sulci. Scientists are using these new images to study geologic activity involving the sulci and effects on the surrounding terrain. This information, coupled with observations by Cassini's other instruments, may answer the question of whether reservoirs of liquid water exist beneath the surface.

Interference... Continued from page 4

"There is some anecdotal evidence that we will get interference," he said. "What we want is quantitative data. What we want to see is whether there's interference in cities, in rural areas, near airports."

Quest for Quantitative Data

That's why he is going on the offensive.

Using Internal Research and Development funding, Piepmeier and his team are installing Goddard- and University of Michigan-developed receivers — hardware that will be used in the SMAP radiometer — on a Twin Otter aircraft to collect data over North America in October. Piepmeier's team will then use the data to determine the level of interference and whether algorithms his team developed effectively mitigate the interference.

"With radiometers, all you do is listen," Piepmeier said. "You listen to the static, which tells us about the Earth and the atmosphere. Radio signals are interference to us. In other words, one person's noise is another person's signal. What we don't want is radar from airports or communications from an oil platform. What we really don't want is to launch SMAP and find the data is unusable," he said. ◆

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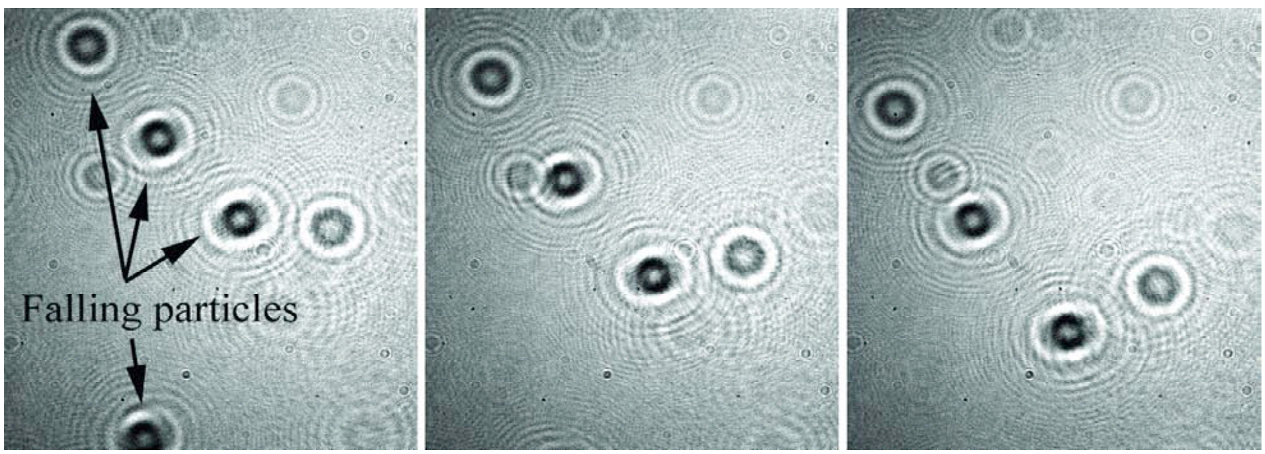
Dust... Continued from page 5



During a field campaign in 2007, Principal Investigator Brent Bos used his Large Depth-of-Field Particle Image Velocimeter to capture these images of dust particles as small as 10 microns.

Other Applications

Characterizing the lunar and Martian dust environments isn't the only application, Bos said. On the Moon, for example, dust particles adhere to spacesuits and other equipment, posing potential health hazards to astronauts if the grit finds its way into living quarters. If installed inside an airlock, however, the PIV could measure the number and sizes of particles being expelled from astronauts and their gear, confirming that the grit had actually left the airlock.

"We want to continue maturing this technology, and ultimately win a flight opportunity on a lunar or Mars lander in the 2014 or 2015 timeframe," Bos said. "With additional funding, I believe we'll be able to meet that goal." ◆

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Goddard Tech Trends

Goddard Tech Trends is published quarterly by the Office of the Chief Technologist at the Goddard Space Flight Center in Greenbelt, Md. The newsletter describes technology developments at Goddard and explains how they are helping NASA to achieve its missions. If you want more information about Goddard technology, contact the Chief Technologist. If you wish to be placed on the newsletter distribution list, contact the editor.

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