National Aeronautics and Space Administration

goddard tech trends

Goddard's New Innovators

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in this issue:

Building a Better Electron Gun

Carbon-Nanotube Technology Shows Promise for Next-Generation Mass Spectrometers

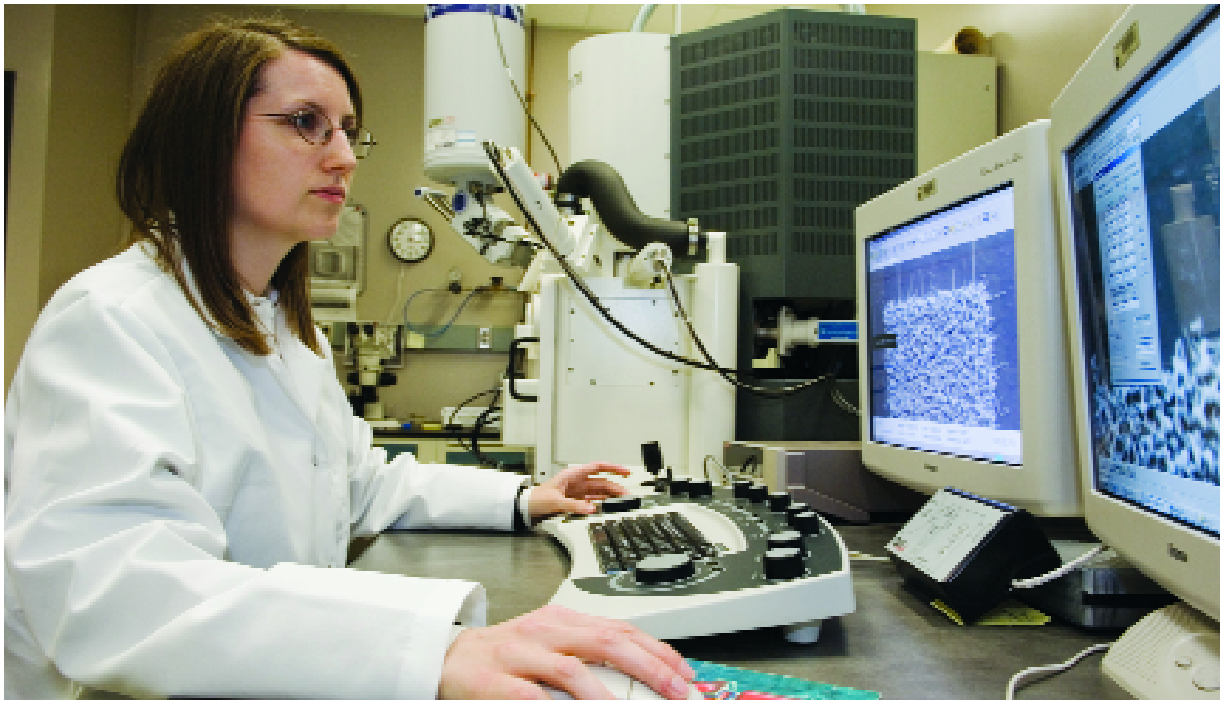

Photo Credit: Chris Gunn

Spacecraft instruments have followed a technology-development trajectory similar to computers. Through advances in technology, they have become smaller and lighter. But assuring a berth on future NASA missions will require scientists and engineers to shrink them even more.

Stephanie Getty, a materials engineer in the Goddard Materials Engineering Branch who was hired in 2004 specifically to apply nanotechnology solutions to instrument designs, has found a promising approach that could assure Goddard's leadership in the field of mass spectrometry, a technique scientists use to determine the composition and abundance of atoms in a molecular substance.

She is now working with scientists in Goddard's Atmospheric Experiments Laboratory and engineers in Goddard's Materials Engineering and Detector Systems Branches to develop a miniaturized "electron gun" for a next-generation, time-of-flight mass spectrometer. In electron-impact-ionization mass spectrometry, the electron gun is the heart of the instrument. It produces and focuses an electron beam that ionizes gas molecules so that the spectrometer can measure their masses and ultimately determine the molecules' chemical makeup.

The team's ultimate goal is to eventually create a mass spectrometer that would be about as large as a CD case and consume less power than a clock radio (about 1 watt). In contrast, the Goddard-developed mass spectrometer that flew on the Huygens probe was roughly the size and weight of a bowling ball and consumed as much power as a small light bulb, which at the time was considered a significant engineering feat.

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On The Cover:

In September, Center Director Ed Weiler announced that 85 research proposals had won funding under Goddard's FY08 Internal Research and Development program. Twenty-three percent represented ideas offered by new innovators — defined as persons with no more than 7 years of professional experience. In this issue, Goddard Tech Trends showcases the work of two new Goddard innovators, La Vida Cooper (left) and Stephanie Getty (right), whose innovative work may one day help NASA to dramatically reduce the size and mass of spacecraft systems and components. In all respects, these two women represent the future of NASA.

Photo Credit: Chris Gunn

Extreme Electronics

Goddard Innovator Lays Groundwork for Developing Cold-Tolerant ASICs

Photo Credit: Chris Gunn

Designing and developing a complex integrated circuit that operates at room temperature is difficult enough. Now imagine trying to craft one that can withstand the harsh temperatures found in space. It's not easy.

"Right now, we don't fully understand how each component or piece reacts to super-cold temperatures or how it will fit together with other components as a system when exposed to extreme environments," says La Vida Cooper, an electronics engineer. She has won Internal Research and Development (IRAD) funding to learn how they behave. The aim is to give Goddard electronics engineers the models they need to more efficiently design application-specific integrated circuits (ASICs) that carry out a particular task even when exposed to harsh temperatures.

The pay-off for NASA could be significant. It could assist the Agency in its goal to further miniaturize spacecraft and instruments.

Today, spacecraft electronics are typically placed inside a protective, thermally controlled enclosure that takes up more mass, says Mike Johnson, an assistant chief for technology for Goddard's Electrical Engineering Division. "What we'd like to do is get rid of that enclosure and develop electronics that can operate under extremely cold temperatures," he says.

Paucity of Standards

At this stage, however, getting rid of that box isn't a viable option. Currently, industry standards are based on components operating over a fairly limited temperature range — not the extremes found in space, Johnson says. Therefore, it takes engineers longer to design the complicated circuits because they can't accurately predict how the individual transistors — the tiny components that make up an integrated circuit — will behave under significantly colder conditions. The lack of models also hinders simulation testing, an important step in ASIC development.

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Spotlight: La Vida Cooper

Having already earned two undergraduate degrees in physics and electrical engineering, the conundrum La Vida Cooper faced in the summer of 2003 before continuing at Johns Hopkins University in pursuit of a masters in electrical and computer engineering was what would she do next?

She accepted a summer opportunity with the NASA Academy, followed by a co-op position, and knew immediately that NASA would be a good fit. In 2005, Cooper became a full-time employee with Goddard's Microelectronics and Signal Processing Branch. She says her work is living up to her expectations.

"First and foremost, I like the fact that there is always a challenging problem to solve or an unanswered question to ponder. Even if a solution exists, there is always room for improvement. It's great to be surrounded by people who are willing to embrace new ideas, and are not easily discouraged in the face of temporary obstacles or setbacks." ◆

NASA has ranked lunar dust as among the top hazards to mitigate before sending humans to the Moon for extended stays — and for good reason. Barbed and electrostatically charged, these ultra-tiny dust particles cling to everything, much like Styrofoam peanuts used for packing. They can gum up machinery, damage space suits, and worse, find their way into astronauts' living quarters, which could cause long-term health problems for inhabitants. For the past couple years, Goddard's Internal Research and Development (IRAD) program has funded innovative ideas aimed at understanding the physics that create the dusty environment and finding ways to mitigate it. Goddard Tech Trends spotlights a few of those technologies in this issue.

Mimicking the Self-Cleaning Lotus Plant

Goddard Researchers Investigate 'Lotus Coatings' for Use in Space

The lotus plant has inspired one Goddard aerospace engineer to develop a special coating that would mimic the plant's unusual self-cleaning properties and help prevent the Moon's powdery grit from accumulating on astronauts and their gear.

Wanda Peters is working with an Atlanta-based company, nGimat, to determine whether the two "lotus coatings" that the company has developed in collaboration with Georgia Tech would work on the lunar surface.

The lotus plant, which lives along muddy waterways in Asia, is well known for its ultra-hydrophobic nature. Despite living in muddy conditions, the plant's leaves and flowers remain clean because they are composed of micron- and nano-scale structures that prevent dirt and water from adhering. Water droplets literally roll off, taking mud and tiny insects with them.

Widespread Application

The ability to replicate these properties could prove invaluable to NASA, says Peters, who heads Goddard's Coatings Engineering Group. The Agency could coat spacesuits, radiators, solar arrays, and other equipment with the material to repel dust and prevent it from accumulating. "The question we need to answer is whether we can really get a lotus coating to work in real life."

So far, environmental test results on nGimat's two formulations are promising. Both have maintained their particle-shedding properties even when exposed to harsh ultraviolet light and other space-like conditions. However, she and her team have had trouble consistently reproducing the formulas. Consequently, Peters said she is considering developing her own coating in parallel with her current research.

Wanda Peters holds a coating-covered sample that she and her team are currently testing to determine the coating's appropriateness for use on the Moon.

Although she has high hopes for eventually producing a space-qualified lotus coating, she concedes that it's only one of several strategies NASA will need to employ to make living and working on the Moon tolerable. Some super-fine dust particles still will find their way into astronauts' living quarters. Consequently, Peters also is looking at other cleaning technologies, including air showers and vibration, to repel dust.

"Habitation areas on the Moon will be like any house. They will get dusty," she says. But given the environmental hazards posed by moondust, "we'll need to minimize it as much as possible." ◆

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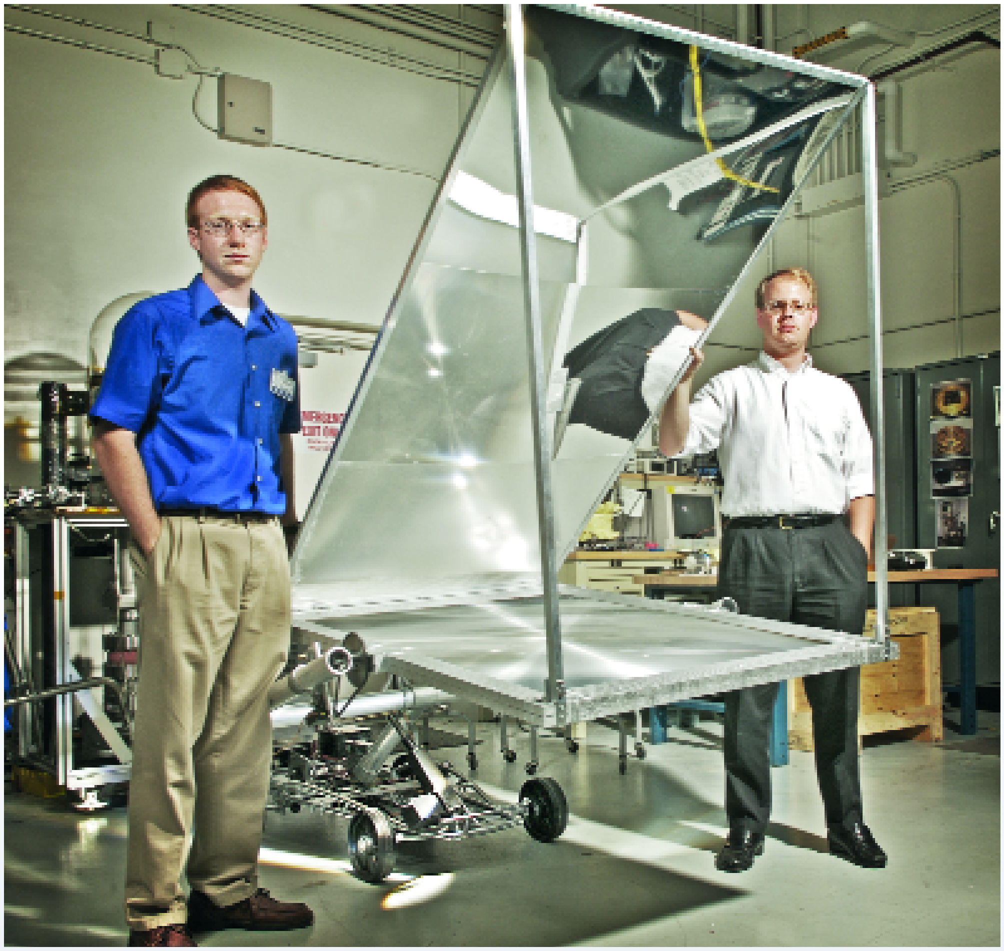
How to Solve the Lunar Dust Problem? Pave the Surface

Goddard technologist Eric Cardiff offers an unusual solution to help diminish the dust dilemma on the Moon: pave the area around a lunar base using nothing more than focused sunlight.

Cardiff is developing a prototype of a four-wheeled vehicle that would use a lens to focus sunlight onto the lunar surface. The sunlight-generated heat would melt or sinter the dust to create a hardened surface.

The current design employs a Fresnel lens, a very lightweight optic that bends light the same way as a normal lens, but takes up significantly less mass. For operations at NASA's proposed polar base near Shackleton Crater, the so-called Dust Mitigation Vehicle (DMV) also would need a primary mirror to reflect the sunlight from the near-horizontal angle of the Sun onto the Fresnel lens.



University of Maryland student Brandon Hall and Principal Investigator Eric Cardiff are using R&D funds to develop a prototype of a so-called Dust Mitigation Vehicle, which would help control the lunar dust problem by melting the regolith around habitat areas.

Inspired by a Previous IRAD Investigation

Cardiff conceived the idea while working on an earlier IRAD-funded technique called vacuum pyrolysis to extract oxygen from the lunar soil. That early concept also made use of a Fresnel lens, which concentrated sunlight before it passed through a window and into a vacuum chamber where the light ultimately heated and melted the regolith, releasing small amounts of oxygen. From his research, he discovered that lunar soil melted at relatively low temperatures, giving birth to the possible dust-mitigation strategy.

Cardiff admits that the idea of melting dust isn't new. A University of Tennessee professor has been working on similar applications using microwave-heating techniques. However, the professor's concept would require substantially more power, which means that his device would have to be tethered to a power source or would have to carry very large and heavy solar panels. Cardiff also says that the technique isn't as efficient. Only half of the energy put into the microwave emitters is released as microwave radiation, which means that the vehicles would have to carry large radiators for the "waste heat."

The advantage of DMV, he says, is that it's lightweight (less than 110 lbs. or 50 kg), requires little power, and could even be used as a science platform. As the top layers melted, the DMV could measure the regolith's physical properties as well as its embedded gases.

The DMV was built as a remote-controlled prototype. It is being tested at the Goddard Propulsion Test Site over simulated lunar dust to see how fast the DMV can really work. ◆

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GoCOMET Team Formed to Advance the Use of Composites

In July, Boeing unveiled the 787 Dreamliner, the world's first jetliner constructed almost entirely of composite materials, about 50 percent by weight.

Goddard's Mechanical Systems Division would like to take a page from Boeing's book and remove the obstacles hindering NASA's use of composites in spacecraft design. The organization has formed a new group — the GoCOMET team — to advance the use of composite materials in major spaceflight structures.

"Goddard has already made a name for itself in the field," said GoCOMET team leader Ken Segal, referring to the composite structures Goddard has designed and built for instruments on the Gamma-ray Large Area Space Telescope, Swift, ICESat (Ice, Cloud, and land Elevation Satellite), and the Solar Dynamics Observatory. In addition, Goddard currently is designing structures for the Lunar Reconnaissance Orbiter, the James Webb Space Telescope, and the Global Precipitation Measurement. "We are one of the few government organizations to offer end-to-end composite capabilities. It's unique," Segal says.

However, he and others believe composites should play an even larger role in spacecraft applications. Composite materials weigh less, offer more design flexibility, and reduce the number of parts needed to assemble a piece of hardware — all important criteria in carrying out operations on the lunar surface. Despite these advantages, however, NASA mission designers historically have been reluctant to use these materials.

Ken Segal poses next to a composite piece manufactured at Goddard. Segal heads the GoCOMET team, which the Mechanical Systems Division formed to encourage greater use of composites in spacecraft design.

Overcoming Reluctance

"In space applications, composites are trickier to deal with," says Ted Swanson, assistant chief for technology for the Mechanical Systems Division. Although we have decades of experience in aluminum and other materials, we don't know nearly as much about composites and how to use them in a space environment. We lack adequate design references and established manufacturing guidelines. That's why there is some reluctance to use them."

To advance their use, GoCOMET is charged with exploring new approaches to decrease the cost of flying composite materials in space and infusing new technologies that will sharply increase their performance over conventional materials. As part of that effort, the group has partnered with the Langley Research Center to carry out a 6-month study to determine the state-of-the-art in industry and detemine which technologies NASA could safely adapt to exploration missions, spaceflight instruments, and other hardware.

In addition, Goddard, the U.S. Air Force, and the Aerospace Corporation co-sponsored a Composite Materials Engineering Technology Workshop at the Applied Physics Laboratory Oct. 16-17 to pull together experts in the field and examine opportunities for partnering.

With fewer science opportunities and reduced R&D funding, advancing Goddard's expertise in composites and expanding their use will require greater collaboration with others, Segal says. "This is important, not just to Goddard, but to NASA." ◆

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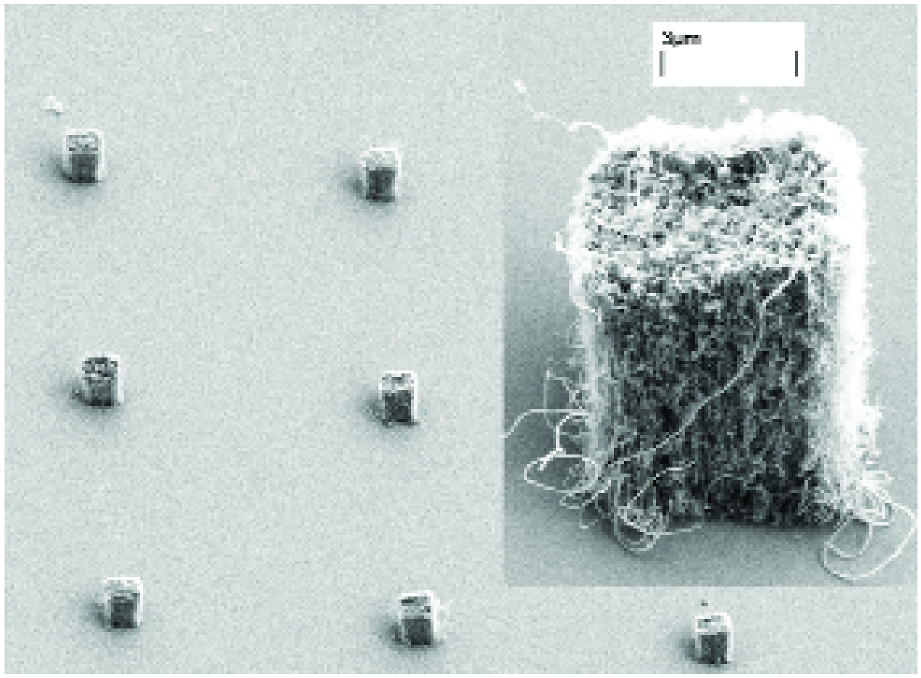
Carbon Nanotubes



This image shows the patterned towers of carbon nanotubes that Principal Investigator Stephanie Getty has created for use in a next-generation electron gun.

Getty's proposed electron gun, however, would be substantially smaller. Developed in part with Goddard Internal Research and Development funding, her technology is made of carbon nanotubes (CNTs), a cylindrical form of graphite.

Grown in a laboratory, carbon nanotubes are just a few tens of nanometers in diameter and demonstrate extraordinary mechanical and electrical properties. For mass spectrometry, their use is especially ideal. By simply applying an electrical field to the nanotubes, electrons are released, which can be focused to form an electron beam — the sole purpose of an electron gun. Compared with more traditional electron-gun technologies, carbon nanotubes also are more efficient because they consume less power and mass and can operate at ambient temperatures.

What makes her design different from other carbon-nanotube designs is the fact that she produces the CNTs not as films, but as patterned arrays of towers on a 5-micron by 5-micron grid grown on a substrate, each tower containing 1,000 individual nanotubes. Although films produce electrons, Getty says testing showed that her patterned towers were more effective at operating at low voltages. They also consumed less power.

Since that demonstration, Getty has developed a box-shaped prototype that measures just one centimeter in width, height, and depth. Over the next year, she plans to improve its packaging, among other improvements, and integrate it with the prototype mass spectrometer now under development.

Currently, Getty places her technology at a readiness level of about three or four. However, in the emerging field of nanotechnology, where most research remains at the proof-of-concept level, her readiness level is actually quite high, she says. "The unique part about this is the application. We're moving past proof-of-concept." ◆

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Spotlight: Stephanie Getty

When Stephanie Getty arrived for her first day of work as a NASA employee, she had no choice but to hit the ground running. Her first assignment: write an R&D proposal and submit it by the end of the week; she had never written a grant proposal in her life.

In retrospect, she says it was beneficial that she had worked as a postdoctoral research associate at the University of Maryland's Physics Department before joining Goddard. She had gotten experience researching big problems, and after spending a few days casting about for a possible application for nanotube technology, she found one. Thus was born the NanoCompass, a magnetometer made of carbon nanotubes.

Although she concedes today that her initial design was "naïve," she received funding and has since fabricated a complete prototype, filed a patent application, given several conference presentations, and authored a journal article on her work. Earlier this year, she also received Goddard's AETD Science and Technology Advancement Award. Despite the success, Getty says she has only one big goal over the next 5 years: "I hope to have worked on a technology that's gone into space." ◆

Extreme Electronics... Continued from page 3

Johnson says models are available for the full military temperature range of -67°F to 257°F (-55°C to 125°C), but they fall far short of the -364° F (-220°C) needed to develop NASA systems. "The models don't exist," he says. "This project will derive models for CMOS circuit-fabrication processes. It complements a related Exploration Technology Development Program effort focused on silicon-germanium circuits."

The First Step

With her IRAD award, Cooper has developed an automatic test set-up that exposes commercially available transistors to a range of temperatures down to -432.67°F (-258.14°C). Initial results so far show that the single transistors she's tested can operate at extremely cold temperatures and power up after 72 hours of no operation. In addition to testing single transistors, she's also planning to test a full suite of circuits, including those used for analog, digital, and mixed-signal electronics.

Once the data are collected, Cooper will be able to extract important parameters and create design and simulation models optimized for cold environments. Using these models Goddard's ASICs Group will be able to efficiently design and test integrated circuits that operate reliably at low temperatures. These circuits can be used in telescope readouts and instrument front-ends.

"If our engineers had this information from the start, they could really shorten the design time," Cooper says. "Principal investigators could reference higher TRLs in their instrument concepts. We also could save on bench and cryo-testing. This really would help in a lot of ways." ◆

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TAKING ON MOONDUST... Continued from pages 4- 5

A MoPED on Every Lunar Mission

New Device Would Measure Electrostatic Charge on Astronauts and Gear

Moondust clings not only because of its varying shapes and jagged edges, but because it carries an electrostatic charge that allows it to float and levitate off the surface.

For astronauts, this highly charged environment poses serious challenges: they, too, carry a static charge, which attracts more levitating dust, and worse yet, exposes them and their equipment to potential physical harm — particularly if they don't dissipate the charge before coming into contact with another charged object.

Goddard scientists Telana Jackson and Bill Farrell may have the solution to help astronauts cope with this on-the-job hazard.

They are developing a concept to create a pencil-size, battery-operated electrometer — the so-called Moon Portable Electrostatic Detector (MoPED) — that could attach to spacesuits or be placed near a rover. "With our electrometer, astronauts could look at a display to see their degree of charging," Jackson says. "That way they would know when to dissipate their charge naturally or by some other means."

MoPED is based on an electrometer that Jackson and Farrell created for their "dust devil" research a few years ago. On Earth, dust devils are mini-cyclones that happen when hot air near the surface rises quickly through a small pocket of cooler, low-pressure air above it. These events interest scientists because dust devils also have been detected on Mars and could be electrical in nature.

The challenge they now face is miniaturizing the original design and creating a device that provides data in real time, Jackson says. Their hope is that MoPED will become standard gear for all lunar-sortie missions. ◆

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Goddard Tech Trends

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