National Aeronautics and Space Administration

Goddard Tech Trends

Volume 3 | Issue 1 | Fall 2006

tech trends

2 Next-Generation X-ray Detectors

3 The Methane Mystery

4 Applying Cryogenics to Human Spaceflight

5 SPHEREs in Space

6 Keeping the Homeland Secure

7 Advanced Manufacturing Adds Capability

On The Cover:

Naoko Iyomoto, a scientist working in the X-ray Astrophysics Laboratory, holds an X-ray microcalorimeter, a sensitive thermometer that precisely measures temperature variations of incoming X-ray photons.

See page 2 for story.

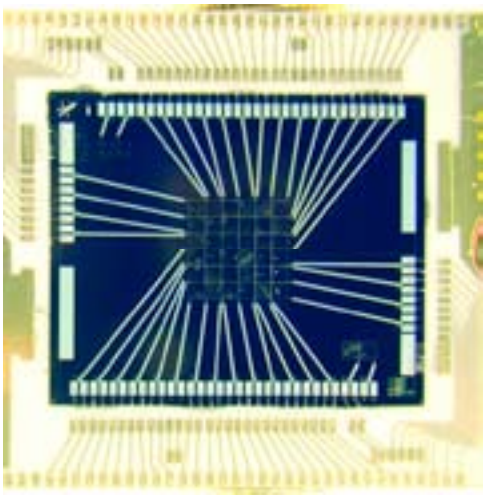
Photo Credit: Chris Gunn

http://www.nasa.gov

The technologies described on pages 2,3, and 4 were among the 71 proposals selected to receive Goddard Internal Research & Development (IRAD) funding for FY07. See the story below for more information about the IRAD program.

Taking the X-Ray Microcalorimeter to the Next Level

Until Astro E-2 — an X-ray mission performed jointly by NASA and Japan's Institute of Space and Astronautical Science — no one had ever flown a microcalorimeter in space. Now Goddard scientist Richard Kelley hopes to advance the technology to the next level and build the "ultimate X-ray digital camera."



This Goddard-developed 32-pixel micorcalorimeter array — the first ever to fly in space — flew on Astro E-2 spacecraft, now called Suzaku.

The operating principle behind a microcalorimeter is simple. When an incoming X-ray hits the microcalorimeter's absorber, the X-ray's energy is converted to heat, which a thermometer then measures. The heat is directly proportional to the X-ray's energy. Knowing a photon's energy can reveal much about the physical properties of the object emitting the radiation. 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.

The Astro E-2 spacecraft, now called Suzaku, carried a spectrometer equipped with a 32-pixel micorcalorimeter array that proved that the technology would work, Kelley said. Now, with funding from various NASA sources, including Goddard's internal investment programs, he hopes to continue improving the technology so that he can ultimately build a 1,000-pixel microcalorimeter array — measuring only one-third of an inch wide — for NASA's proposed next-generation X-ray mission, Constellation-X.

Building a 1,000-Pixel Array

More pixels mean higher-resolution images and spectroscopic measurements. "Our goal is to make the ultimate X-ray digital camera that has lots of pixels and colors," said Kelley, Goddard's calorimeter

Continued, Page 6

Goddard Announces Winners of FY07 Internal Research and Development Program

The 71 proposals that will receive funding under Goddard's revamped FY07 Internal Research and Development (IRAD) program all demonstrated the potential to keep the Center on the cutting edge and win new work in the near- to mid-term, said Goddard Chief Technologist Peter Hughes.

Of the 263 applications submitted, the overwhelming majority met the requirement of linking the proposed R&D to already-published opportunities in NASA's future mission forecast. Because of a 30 percent cutback in available resources, however, Hughes said the Center only had enough money to fund 27 percent of the proposals.

Nevertheless, he said he was pleased with the overall portfolio of investments and believes the "exhaustive" selection process succeeded in creating "synergies," eliminating duplicated efforts, and identifying gaps in the investment portfolio.

Investment Categories

Winning proposals fell into several categories, including mission concepts, lasers, exploration, next-generation instruments, space systems technologies, and advanced concepts (see related stories on pages 2, 3, and 4).

The Center revamped the annual awards program earlier this year, consolidating its three former R&D funding programs into a single investment program. The new IRAD program featured a "top-down" directed program that targeted near-term "must wins" and a more traditional call for proposals that solicited research ideas for technology-development concepts that supported Goddard's strategic lines of business.◆

Contact:

Lisa.W.Callahan@nasa.gov or 301.286.1212

The Methane Mystery

Goddard Invests in New Laser to Detect Gas on Martian Surface

Two years ago, scientists created a buzz when they announced they had detected the presence of small amounts — barely more than 10 parts per billion — of methane gas in the Martian atmosphere. The question was, where did it come from?

Did it emerge from a volcanic eruption? Was the gas carried into the atmosphere by a grazing comet or asteroid or one that hit the surface recently? Did an inorganic process produce the gas? Or, more tantalizing, did it emerge from beneath the Martian surface from living organisms that produce the gas as a byproduct of their survival?

Although the debate continues, one thing is certain: Scientists won't be able to answer that question until they locate the methane source on the planet.

Orbiting Laser-Based Absorption Spectrometer

Michael Krainak, head of Goddard's Laser and Opto-Electrical Branch, hopes his organization will do just that by developing an orbiting laser-based absorption spectrometer that would pinpoint the location and measure the intensity of methane and other trace gases, which could indicate the presence of life beneath the planet's surface. Armed with such a global map, planetary scientists could then decide where to land rovers and other scientific instruments to gather in-situ data, which might settle the debate over whether life exists or once existed on Mars.

Laser spectroscopy is a powerful tool for carrying out the mission. When light passes through elements and molecules, specific wavelengths of that light are absorbed and result in a distinct pattern that identifies the molecule.

By tuning laser pulses to specific wavelengths, scientists can target the gas they wish to detect. Therein lies the beauty of Goddard's instrument. It's equipped with an optical parametric oscillator — a device that converts one wavelength to another — and therefore, is tunable in the near- to mid-infrared wavelength bands useful for identifying methane, carbon dioxide, sulfur dioxide, nitrous oxide, and other gases. The laser instrument also offers the added benefit of being able to operate day and night because it doesn't need sunlight to study absorption features. In essence, it brings its own "sun" to orbit, Krainak said.

Becoming the Obvious Choice

Since beginning work on the instrument 8 years ago, Krainak says the branch has made good progress. With the Internal Research and Development (IRAD) funding, the branch plans to take laboratory measurements of methane and other gases using a breadboard of its instrument. Successful demonstrations could give Goddard technologists the ammunition they need to attract additional funding and advance the instrument's technological readiness. The ultimate goal is to make the instrument the obvious choice for future missions.

In addition to Mars exploration, Krainak said the instrument has a wide range of uses on Earth, including global warming studies and medical testing. ◆

Contact:

Michael.A.Krainak@nasa.gov or 301.286.4881

Photo Credit: Chris Gunn

Emily Wilson tests the breadboard of a laser-based absorption spectrometer, which is designed to detect methane and other gases that could indicate the presence of life on Mars.

Cryogenic Technology Could Find Application with Human Spaceflight

Goddard's technical know-how working with cryogenic fluids to cool scientific instruments may find an application with human spaceflight, specifically with the proposed Lunar Lander now under study at NASA Headquarters.

The Center's Cryogenic and Fluids Branch has received NASA funding to do a sub-scale demonstration of a cryogenic fuel-storage system, which could be used on the propulsion system of the Lunar Lander and other elements of the exploration mission architecture, including possibly the Earth Departure Stage, the upper stage of NASA's next-generation Ares V heavy-lift vehicle.

The Cosmic Background Explorer, whose measurements recently resulted in a Nobel Prize for the spacecraft's principal investigator, John Mather, used Goddard-developed cryogenic dewars to keep its sensitive instruments extremely cold.

Goddard Research Money to Fund Demo

Using funding under Goddard's Internal Research and Development program, the branch will develop a small, flight-like system to show that its technology will prevent cryogenic propellants from boiling off during long-duration spaceflight, said Branch Chief Susan Breon. Cryogenic propellants, such as liquid oxygen and hydrogen, perform better and consume less mass than more traditional propellants. However, they are difficult to store because they can boil off quickly without proper insulation.

Breon doesn't see boil-off as a problem. "These rates are manageable," she said. She cited Goddard's past experience using long-life dewars to store cryogenic fluids needed to cool astronomical instruments to near absolute zero or -273 degrees Celsius. For infrared space astronomy, keeping the instrument extremely cold is important because the heat generated by the telescope itself will simply overwhelm the infrared signals astronomers are trying to detect.

The Cosmic Background Explorer, Gravity Probe-B, the X-ray Spectrometer aboard Astro-E2, now called Suzaku, and the Spitzer Space Telescope all flew cryogenic systems.

"We have something to bring to the table," Breon said. Although other NASA Centers have worked with cryogens, Breon said they have focused more on the component level. "We've done flight systems."

The question of whether cryogenic propellants could be used on the Lunar Lander came to light during the Lunar Lander Concept Studies that took place at Goddard and other NASA Centers during the summer. "We were asked whether we could take our technology and apply it to cryo-propellants and still save mass," Breon said. "The answer turned out to be yes." The subscale demonstration aims to prove that point, she said. ◆

Contact:

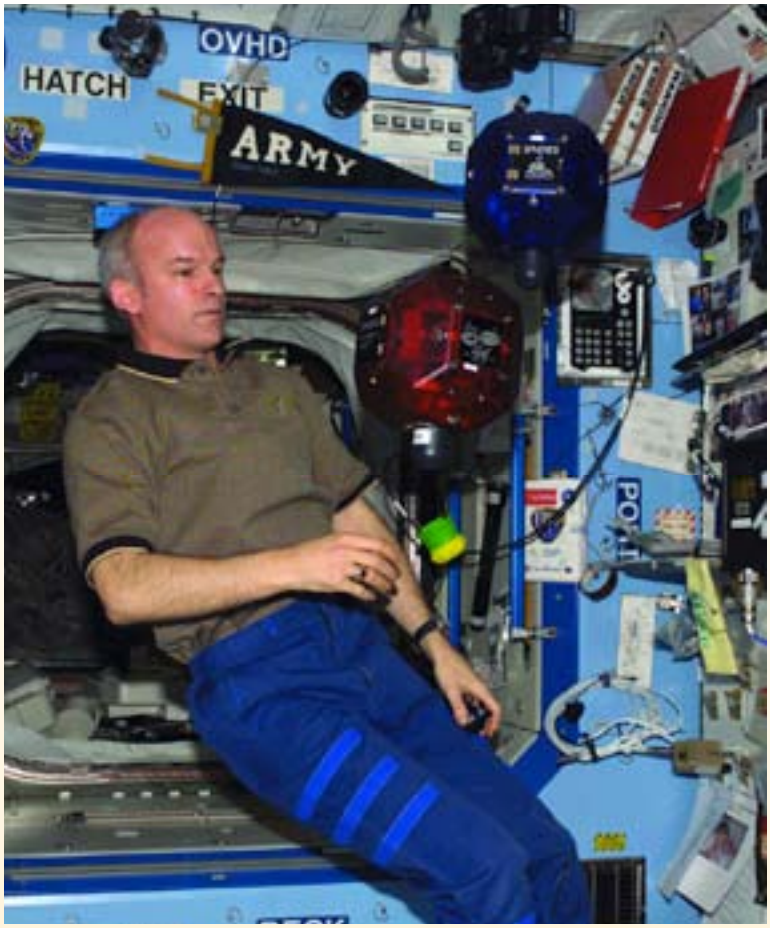
Susan.R.Breon@nasa.gov or 301.286.5405

SPHEREs in Space

Goddard Technologist to Test Experimental Algorithm on Tiny Satellites

An experimental algorithm that could one day enable multiple satellites to fly autonomously in formation — a critical technology for NASA's proposed Terrestrial Planet Finder and other future missions — is expected to be tested for the first time on two bowling ball-size testbed satellites now flying onboard the International Space Station.

If all goes as planned, Goddard technologist Russell Carpenter could begin testing the mathematical model, which he calls Pluribus, as early as November on the SPHERE satellites, developed by the Massachusetts Institute of Technology (MIT) with funding from the Defense Department, Goddard, and other NASA Centers. Each SPHERE — short for Synchronized Position Hold Engage Re-orient — weighs only 7 lbs., measures 8 inches in diameter, and is specially equipped with sensors, thrusters, and a microprocessor to test high-risk control and autonomy techniques.



U.S. astronaut Jeff Williams oversees the action of two SPHEREs now onboard the International Space Station. Goddard technologist Russell Carpenter is expected to use the miniature satellites to test a formation-flying algorithm he has developed.

Star Wars Inspiration

MIT began developing the tiny satellites 6 years ago after Professor David Miller showed his students the movie, "Star Wars," and challenged them to build one of the floating battle droids depicted in the film. Two currently are flying onboard the space station, and a third is expected to arrive in December.

Carpenter's help securing financial support to initially fly and test the SPHEREs on NASA's KC-135 reduced-gravity aircraft in 2003 earned him flight time on the space station. His algorithm is designed to decentralize control of satellite operations and allow each satellite to fly autonomously in formation. With Pluribus, spacecraft cooperatively track planned maneuvers and trajectories, processing and transmitting only local measurement information to one another to maintain a formation.

Ground Testing Performed

In addition to testing Pluribus on the KC-135 — an effort supported by Bo Naasz of the Center's Flight Dynamics Branch — Carpenter ran Pluribus in MATLAB, which is a high-level technical computing language and interactive environment for algorithm development, data visualization, and data analysis. However, MATLAB simulations are limited in accuracy and the KC-135 provides only up to 20 seconds of microgravity, which isn't enough time to test satellite formations, he said.

Because the space station offers six degrees of freedom, fewer disturbances, and virtually unlimited testing time, experiments there will give Carpenter the time he needs to see how his algorithm performs in space, he said. That knowledge will allow him to refine the technology and move to the next level of development — perhaps a flight opportunity offered through the Agency's New Millennium Program.

His experiment is a long time coming. The small satellites, which are color coded to easily identify them, were initially slated to reach the space station in 2004, but the 2003 Columbia accident prevented their launch until earlier this year. If he doesn't carry out his experiment in November, Carpenter said he might be able to perform his experiment in January. ◆

Contact:

James.R.Carpenter@nasa.gov or 301.286.7526

Astrophysics Detectors to Help Keep the Homeland Secure

Goddard Scientist to Develop Neutron-Imaging Camera

Goddard scientist Stanley Hunter and the Naval Surface Warfare Center (NSWC) in Carderock, Md., have joined forces to develop a Neutron Imaging Camera (NIC) that the U.S. military could use to detect and interdict weapons-grade plutonium hidden inside of shipping containers.

The Neutron Imaging Camera that a Goddard scientist is under contract to develop would be able to detect nuclear material hidden inside of shipping containers.

Under the $10 million effort funded by the Defense Threat Reduction Agency, Hunter and up to 15 other Goddard employees will extend the application of Goddard's "Three-Dimensional Track Imager (3-DTI)" now being developed for medium- and high-energy gamma-ray telescopes to high-resolution, fast-neutron imaging. Working with Noel Guardala, a NSWC nuclear physicist, Hunter will build, test, and calibrate half-scale and full-scale prototypes of NIC during the 3-year effort.

Long-Range Detection Capability

NIC, which will pinpoint the location of nuclear material from hundreds of meters away, could be placed on trucks, boats, or aircraft. Using this device, the military could stop the shipment of nuclear materials long before they reached a U.S. port. Although several neutron detectors are currently available, they aren't sensitive to fast neutrons and can't detect nuclear material at a distance. They also can't provide directional information that would reveal which container holds the material, said Hunter, who works at Goddard's Astroparticle Physics Laboratory

The Goddard/NSWC collaboration was formed several years ago when Hunter and Guardala were having a conversation about homeland security. "We realized that Goddard's gamma–ray imaging technology could be easily adapted to neutron imaging," Hunter said.

Continued, Page 8

Microcalorimeter... *Continued from page 2*

development team lead. He concedes that making the jump from a 32-pixel array used on Suzaku's Goddard-built X-ray Spectrometer (XRS) to a proposed 1,000-pixel array presents many challenges. As a result, he and his team will be pursuing opportunities to use this technology on an intermediate mission. "We would like something in between to help us solve the hard problems and allow us to apply the technology to important problems in high-energy astrophysics," he said.

To build a 1,000-pixel array, Goddard's microcalorimeter group has had to advance the readiness of yet another new technology — the transition edge sensor (TES), a highly sensitive thermometer made of superconducting film. The advantage to using TES on a microcalorimeter array is that it offers higher spectral resolution than the Suzaku instrument and it recovers faster after measuring the temperature of each incoming X-ray photon. This would allow scientists to apply the device to a wider range of celestial sources.

Goddard has a long history in microcalorimetry. In the early 1980s, Goddard scientists first proposed the approach and within a year had developed a proof-of-concept device. Scientists originally conceived it to fly on the Advanced X-ray Astronomy Facility (AXAF), one of NASA's proposed Great Observatories. Due to the downsizing of that mission, however, the technology was used instead on Suzaku.

"This is technology where Goddard is very competitive," Kelley said. However, without R&D investments, it would be difficult maintaining his core team and improving the performance of the technology, he said. ◆

Contact:

Richard.L.Kelley@nasa.gov or 301.286.7266

Build It and They Will Come

Advanced Manufacturing Branch Adds New Capability

Goddard's ability to machine and assure the accuracy of specialty parts for spacecraft and scientific instruments has advanced to the next level of sophistication now that the Center has acquired a high-precision optical-measuring machine, which it has housed in a Class-100 clean room, according to Garcia Blount, head of Goddard's Advanced Manufacturing Branch.

The machine, the Smartscope Quest 600, adds a new dimension to what his organization can offer in the way of machining components, checking their accuracy, and retooling them if necessary, Blount said. "Our main goal is to not only make specialty parts, but to make sure that they're accurate. With this machine and the high-speed machining center we acquired more than a year ago, we can do all these things within a day."

James Webb Space Telescope First Customer

The James Webb Space Telescope project will be the first to use the Smartscope when verification testing begins on the project's microshutter arrays, an enabling technology for the telescope's Near-Infrared Spectrograph, said Greg Woytko, manager of the Instrument Development Lab.

Each microshutter array is made up of 62,415 tiny shutters — each the width of a human hair. Precisely aligned on a silicon grid, they open or close to allow or prevent starlight from entering the spectrograph. However, astronomers will need to know the precise position of each shutter so that they know which shutters to open or close to get a particular field of view. Ultimately, the spectrograph will require eight arrays — four for the actual instrument and four for backup.

"The Smartscope is just the right tool to verify the location of each shutter," said Scott Schwinger, the lead mechanical engineer on the microshutter project. And because it is capable of detecting alignment problems that are thousands of times smaller than the width of a human hair, the Smartscope also will help technicians precisely align the arrays onto the silicon grid. "Verification will be included in the assembly process," he said.

Without Smartscope, Schwinger and his colleagues would have had to verify the arrays optically. "We'd have to choose three or four data points, but with this machine, we can see each shutter panel," he said.

Other Specialty Equipment

George Bertholdt, a quality assurance expert who will operate the Smartscope, expects the machine to get heavy use in the months ahead — especially when used in conjunction with the MIKRON high-speed machining center housed nearby. With the MIKRON, technicians

Continued, Page 8

The Smartscope is the latest addition to Goddard's Advanced Manufacturing Branch. A highly precise measurement tool, it is now housed in a Class-100 clean room in Building 5. George Bertholdt (in the forefront) operates the machine.

Build It... Continued from page 7

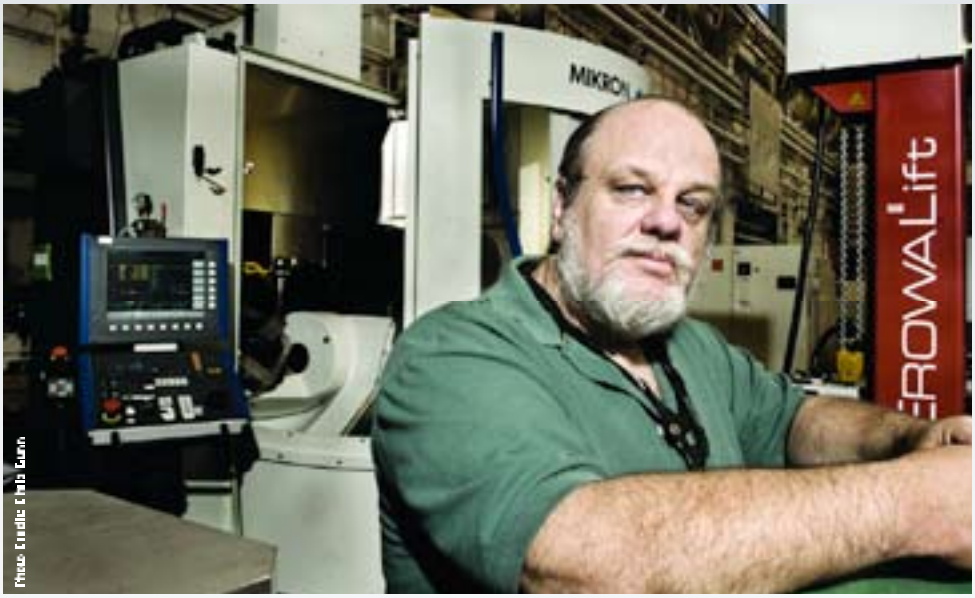


Photo: Credit: Chris Gunn

Matt Showalter, Sr. operates Goddard's high-performance machining laboratory, a new capability for the Goddard Advanced Manufacturing Branch.

can make tiny parts from all types of materials, including aluminum and inconel, a nickel-based superalloy that resists corrosion even at high temperatures. "We basically have people lining up. As they say, if you build it, they will come," he said.

Other special equipment the branch offers is the StereoLithography Apparatus, which uses liquid resins to create parts for prototypes. This way, engineers know if their designs will work before spending the time and money building hardware, Woytko said. "We're just trying to meet the needs of our customers and position ourselves to meet their future needs," he said, adding that potential customers should visit the group's Web site, **http://web547.gsfc.nasa.gov/amb**, to learn more about the facility's upgrades and services. ◆

Contact:

gwoytko@mscmail.gsfc.nasa.gov or 301.286.8424

Detectors... Continued from page 6

'Everyone Wins'

"It's a plus for Goddard," Hunter said. "We've been given (Defense Department) money to develop the 3-DTI large-area detector for NIC. This is the same technology that we need for imaging high-energy gamma rays. It's a two-way street and everyone wins."

The 3-DTI technology is expected to result in a high-angular-resolution telescope for future NASA missions, such as the Advanced Compton Telescope (ACT). ACT is the next major step in medium-energy, gamma-ray astronomy, and is expected to investigate the production of elements in supernova and how these elements are distributed throughout the galaxy. ◆

Contact:

Stanley.D.Hunter@nasa.gov or 301.286.7280

Goddard Tech Trends

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

Peter M. Hughes
Chief Technologist
Code 502
301.286.2342
Peter.M.Hughes@nasa.gov

Lisa W. Callahan
Deputy Chief Technologist
Code 502
301.286.1212
Lisa.W.Callahan@nasa.gov

Lori J. Keesey
Editor
301.258.0192
ljkeesey@comcast.net

np-2006-2-752-GSFC (revised 10/06)