National Aeronautics and Space Administration

Cutting edge

Goddard's Emerging Technologies

The Highwire Act | Tapping Into a Very Large Antenna

Scientist Antti Pulkkinen is using high-voltage power transmission lines as a very large antenna to measure a space weather-related phenomenon. (Photo Credit: Bill Hrybyk/NASA)

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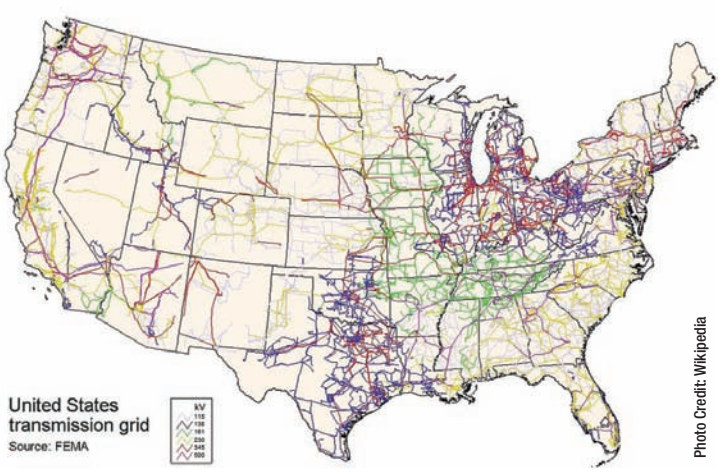
High-Voltage Transmission Lines to Act as Antenna in First-of-its-Kind Space-Weather Project

A Goddard scientist is launching a one-to-two-year pilot project this summer that takes advantage of U.S. high-voltage power transmission lines to measure a phenomenon that has caused widespread power outages in the past.

Heliophysicist Antti Pulkkinen and his team are installing scientific substations beneath high-voltage power transmission lines operated by Dominion Virginia Power this summer to measure in real-time a phenomenon known as geomagnetically induced currents (GICs). "This is the first time we have used the U.S. high-voltage power transmission system as a science tool to map large-scale GICs," Pulkkinen said. "This application will allow unprecedented, game-changing data gathering over a wide range of spatial and temporal scales."



This graphic shows the high-voltage power transmission system in the U.S. Principal Investigator Antti Pulkkinen wants to take advantage of this existing "antenna" to measure a phenomenon that has led to widespread power outages in the past.

In addition to gathering data important to the power industry — especially if it's expanded nationwide as currently planned — the project will allow heliophysicists to "reverse engineer" the data to learn more about what happens to Earth's upper atmosphere when GICs are generated during severe space weather, Pulkkinen said, adding he is now developing computer algorithms to extract that data for scientific research. "Not only will this benefit the utility industry, it also benefits science," he said.

Solar Storms the Culprit

GICs typically occur one-to-three days after the sun unleashes a coronal mass ejection, a gigantic bubble of charged particles that can carry up to 10 billion tons of matter. These bubbles accelerate to several million miles per hour as they race across space. If a blob of material slams into Earth's near-space atmosphere, the impact causes Earth's magnetosphere — and electric currents within it — to fluctuate. These variations induce electric currents that can flow through any large-scale conductive structure, including power lines, oil and gas pipelines, undersea communications cables, telephone and telegraph networks, and railways.

An extreme example of a GIC occurrence was the great magnetic storm of March 1989 — one of the largest disturbances of the 20th century. Rapid variations in the geomagnetic field led to intensely induced electric fields at the Earth's surface. This electric field caused currents to flow through conducting structures — in this case, the Canadian Hydro-Quebec power grid. The excess current collapsed the transmission system, causing the loss of electric power to more than six million people.

According to the U.S. Geological Survey, had the blackout occurred in the Northeastern U.S., the economic impact could have exceeded $10 billion, to say nothing of the deleterious impact on emergency services and reduction in public safety.

Nation's Grid Highest Concern

Although large solar events can disrupt communications and even potentially corrode pipeline steel, the impact on the nation's electric grid is perhaps the highest concern at the moment, Pulkkinen said. "It's the hottest topic out there right now," he said, adding that the Federal Energy Regulatory Commission is now developing standards to mitigate the GIC threat. "We need to better understand how these events affect the U.S. power grid," he added.

His pilot program is designed to help find out, Pulkkinen said.

Funded by R&D Programs

Funded by NASA's Center Innovation Fund and Goddard's Internal Research and Development (IRAD) program, the team is creating three substations, all equipped with commercially available magnetometers capable of precisely measuring GICs. Once inserted inside a protective, watertight housing unit, designed by Goddard engineer Todd Bonalsky, the team will bury the gear four feet into the ground — two directly below Dominion Virginia Power's high-voltage lines and the third one-to-two miles away. The latter will provide reference measurements.

Troy Ames (left) and Carl Hostetter (right) created LabNotes, a program that will allow heliophysicist Antti Pulkkinen to command and control instrumentation via an iPad-Mini.

"In essence, we're tapping into a very large antenna, Pulkkinen said. "The high-voltage lines are the antennae. During solar storms, violent changes in the electric current occur in near-space, which then are sensed by the transmission lines."

Ubiquitous iPad Finds Scientific Application

To command and control the magnetometers, Pulkkinen's team is using another IRAD-developed technology, LabNotes. This iPad application, developed by Goddard engineers Carl Hostetter and Troy Ames, will time tag and geo-locate the magnetometers' data, and then deliver the information to a server via a cellular data network, Hostetter explained. In addition to sending one sample per second, the LabNotes-equipped iPad-Mini also could monitor the data and send a text message should an event warrant attention.

"Now that everyone is walking around with this type of computer, which is more powerful than some supercomputers of 15 years ago, we thought we may as well use it for scientific purposes," Hostetter said, adding that its relatively small size and low-power consumption make it ideal for science gathering. Although Pulkkinen's team is the first to actually use the application, Hostetter said the technology has interested a number of other projects, including one involving agricultural needs in Africa (see related story, page 6).

The Goal: Nationwide Coverage

The project's objective, Pulkkinen added, is making the equipment as inexpensive and versatile as possible. Although the pilot project begins with only three substations, Pulkkinen wants to ultimately deploy hundreds across the nation. "We envision that after a one-to-two-year pilot phase, long-term funding from a multi-agency collaboration and public-private partnerships will make this happen."

"Impacts to the nation's power grid are currently the highest space-weather concern in the U.S.," he added. With federal regulations on the horizon, Pulkkinen said the measurements would help define the most effective techniques for mitigating GIC threats. ❖

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OCULLAR Sees Ocean Color Day and Night

Instrument to Provide First-Ever Around-the-Clock Measurements

A Goddard-led team has developed an instrument capable of observing ocean color during normal sunlight conditions and under moonlight — a first-ever capability that will allow scientists to monitor the health and chemistry of the planet's oceans literally around the clock.

The prototype Ocean Color Underwater Low Light Advanced Radiometer (OCULLAR) has shown in field testing that it can measure ocean color under low-light conditions across multiple wavelength bands, from the ultraviolet to the near-infrared. In contrast, current remote-sensing instruments can obtain measurements — based on electromagnetic energy emitted by the sun, transmitted through the atmosphere, reflected off the Earth's surface, or upwelled from water masses — only during daylight hours, said Principal Investigator Stan Hooker.

First-of-a-Kind Capability

Of particular interest to scientists studying ocean color is phytoplankton, the microscopic ocean plants that form the base of the oceanic food web. These tiny plants use sunlight and carbon dioxide to produce organic carbon. This process, called photosynthesis, is possible because plants contain chlorophyll, green-colored compounds that trap the energy from sunlight. Because different types of phytoplankton contain different kinds of chlorophyll, measuring the color of a particular area allows scientists to estimate the amount and general type of phytoplankton there. Since phytoplankton also depend on specific conditions for growth, they frequently become the first to be affected by pollution or some other change in their environment.

"Ocean color is what we see and is a big part of understanding the ocean's diversity," Hooker explained. "You can figure out what's happening in the ocean by looking at the different colors or wavelengths, which then are used to determine what constituents in the water are creating that color."

Until now, however, obtaining these measurements was limited to daylight hours and only dur-

Photo Credit: Bill Hrybyk/NASA

Above: Principal Investigator Stan Hooker holds his prototype OCULLAR instrument, which has demonstrated that it can observe ocean color under low-light conditions.

Lower right: NASA images showing Earth at night inspired Principal Investigator Stan Hooker to develop an instrument that could measure ocean color under low-light conditions.

Photo Credit: NASA

ing the spring, summer, and fall months in the polar regions — a problem Hooker sought to correct with OCULLAR. Inspired in part by NASA "black marble" imagery, which showed the Earth at night, Hooker thought, "with the right technology, we could look at the planet at night."

The need, he said, was compelling. "The light levels are so low, you literally lose hours of data around the world and, at the polar areas, an entire season of data."

A Marriage of Two Detector Systems

The team, which also includes Charles Booth and John Morrow, both scientists with Biospherical Instruments, Inc., in San Diego, created the new capability by pairing two light-measuring, but distinctively different, detector systems: a miniature and ruggedized photomultiplier tube (PMT) with an existing silicon photodetector microradiometer, with an embedded microprocessor. When commercialized, Hooker said hybrid OCULLAR instruments would be equipped with seven PMTs paired with seven silicon photodetectors. An eighth photodetector will measure a wavelength useful to ocean color, but difficult to measure with a PMT.

Its functioning is straightforward. When photons — the fundamental particles of light — strike a silicon detector, the photons cause a response that is measured as voltage. When fewer and fewer photons are detected, as occurs under low-light conditions, the detector reports a smaller and smaller voltage. As a result, the microradiometer's computer "brain" instructs the second detector system — the photomultiplier tube — to swing into action. As its name implies, the PMT multiplies the effect of the photons that enter the system to create a cascade that OCULLAR can easily sense. The photomultiplier capability is not activated under normal sunlight conditions.

Considerably smaller than older legacy ocean-color instruments, which could be as large as an office trash can, an OCULLAR instrument will measure three-and-a-half inches in diameter and about a foot in length — making it compact enough for use on a range of platforms.

"We thought we could pair a photomultiplier tube with a smart silicon photodetector, which we equipped with a computer brain, but we had never done it before," Hooker said. "So we used R&D funds to test that hypothesis. We were completely successful."

Leading the Way to Commercialization

During a field campaign measuring nighttime light off the coast of San Diego — a site purposively selected because future NASA Earth remote-sensing missions likely will concentrate on coastal observations — the team proved the prototype's ruggedness and high sensitivity over a large range of light. "In fact, we were more successful than we thought we would be," Hooker added.

Continued on page 12

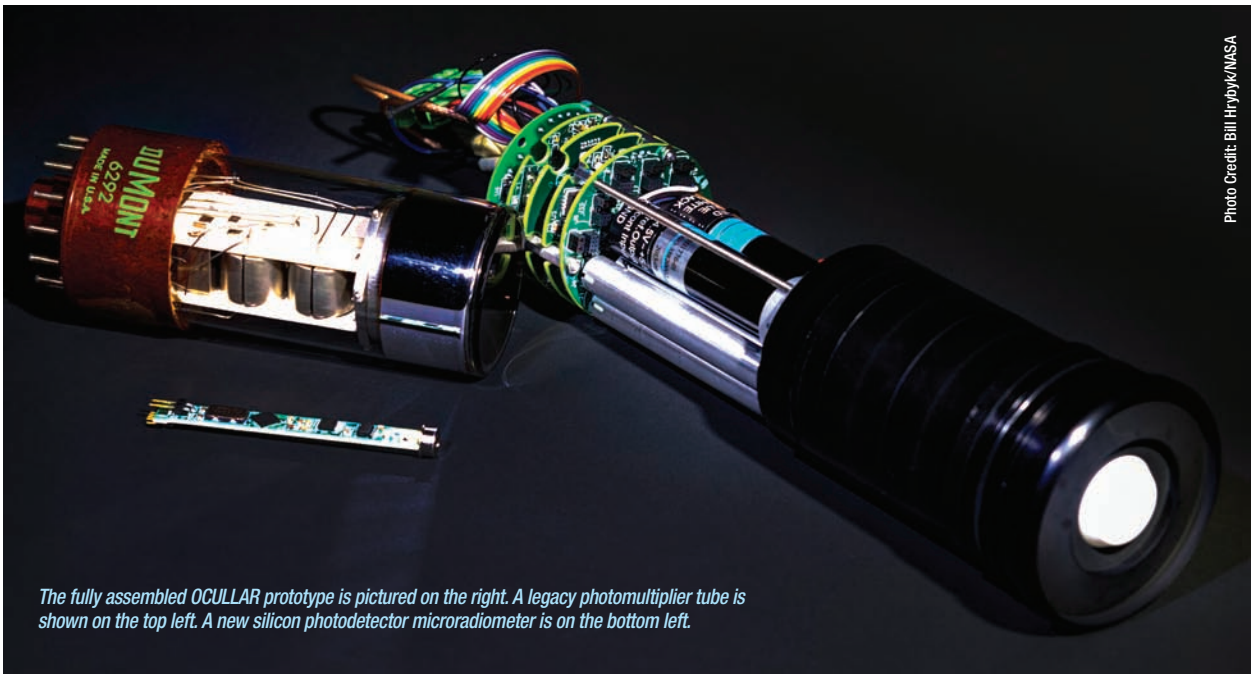


Photo Credit: Bill Hrybyk/NASA

The fully assembled OCULLAR prototype is pictured on the right. A legacy photomultiplier tube is shown on the top left. A new silicon photodetector microradiometer is on the bottom left.

Goddard Technology to Deliver Satellite Data to African Farmers

From hundreds of miles in orbit, NASA satellites can measure how much rain falls in Niger or detect plant health in Mali. But on the ground, many African farmers and food distributors don't have good information about the growing conditions a few dozen miles down the road.

Teaming up with an African agriculture organization, NASA Goddard researchers aim to bring satellite data on precipitation and vegetation health to the cell phones of thousands of farmers, food distributors, and others in 17 African countries.

A new program is bringing together scientists from two Goddard branches and an African non-profit to get relevant satellite data into the hands — and cell phones — of people who could use it the most. The program, funded by the Advanced Collaborative Connections for Earth Systems Science program, will build on two Goddard-developed technologies — LabNotes and FieldNotes — to help scientists collect and track data.

"Putting the information in the hands of agriculture users is one of the many ways that we can show that the satellite data has benefits to society," said Molly Brown, a research scientist with Goddard's Biospheric Sciences Laboratory.

Brown and her colleagues already have developed a 30-year dataset of satellite information on African precipitation rates, vegetation health, soil moisture, and evapotranspiration — all indicators of crop health in a given area. With researchers from Columbia University, she is developing a system that can improve the way insurance companies set rates for drought protection.

That data, however, also would be important information to local farmers and food distributors who have to determine which regions have a surplus of maize, millet, rice, and other crops — and therefore which regions they should focus on to purchase excess food to sell at central markets. When distributors can buy excess food, it can encourage farmers to grow more in good years, knowing that there is a market. More food production, and more efficient distribution, could improve food security for the region.

Goddard-Developed Cell Phone Application

"All the background has been done. We need to write an application that can go on a cell phone," Brown said. "You put in your latitude and longitude, and it'll tell you whether or not it rained last week, if it's above or below average… The question is, how is this year progressing compared with previous years? That is exactly the information people want."

After a chance meeting with a representative of the African-based non-profit AGRA, or the Alliance for a Green Revolution in Africa, Brown started looking for ways to get satellite data to farmers and distributors through the mFarms platform. mFarms provides agricultural information via cell phones to its network — 80,000 farmers and thousands of other distributors, and warehouses in 17 African countries.

Agriculture in sub-Saharan Africa consists mostly of small farms, said Matieyedou Konlambigue, program officer with AGRA. The mFarms platform connects farmers with marketing agents and buyers, creating a database of how many acres farmers plant, tracking the productivity of fields and more. With NASA satellite data, the program can expand to include growing conditions for specific locations, and notifications of potential weather-related problems.

"The collaboration with NASA will be revolutionary," Konlambigue wrote in an email. "The geophysical

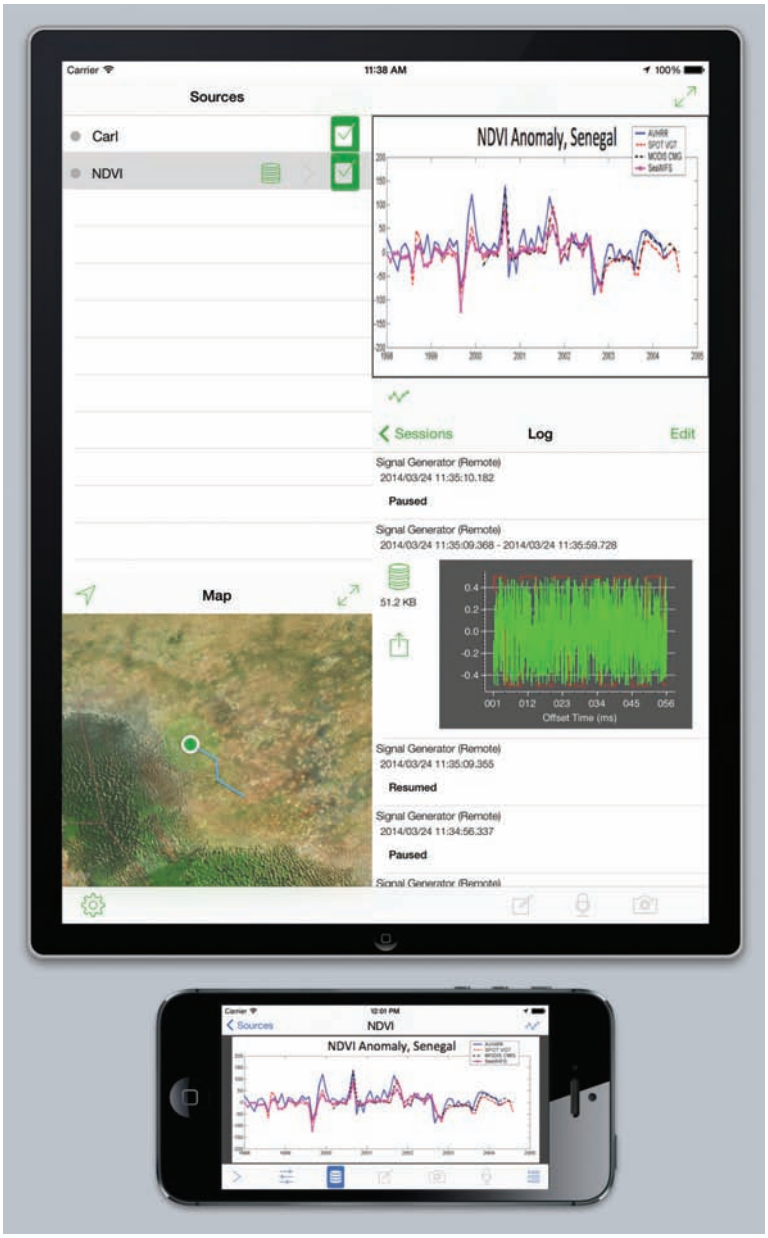
data will be processed into useful information and channeled through [mobile devices] to agricultural value chain actors in order to improve their planning and decision making."

To make this happen, Brown recruited Goddard's Science Data Processing Branch to work with mFarms and reach its network of farmers and distributors. Two projects started with Goddard Internal Research and Development program funding could help with the effort, said Tom Flatley, the branch head.

Data at Users' Fingertips

One, called LabNotes, is an app for mobile devices that connects to a data-gathering instrument. LabNotes, which a heliophysics-related project is applying to its data-gathering needs (see related story, page 2), can both send commands to the instrument and log and compile the data it receives. The second technology, called FieldNotes, is an app that collects and displays information from a variety of pre-set sources, including data from field instruments, pictures that others have shared, weather information, and other inputs depending on user need. Goddard computer engineers Troy Ames and Carl Hostetter developed the technologies.

"If they were getting soil-moisture data from the satellites, and some different gauges in their fields, the weather data coming in and somebody else's observation from a farm a couple miles down the road," Flatley said, "this could tie all that together."



Goddard computer engineers are developing a web and cell phone application that will display information from NASA satellites and other sources useful to African farmers and food distributors. While they're still determining which information will be most useful, they plan to base the app on the Goddard-developed program FieldNotes, a mock-up of which is seen here.

Jeff Hosler, a supervisory computer engineer at Goddard, will work with the mFarms team to determine what technological capabilities and infrastructure the network of farmers and distributors have and what specific kinds of information will be most useful. "It's rewarding that while we're working on these scientific applications for FieldNotes, this app could also be applied to people's everyday lives," Hosler said. "For some people, their livelihood depends on a lot of this kind of information."

The project also is a way to provide information to countries that helped provide the ground validation essential for researchers, Brown said. Researchers in Africa have provided on-the-ground measurements of rain and soil moisture, but the analysis of the information often doesn't come back to agricultural organizations and meteorologists.

"It's really important we do a good job transferring the benefits of satellite data to people in Africa," she said. ❖

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Heliophysicists Blaze a CubeSat Trail

Goddard Team Wins NASA Smallsat Mission

Literally one month after ground controllers made contact with a tiny Goddard-developed satellite designed to study mysterious and incredibly powerful gamma-ray bursts in Earth's upper atmosphere, NASA announced that another Goddard-led smallsat mission had become the latest to win an agency-funded CubeSat launch opportunity.

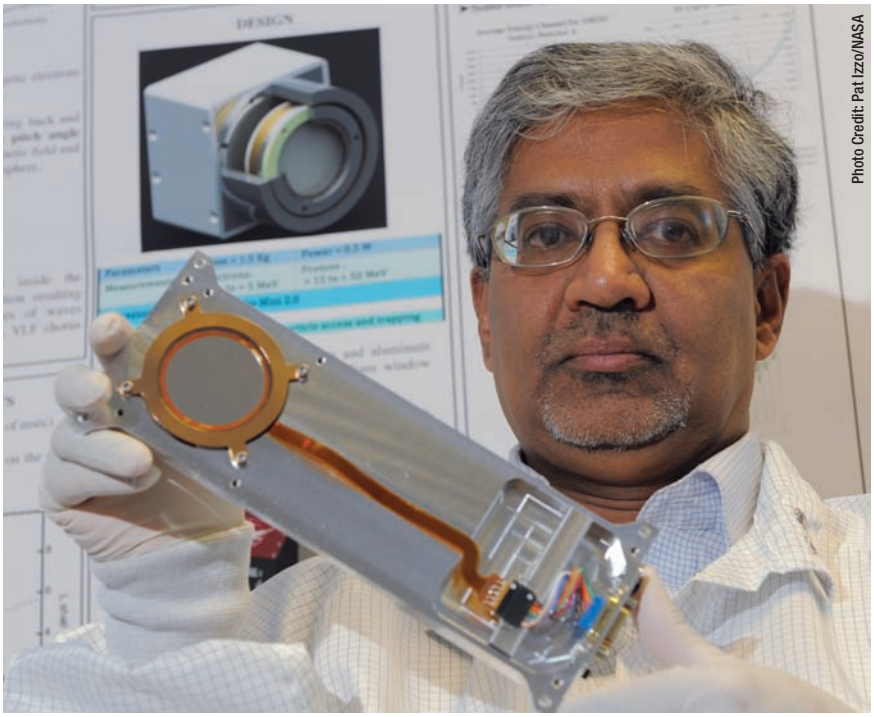


Photo Credit: Pat Izzo/NASA

NASA selected the Compact Radiation belt Explorer (CeREs) mission as one of 16 small satellites to receive funding under its CubeSat Launch Initiative. CeREs Principal Investigator Shri Kanekal holds an early version of one of the mission's solid-state detectors.

NASA selected the Compact Radiation belt Explorer (CeREs) mission, now being developed by a team led by Goddard heliophysicist Shri Kanekal and the Southwest Research Institute in San Antonio, Texas, as one of 16 small satellites to receive funding under the fifth round of its CubeSat Launch Initiative. The cube-shaped satellites are comprised of individual units, each about four inches on a side. They have a volume of about one quart and weigh about three pounds. CeRES is a three-unit or 3-U satellite. One unit will be occupied by a science payload or sensor.

NASA's selection of CeREs, developed in part with Goddard Internal Research and Development (IRAD) program funding (*CuttingEdge,* Winter 2013, Page 6), will study charged-particle dynamics in Earth's radiation belts using a novel sensor called the Miniaturized Electron and Proton Telescope and follows the successful launch and operation of Firefly. Firefly is gathering data on lightning and its potential connection to mysterious terrestrial gamma-ray flashes first discovered by the Compton Gamma Ray Observatory in the 1990s (*Goddard Tech Trends,* Fall 2009, Page 5).

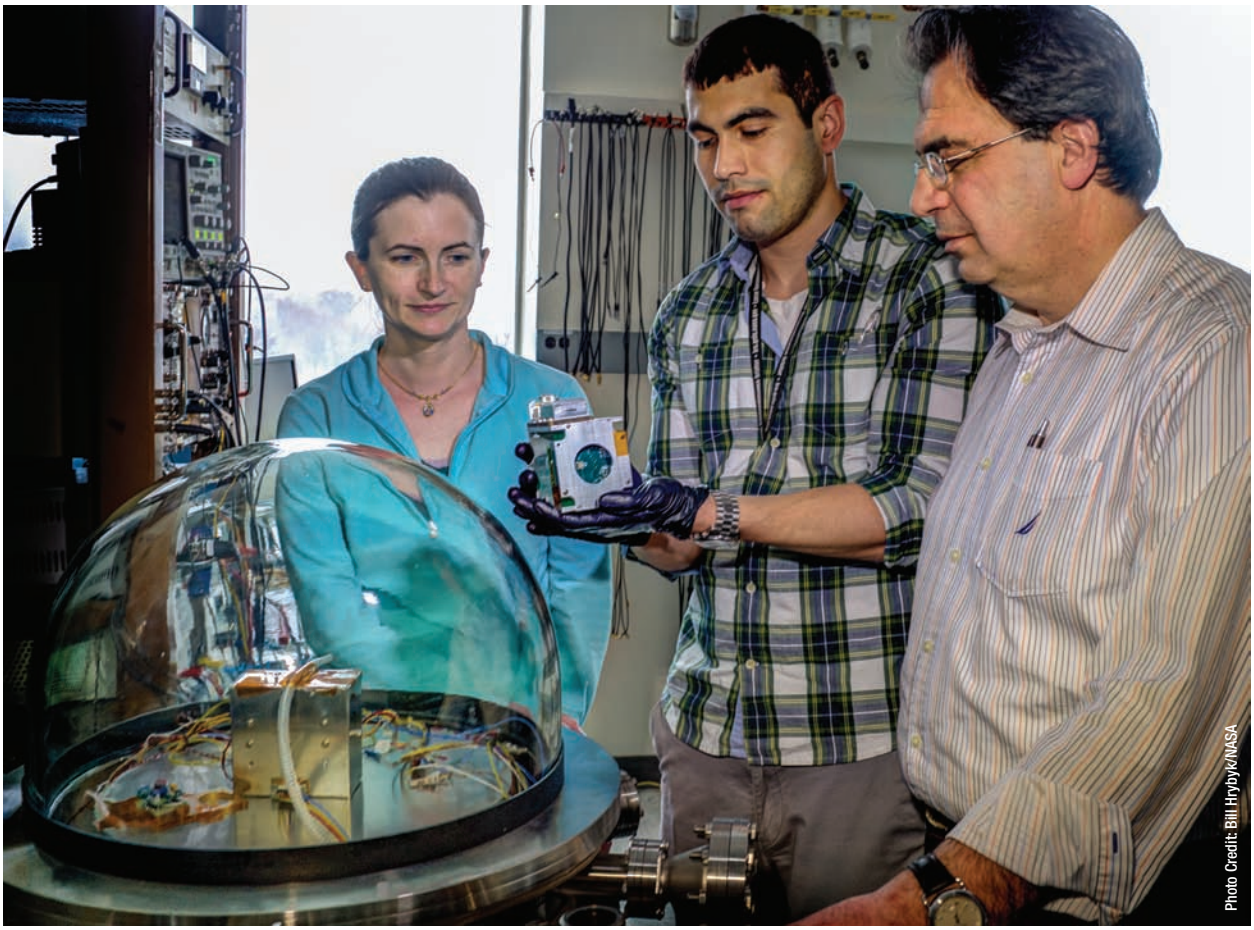
CeRES, which is expected to launch in 2015, will carry a small telescope, consisting of a stack of silicon solid-state detectors that will measure energetic electrons and protons in Earth's Van Allen radiation bands, the concentric bands of charged particles around Earth. Its measurements will provide details about the electron-burst phenomenon — short bursts of electrons that precipitate into the Earth's atmosphere and their role in the loss of electrons in the radiation belts. It will augment the science of the Van Allen Probes, a major flagship mission, Kanekal said.

Just the Latest in CubeSat Successes

Kanekal's successful proposal represents just the latest in CubeSat-related achievements within Goddard's Heliophysics Division.

Two other Goddard heliophysicists are expected to deliver miniaturized CubeSat instruments this year, continuing a growing NASA-wide trend making greater use of these low-cost platforms.

"Given the costs of getting into space and the limited launch opportunities for larger payloads, it stands to reason that those who could benefit from CubeSat platforms would pursue this technology aggressively," said Goddard Deputy Chief Technologist Deborah Amato. "At Goddard, the Heliophysics Division, which would benefit from simultaneous, multipoint observations, certainly is taking advantage of the opportunity."



Marcello Rodriguez (center) is holding in his palm the miniaturized ion/neutral mass spectrometer, as Sarah Jones and Nick Paschalidis look on. The instrument is being tested with ion and neutral gases in a controlled vacuum inside the bell jar shown in the foreground.

NSF-Funded Exo Mission

Nick Paschalidis and his core instrument team, including co-lead Sarah Jones and system engineer Marcello Rodriguez, are developing a new-generation, miniaturized ion/neutral mass spectrometer, a high-demand instrument in heliophysics. Supported by Goddard's IRAD program, the team is expected to deliver the first in a series of instruments for the Exo mission, funded by the National Science Foundation. The California Polytechnic State University is building the 3-U satellite, which will be launched aboard a Delta II launch vehicle in October from the Vandenberg Air Force Base.

From its polar orbit, the compact mass spectrometer, based on time-of-flight technology, will measure the composition and density of various ions and neutral elements in Earth's lower exosphere and upper ionosphere. "We're trying to measure the mixture — their personalities, how they play together," Paschalidis said, adding that NASA has a strong interest in making these in-situ measurements with one compact mass spectrometer. With the data, scientists will gain greater insights not only into the dynamics of the ionosphere-thermosphere-mesosphere system, but also the steady-state atmospheric conditions in the background.

Ultimately, the team wants to fly many of these instruments to gather simultaneous multipoint measurements, which are only possible with CubeSat platforms, Paschalidis said.

Air Force University Nanosat Program

Meanwhile, another Goddard heliophysicist, Georgia de Nolfo, is set to deliver the miniature neutron spectrometer for inner radiation belt studies this October. Supported by Goddard's IRAD program, the instrument is being developed under the auspices of the Air Force University Nanosat Program. Although a launch is not yet guaranteed, it could fly in 2015 or 2016 aboard a 6-U CubeSat built by New Mexico State University.

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DANY to Prove Prowess on Sounding-Rocket Mission

Inventors to File Patent Application for CubeSat Technology

Wallops engineers are demonstrating a new technology that promises to reliably deploy stowed solar panels, antennas, or even sunshades on a new class of small satellites called CubeSats.

The Diminutive Assembly for Nanosatellite deploYables (DANY), which Principal Investigator Luis Santos Soto plans to demonstrate on a sounding-rocket mission in May, was designed to unlatch a stowed device — in this case, a hinged piece of aluminum simulating a solar panel. The flight demonstration could advance DANY's technology-readiness level, paving the way for its possible infusion into future CubeSat missions and ultimate commercialization, Santos Soto said, adding he is in the process of filing a patent application.

The miniature release mechanism measures nearly three inches long, one and a quarter inch wide, and less than a quarter-inch thick. It operates much like a car-door latch, Santos Soto said. Affixed to the exterior of a CubeSat, it fastens an antenna, solar panel, or some other deployable in place during launch and then, upon command, applies a current that activates a heating element that melts a plastic retainer constraining the component. After the satellite reaches its intended orbit, the satellite activates the heating element and the stowed deployable can swing open to begin operations.

Designed for 6-U CubeSats

Santos Soto designed and built DANY specifically for six-unit or 6-U CubeSats, rectangular-shaped satellites that measure about a foot in height. Though invented by the California Polytechnic State University and Stanford University in 1999, CubeSats only in recent years have become more popular among government agencies seeking reliable, low-cost access to space. In 2007, NASA, the National Reconnaissance Office, and the Air Force determined that the technology had matured sufficiently for their applications and began investing heavily in CubeSat activities.

For Santos Soto, DANY's development was borne out of necessity. "I started working on CubeSats five years ago and every time I looked for a release mechanism, I couldn't find one small enough or one that could be placed on the outside of a CubeSat," thereby preserving more room inside for instruments and other hardware, he said. "Every little bit of volume is precious."

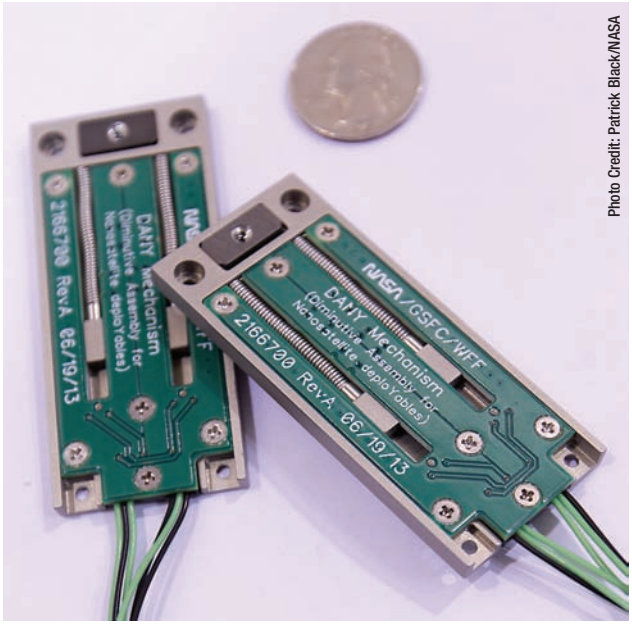

Photo Credit: Patrick Black/NASA

The Diminutive Assembly for Nanosatellite deploYables stows solar panels, antennas, or even sunshades on CubeSats. The two devices are placed next to a quarter to show their relative size.

Furthermore, the monofilament line that many use to tie a deployable in place did not offer the stability or reliability that Santos Soto sought. "It's like tying your car door shut with a rope. It could shake and rattle, making the launch environment somewhat unpredictable," Santos Soto explained. Using Internal Research and Development program funding, he created a rigid interface capable of withstanding 300 pounds of force while locking the deployable in place. With its embedded electronic switches, DANY not only releases deployables, but also sends a signal alerting ground controllers when the deployable is released.

Santos Soto said he is confident DANY will ultimately find widespread application within the CubeSat community, not only because of its reliability but also its low cost. Manufacturing 15 units will cost about $700 per mechanism, Santos Soto said, making DANY an attractive technology for CubeSat manufacturers. "With NASA becoming more involved with CubeSats, there is a need for reliable, preloaded mechanisms like DANY to meet the higher design standard. There is currently nothing like DANY available," Santos Soto said. ❖

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New Technique Could Be Used to Search Space Dust for Life's Ingredients

Scientists at Goddard's Astrobiology Analytical Laboratory recently applied an advanced technology to inspect extremely small, difficult-to-analyze meteorite samples — a technique that could prove invaluable for future NASA sample-return missions whose sample sizes likely will be limited.

Led by scientist Michael Callahan, a team has found amino acids in a 360-microgram sample of the Murchison meteorite. Although the sample was 1,000 times smaller than typical sample sizes, "we got the same results looking at a very small fragment as we did from a much larger fragment from the same meteorite," Callahan said.

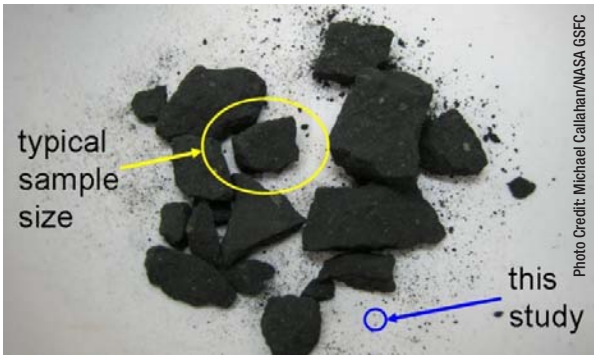
As a result of this proof-of-concept study that investigated the technology's effectiveness, he said scientists are closer to obtaining a tool that effectively investigates other small-scale extraterrestrial materials, including micrometeorites, interplanetary dust particles, and cometary particles returned to Earth by NASA's Stardust mission in 2006. "The traditional techniques used to study these materials usually involve inorganic or elemental composition," Callahan said. "Targeting biologically relevant molecules in these samples is not routine yet. We are not there either, but we are getting there."

Scientists are interested in studying these samples because a growing body of evidence suggests that material created in space and delivered to Earth by comet and meteor impacts could have seeded life here. Carbon-rich meteorites contain amino acids, which are critical to making proteins — important molecules used to make structures like hair and skin or to speed up or regulate chemical reactions.

However, these carbon-rich meteorites are relatively rare, comprising less than five percent of recovered meteorites. Furthermore, meteorites make up just a portion of the extraterrestrial materials that come to Earth and the concentration of building-block molecules found in these materials is low, typically parts-per-million or parts-per-billion. This raises the question of how significant their supply of raw material was.

Could it be that dust from comets and asteroids have played a greater, more significant role?

The team's proof-of-concept study was aimed at answering that question. "Extracting much less meteorite powder translates into having much lower amino acid concentration for analyses," said Callahan. "Therefore we need the most sensitive techniques available. Also, since meteorite samples can be highly complex, techniques that are specific for these compounds are necessary, too."



This photo compares the sample size typically used in meteorite studies (yellow oval) to the sample size used with the new equipment (blue circle) in Goddard's Astrobiology Analytical Laboratory.

The team used a nanoflow liquid chromatography instrument to sort the molecules in a water extract from the meteorite sample. It applied nanoelectrospray ionization to give the molecules an electric charge and then delivered them to a high-resolution mass spectrometer instrument, which identified the molecules based on their mass. "We are pioneering the application of these techniques for the study of meteoritic organics," said Callahan. "These techniques can be highly finicky, so just getting results was the first challenge."

Although the team said it still must fine-tune the technique, the successful demonstration paves the way for searching substantially smaller samples. Scientists also could apply it to other planetary-type applications.

"This technology also will be extremely useful to search for amino acids and other potential chemical bio-signatures in samples returned from Mars and eventually plume materials from the outer planet icy moons Enceladus and Europa," said Daniel Glavin, a Goddard scientist who works in the astrobiology lab. ❖

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OCULLAR, *continued from page 5*

"A human can see objects under full sunlight and barely see objects under a moonless night," explained Hooker. "The illumination for the former is about a billion times the illumination of the latter. The value can be represented as 10 raised to the ninth power, or nine decades of dynamic range. OCULLAR sensors have 14 decades of linear dynamic range, with the added responsivity at the low end of illumination," he added. "So, OCULLAR sensors have five more decades of response to low light than the human eye."

The successful OCULLAR demonstration leads the way to anticipated commercialization and creates a new capability for oceanographers, climate scientists, and others interested in quantifying, understanding, and monitoring the biological productivity of oceans, coastal areas, and inland waters, Hooker said.

The next step is to develop a flight-ready instrument that could be flown first at low altitude and then ultimately on a high-altitude research aircraft, such as NASA's unmanned Global Hawk. The OCULLAR team wants to commercialize the new technology as a low-cost instrument. The idea is to dispatch as many of these instruments as possible to obtain global ocean observations. "We want to start on the ground and keep going upward," Hooker said. Ultimately, the team wants to fly the technology in space.

"We're building something that sees better than the human eye," Hooker said, adding that the instrument could measure conditions under twilight, moonlight, and even beneath sea ice. "And that's quite an accomplishment." ❖

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CubeSat Trail, *continued from page 9*

Her low-power, lightweight instrument is equipped with modern scintillator and readout technologies. Specifically developed for smallsat opportunities, it will give scientists a better understanding of the dynamics in the inner radiation belts, and therefore, the potential radiation hazards to satellites and local space weather. "The Air Force is particularly interested in monitoring neutrons because they pose a significant danger to both avionics and crew members in high-altitude aircraft," de Nolfo explained.

Although she is making good progress building the instrument, she is not yet certain when the instrument will get a ride. Given the importance of the data it will gather, de Nolfo said, "I'm feeling pretty positive it will go all the way to flight." ❖

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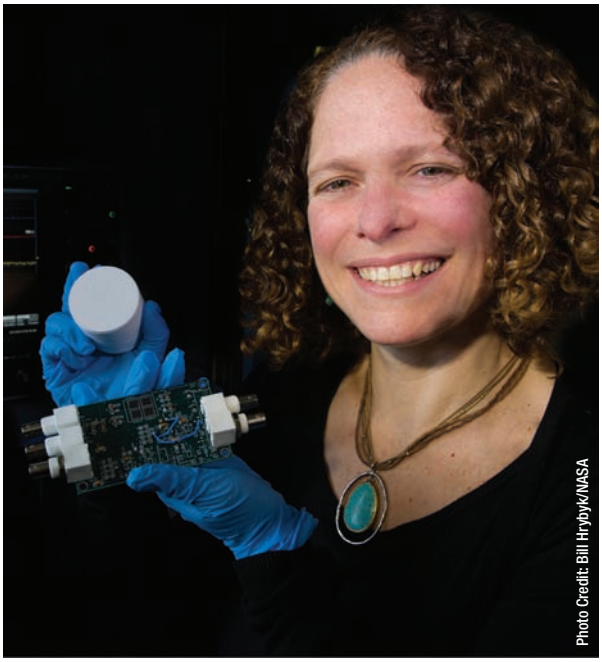

Goddard scientist Georgia de Nolfo holds components that make up her miniature neutron spectrometer, which she's developing for a CubeSat mission sponsored by the Air Force University Nanosat Program.

Cutting edge Goddard's Emerging Technologies

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