National Aeronautics and Space Administration

goddard tech trends

‘It’s Up to Us’

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Conversation with Christyl Johnson: Collaborating on a New Level

Except for a two-year stint as a detailee to the White House Office of Science and Technology Policy, Christyl Johnson has spent her entire professional career working for NASA. In December, she assumed her new job as Goddard's Deputy Director for Science and Technology — a position that requires her to oversee Goddard's research and development portfolio and formulate the center's future science and technology goals. In a recent interview, she talked about the challenges NASA faces and her plans to better position Goddard to overcome those hurdles.

What are the challenges on the horizon?

The environment is shifting. We can't count on the funding we have been accustomed to getting. What will more than likely happen, given our budget deficits, are further cuts in discretionary funding. Making matters worse is talk among some congressional staffers who have suggested that perhaps we need to carve out parts of NASA and give those responsibilities to other government agencies as a way to help reduce the annual budget. Cost overruns on high-profile missions have, I believe, exacerbated the situation. Although these ideas may never gain traction, and they certainly aren't a reality for the Obama administration, the talk nonetheless is out there.

What should NASA, and more particularly Goddard, do to secure their future?

Given the budget realities, we need to do more with less. I'm not suggesting that we cut back on important technology-development efforts, but we do need to work with other federal agencies and private industry to develop mutually beneficial technologies. There is money out there. People in industry have R&D programs. The Department of Defense has even deeper pockets. By collaborating, we can spread the costs of innovation and, more particularly, reduce the costs borne by NASA.

What do you think is the biggest barrier to collaboration?

Part of the problem is that people, including government agencies, are accustomed to viewing their R&D efforts as belonging exclusively to them. They erect stovepipes. In an environment of diminishing resources, however, we need to significantly reduce those barriers.

How do you propose to do that?

Let me first say that our technologists do collaborate. They do look beyond these walls to find partners in academia and industry who can help them advance emerging technologies. Examples abound, and, in fact, many of them are highlighted in each issue of *Goddard Tech Trends*. I applaud these efforts and encourage more of it. I strongly believe collaboration is the linchpin to future success. With that said, however, I believe we need to be more strategic and do more to focus our efforts. We already have great IRAD (Internal Research and Development) and Bid and Proposal capabilities. Now, I'm adding a third leg to the stool. In a few weeks, I plan to officially roll out the Strategic Collaboration Initiative. I'm excited about the possibilities.

What exactly is the Strategic Collaboration Initiative?

Anyone who has ever submitted an IRAD proposal knows that to win funding, he or she must demonstrate that the proposal maps to one or more of Goddard's lines of business — the technical areas we believe are strategically important to the center. Currently, we look across our seven lines of business and identify technologies that should be developed over the next several years to ensure Goddard's competitiveness and our ability to meet future science and exploration goals. Under SCI, or the Strategic Collaboration Initiative, we will take this focus one step further. We will make a concerted, top-down effort to establish formal relationships with other federal agencies, private industry, and academia.

How will SCI benefit the technology community?

Our goal is to get buy-in at the executive level. What we expect is that these top-level relationships will foster a culture of collaboration, making it easier for our people and theirs to combine resources and partner on important technologies beneficial to all. Collaboration is vital. Budget reductions are on our horizon, but that doesn't mean our future isn't bright. Actually, the sky is the limit as long as we think creatively about doing more with less. It's up to us. ◆

About the Cover: *The Data Exploration Theater, developed by the Center for Climate Simulation, provides the backdrop for this photo of Christyl Johnson. The theater features a 17-by-6-foot multi-screen visualization wall.*

Photo Credit: Pat Izzo

'Miracle' Material Promises Game-Changing Capabilities

The rush is on worldwide to perfect a "miracle" material believed to be the strongest, most conductive ever developed. A team of Goddard technologists has taken up the challenge and is now producing the material as a transparent conductive electrode that, in testing, has proven to perform better than the current state-of-the-art.

Technologist Mahmooda Sultana examines graphene film under an optical microscope.

With Goddard Internal Research and Development (IRAD) funding, engineers Mary Li and Mahmooda Sultana have set up fabrication facilities to produce graphene, a new material first discovered in 2004 by Russian-born scientists Andre Geim and Konstantin Novoselov, who received the Nobel Prize last year for their work.

Heralded as "the next big thing," graphene is just one atom thick and composed of carbon atoms arranged in tightly bound hexagons best visualized as atomic-scale chicken wire. Five times stronger than structural steel, it not only is the strongest material ever measured, but also the most conductive and transparent, making it ideal for touchscreens, light panels, and solar cells, among many other potential uses.

Since its discovery, hundreds of companies have launched research efforts. Although a commercial product has yet to emerge, the South Korea-based Samsung Group has reported building a 25-inch flexible touchscreen using graphene. IBM also has produced a 150-gigahertz transistor. The obvious benefits to businesses and consumers are faster, thinner, and more flexible electronic devices.

For NASA, the possibilities are just as exciting, Li said. "If we have this technology, we can make a lot of things that will be game changing." Potential applications include everything from transparent electrodes, flexible electronics, ultrafast lasers, and single-molecule chemical detectors, to ultracapacitors and frequency multipliers for data transmission. "This technology is excellent for any electronics application, but really the sky's the limit for applications," said Terry Doiron, assistant chief for technology for Goddard's Instrument Systems and Technology Division.

Although possibilities abound, the first application the team has decided to pursue with its university partners — Stevens Institute of Technology, Central Florida University, and University of Maryland — is graphene-based transparent conductive electrodes for large detector arrays. Conductive electrodes help convert optical energy into electrical energy and carry the signal to a readout device, requiring a high level of transparency for the signal to be received and read.

Currently, technologists use a solution of indium oxide to fabricate these devices. However, the material has drawbacks. Indium is rare, and therefore, expensive. Furthermore, the material is brittle and does not offer the level of transparency required by scientists to capture certain wavelength bands, Li said. Given graphene's extraordinary properties, it offers a viable alternative to current technologies, she added.

Since receiving IRAD funding this year, the team has begun experimenting with two different fabrication techniques. One, called micromechanical cleavage or exfoliation, involves peeling off a thin sheet of graphite that only can be seen with a microscope and placing the sample onto a silicon dioxide substrate. The other technique, chemical vapor deposition, requires technicians to place a metal substrate into a vacuum chamber and inject gases that then react or decompose to produce the desired deposit.

After "tweaking" the recipe, Sultana says she has produced several exfoliated graphene films. "We're getting a high yield and relatively large pieces," she said. Even better, testing has shown them to be 97 percent transparent in the near-infrared wavelength band and between 97 and 90 percent in the visible. "This compares quite well with the indium tin oxide film used in transparent electrodes, which has a transparency of between 80 and 90 percent in the near infrared and can drop down to 60 percent or even lower in the visible regime, depending on the film thickness," she said.

Fabricating graphene through chemical vapor deposition using a recently installed six-inch furnace would result in larger films and remains a goal for the team, Sultana said. "This technique is still new and we haven't yet perfected the recipe. We're still in the learning stage," Sultana added. "But we have momentum. As we get better control over the growth process, we will grow better and better graphene. This is going to be a win in the long term." ◆

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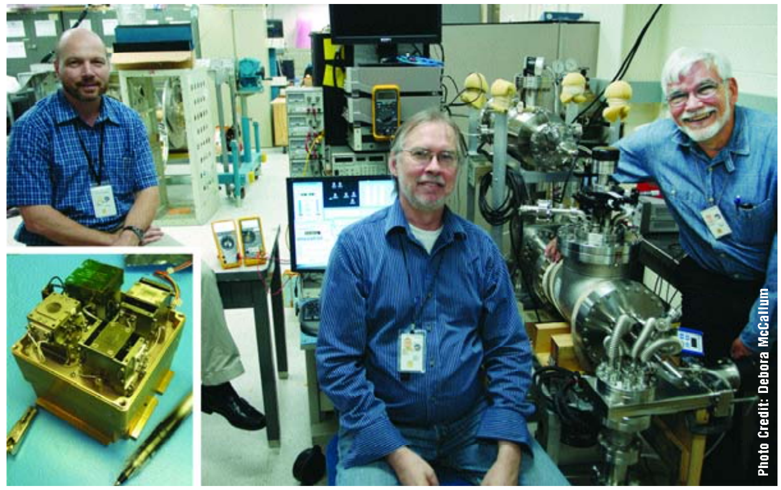
The WINCS 'Factory'

Technologists to Deliver First of Many Miniaturized Helio Instruments this Fall

More than a decade ago, technologist Fred Herrero realized that to truly understand the ever-changing dynamics of Earth's upper atmosphere, he would need an armada of satellites gathering simultaneous, multipoint measurements. With satellites costing $100 million or more, he knew that was out of the question.



The WINCS development team includes (from left to right) Patrick Roman, Rusty Jones, and Fred Herrero. The inset shows a close-up of the WINCS instrument, which is specially designed to fly on Cubesats.

His solution: Promote the development of tiny, less expensive satellites and develop a miniaturized instrument ideally suited to gather data about Earth's ionosphere and thermosphere, a volatile slice of the atmosphere that stretches from about 60 miles to more than 350 miles above Earth's surface. His vision is becoming a reality.

This fall, Herrero and his team, including technologists Rusty Jones and Patrick Roman, are expected to begin delivering the first of several units of the Winds-Ion-Neutral Composition Suite (WINCS). The instrument, developed with significant support from Herrero's partner, Andrew Nicholas of the Naval Research Laboratory (NRL), includes four spectrometers and three detectors assembled into a three-inch package using just 1.3 watts of power. Its diminutive size makes it an ideal payload for an emerging class of small spacecraft, often called Cubesats, promoted in recent years by the Department of Defense and the National Science Foundation.

"By merit of Moore's law, the goal of any technological development should be the reduction of volume and power," technologist Jones said. "WINCS is a significant and brilliant step in that direction. Because of Fred's insights, I suspect that one day in the foreseeable future, we will see mass spectrometers the size of wristwatches."

As of today, the team is scheduled to deliver a total of seven instruments, all slated to fly on Cubesat missions over the next few years. In the fall, the team will deliver the first of three to NRL, followed by one to the Air Force Research Laboratory, one to the University of Michigan, and two to Boeing Aerospace, which is developing a Cubesat mission for the Air Force. The European Space Agency also is interested in buying the instrument, as is a Spanish aerospace company, Herrero said.

"Once we deliver the first, it will be like a little factory here," he added. "What's amazing about WINCS is not just its small size. It also will enable measurements we've never made before. For the first time, we will be able to measure the full vector of wind."

Herrero began conceptualizing WINCS more than a decade ago when he realized that to truly understand the ionosphere and thermosphere, scientists would have to gather multipoint measurements of the direction and temperature of winds, neutrals and ions, as well as their composition. Last year, the team received Goddard Internal Research and Development funding to improve the instrument's resolution, and more importantly, its reliability. "The improvements drastically increased reliability far over any such instruments gathering data in this portion of the atmosphere," Herrero said.

The information he and his partners seek is of practical importance. "Everyone in this field is interested in the types of measurements WINCS can make," Roman said.

The ionosphere and thermosphere are heavily influenced by the energy carried through space by the solar wind. Under particularly tumultuous conditions, this energy can heat up the thermosphere, which then expands, exerting an atmospheric drag on orbiting spacecraft. Ultimately, the spacecraft prematurely lose altitude and plunge to Earth. The ionosphere, meanwhile, is the medium through which satellite communications must travel. If the ionosphere is disrupted, communications signals are thrown off.

Understanding this region is made more challenging because the environment changes quickly with distance — a situation that requires multiple satellites gathering the same data at various locations around the globe. "We're not going to learn anything new with just one satellite," Herrero said. "We need at least 50 satellites. Thank goodness, someone came up with the idea of a Cubesat." ◆

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New HHT-Based Data-Processing Tool Nears Completion

Jennifer Sichler, Karin Blank (not pictured) and Semion Kizhner expect to complete by the end of September a next-generation data-processing system based on the world-renowned Hilbert-Huang TransformMethod.

An engineering tool that implemented a set of algorithms made famous by former Goddard scientist Norden Huang for analyzing data and images from nonlinear and nonstationary sources — everything from ocean currents and earthquakes, to traffic moving over bridges — is about to become more capable.

Goddard technologists Semion Kizhner, Karin Blank, and Jennifer Sichler say they expect to complete by the end of September a next-generation data-processing system based on the world-renowned Hilbert-Huang Transform (HHT) Method.

Huang, who began developing the method in 1995 as part of his oceanography research at Goddard, originally developed the set of algorithms to decompose complicated nonlinear, nonstationary signals into their intrinsic components. By separating these signals into their constituent parts, researchers could glean more information about the object being studied when using classical spectral analysis. The method is now being used in climate studies, earthquake-prone structural engineering, geophysical exploration, submarine design, structural-damage detection in bridges and buildings, and satellite data analysis, to name a few applications.

The new data-processing system that makes use of these algorithms makes it faster and more efficient to spectrally analyze two-dimensional spectral signals and find trends in the data. Called HHT2, the technology is a follow-on to HHT1, which Kizhner, Blank, Huang, and other Goddard technologists developed in 2003 with Internal Research and Development (IRAD) funding before Huang left Goddard to become a professor at National Central University in Taiwan.

However, the key difference between the two is that the latest version takes data analysis to the next level of sophistication, said Jacqueline Le Moigne, assistant chief for technology for Goddard's Software Engineering Division. "With the original system, we were able to characterize one-dimensional signals, such as the spectra of different materials," she said. "Instead of looking at every point of the spectrum, we could use the HHT1 system to characterize it by its significant features."

With the new system, however, scientists would be able to characterize the spatial connections between pixels, such as water near a forest, roads near buildings, or differentiate a relatively smooth area from a textured one, Le Moigne said. In other words, the system removes the noise to find more detailed trends in the data, Blank added.

Kizhner, Blank, and Sichler, who began working on the technology in 2011 after receiving funding from the IRAD program, say they expect to finish a prototype of the data-processing tool by the end of the fiscal year and then seek external partnerships to further advance its applications.

The most obvious beneficiary, at least in the near term, is onboard processing, said Kizhner, who led the HHT2 development effort. "Currently, most satellite remote-sensing data are processed here on the ground." However with HHT2, an instrument's data-handling system would be able to eliminate signal noise before downlinking the data to a ground station. "By enabling onboard processing on the instrument itself, we will be able to reduce signal noise and reduce the amount of data that must be transmitted to the ground," Kizhner said.

With future missions expected to gather larger and more complex data sets, the technology will prove especially beneficial, he said. "As we progress, I believe the technology will open up areas we aren't currently aware of yet." ◆

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New Pyrolysis Oven Eclipses Model Flying on Goddard's SAM

One of the most important technologies flying on the Sample Analysis at Mars (SAM) instrument suite — a coffee can-sized pyrolysis oven capable of heating rock and soil samples to scorching, metal-melting temperatures — has been eclipsed by a smaller, more capable oven that will be demonstrated for the first time later this summer during a field campaign in northern Arizona.

Now under development by Principal Investigator Daniel Glavin and his team, the new oven is roughly the size of a soup can and would play a central role on a promising new instrument called the Volatile Analysis by Pyrolysis of Regolith (VAPoR). VAPoR is a miniaturized version of SAM, and like SAM, would analyze gases in the atmosphere and those produced when its onboard oven heats powdered soil and rock samples to temperatures that would melt aluminum.

Technologist Marvin Noreiga is shown here with a next-generation oven that is more powerful than the model flying on the Sample Analysis at Mars instrument suite.

SAM is one of 10 science instruments on Curiosity (also known as the Mars Science Laboratory rover), which NASA plans to launch later this year to determine whether life ever existed on Mars. While SAM will analyze gases to determine whether they contain organic compounds necessary for life, VAPoR is being designed to search for water, oxygen, noble gases, and organics at high-priority astrobiological targets.

The new oven-equipped VAPoR will get a test drive in late August when Glavin and Goddard scientists Jake Bleacher, Jim Rice, and Charles Malespin take the prototype field instrument, now the size of a dormitory refrigerator, to a lava flow in northern Arizona for this year's DesertRATS (Research and Technology Studies) expedition. DesertRATS provides engineers and scientists an opportunity to carry out technology-development research in environments similar to those found on other solar system bodies.

"To date, the oven is one of the bigger successes of the VAPoR development effort," Glavin said. In laboratory tests, he has shown the oven can heat samples to 2,192 degrees Fahrenheit using only 46 watts of power, which is less than needed to power a standard household light bulb. In comparison, SAM's slightly larger oven will heat samples to 1,742 degrees Fahrenheit using a similar amount of power.

Because different elements vaporize at different temperatures, the ability to generate hotter temperatures will benefit a broader range of scientific research, Glavin said. For example, geochronology, the science of determining the age of rocks, analyzes potassium and argon. These two elements vaporize at 2,192-2,372 degrees Fahrenheit, making the oven an ideal tool for this type of science, he said.

"It's more efficient because it's more compact," Glavin explained. To analyze samples with SAM, Curiosity's robotic arm must first scoop up soil and rock samples. A separate mechanism then grinds and delivers the samples to 74 small cups or vials attached to a carousel-like device that rotates and inserts the vial inside the coffee can-size oven. As the oven slowly heats, the sample releases gases that SAM's three spectrometers can analyze.

Glavin and his team have made a few important design changes. Instead of building two different mechanisms to deliver and heat samples, the VAPoR team combined the functions. "The real innovation was coming up with the idea of combining the cup with the oven," Glavin said. And because the vials are only the size of a thimble, it takes considerably less energy to produce the hotter temperatures. In addition, the system offers "a lot more redundancy. With VAPoR, we have six individual ovens, whereas SAM has two," Glavin said. ◆

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Fill 'Er Up

Technologist to Demonstrate New Fuel-Storage Technique

Powering to an asteroid or another destination will take more than just an able ride. It will require a tank-full of fuel and the ability to refuel along the way. Goddard technologist Shuvo Mustafi is developing a long-duration, fuel-storage technology that could assure space travelers' access to the super-cold propellant needed to power their crafts.

"Future missions will require vehicles with the flexibility to remain in space for months to years," Mustafi explained. "Cryogenic fuels, like liquid hydrogen, are the best for powering these missions because of their superior specific impulse capability, which means they allow a greater percentage of the vehicle's initial mass to be devoted to payload. Unfortunately, they boil off."

Technologists assisting in the development of a new cryogenic fuel-storage technology pose beside a precursor to the subscale experiment they hope to demonstrate in 2012. Team members include from left to right: John Francis, Peter Oas, Brittany Gay, Peter Barfknecht, and Shuvo Mustafi. Not pictured are Xiaoyi Li, Tim Powers, and Lee Kersting.

Liquid hydrogen, for example, boils at 20 Kelvin at atmospheric pressure (only 20 degrees above absolute zero). As the liquid boils, the resulting hydrogen gas needs to be vented, reducing the amount of fuel available for propulsion. "That's why NASA has in the past confined its use to launch vehicles and orbital-insertion stages where the hold times were minimal," Mustafi said.

Mustafi's team, however, has developed a technique for extending their hold times, potentially making cryogenic fuels viable not only for future human spaceflight, but also for science missions to far-flung planets and asteroids. They also envision the development of long-duration, in-space cryogenic fuel storage, cryogenic fuel depots, and other applications.

The group is using funding from Goddard's Internal Research and Development and NASA's Enabling Technology Development and Demonstration programs to advance the so-called Thermodynamic Cryogen Subcooler (TCS). The technology uses a fraction of the liquid hydrogen to chill the bulk hydrogen — already at 20 Kelvin — to a targeted 16 Kelvin. This would enable a tripling of the vent-free hold time over the current state-of-the-art, Mustafi said. The entire process would be handled on the launchpad, he added.

Mustafi is now developing a subscale version of TCS and may demonstrate it under the "Technology Demonstration Mission" program sponsored by the Agency's Office of the Chief Technologist. Under this program, selected technologies are expected to obtain flight opportunities in the 2015-2018 timeframe. He also is pursuing other NASA funding.

"If you ultimately want to go to the Moon, Mars, or even beyond, you need to store fuel. It's a challenge, but that's the purpose of this effort," Mustafi said. ◆

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Magnetometers to Map Jupiter's Magnetic Field in 3D

The dynamo, or "engine," that powered the now-spotty magnetic field on Mars is long dead. Earth's is buried deep underground and Venus doesn't have one at all. But the dynamo powering Jupiter's magnetic field, which is about 20 times more powerful than Earth's, lays about one-quarter of the way beneath the surface and is just right for scientific scrutiny.

The Juno spacecraft's twin magnetometers are mounted on a boom that extends from the end of one of the solar arrays.

Thanks to two Goddard-developed magnetometers flying on NASA's Juno mission, scientists will get a chance to figure out exactly how Jupiter's dynamo works. The spacecraft begins its five-year, 400-million-mile voyage to the gas giant in August. Upon arrival, Juno will orbit Jupiter roughly 30 times — the first spacecraft to travel pole to pole rather than around the planet's equator — to investigate with its nine instruments the planet's elusive core, measure water and ammonia in its atmosphere, observe its intense auroras, and, of course, map its powerful magnetic field.

"The Pioneer 10 and 11 missions in the early 1970s and Voyagers 1 and 2 in the late '70s gathered valuable information about Jupiter's magnetic field," says Goddard's Jack Connerney, Juno's deputy principal investigator. Connerney is collaborating with Juno Principal Investigator Scott Bolton, a scientist at the Southwest Research Institute in San Antonio, Texas. "But Juno will be the first true magnetic mapping mission to Jupiter."

The keys to studying Jupiter's powerful magnetic field are the spacecraft's twin magnetometers that sit about 6-1/2 feet apart on the spacecraft magnetometer boom, a composite structure extending from the end of one of the spacecraft's three solar arrays. Developed by Goddard's Planetary Magnetospheres Lab, the instruments will measure the magnitude and direction of Jupiter's magnetic field with 10 to 100 times greater accuracy than any previous instrument.

The exquisite measurement accuracy is only partly due to the magnetometers' design and painstaking calibration, Connerney says. Just as important are the star cameras attached to sensors on both magnetometers. The star cameras, developed by the Danish Technical University, will determine the orientation of the sensors by looking at the field of stars, accurately monitoring how the magnetometers are oriented in space.

Because Juno will skim right over Jupiter's atmosphere during every orbit, it will feel the full intensity of the planet's strong magnetic field. Yet elsewhere in the orbit, Juno will measure a field that's about 10 million times weaker. Only the magnetometers on Voyager 1 and 2 could have measured such extremes in magnetic intensity. But to measure the low and high fields, the Voyagers needed separate instruments. Juno doesn't.

"With the magnetic measurements that we'll make with Juno, we should be able to figure out more precisely how far beneath the surface Jupiter's dynamo resides," Connerney says. "No previous mission to Jupiter could make the measurements necessary to do this."

"If Jupiter's magnetic field has the same kind of long-term variation as Earth's, our measurements will be accurate enough to detect that," Connerney says. "Such accurate measurements of how the field changes over time will let us visualize for the first time how the planet's dynamo works, giving us a new understanding of the dynamos of Earth and other planets in our solar system and beyond." ◆

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