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# Goddard Tech Trends

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## On The Cover:

Goddard technologist Vince Bly displays a single-crystal silicon mirror. See story on page 3.

Photo Credit: Chris Gunn

# Technologists Demonstrate End-to-End Internet-Based Communication System

Goddard technologists, who have long championed the use of basic computer networking protocols to communicate in space, have demonstrated a system using flight-compatible hardware in a space-flight environment.

In a series of recent demonstrations that participants described as moving "the state-of-the-art one step forward," a team of Goddard technologists debuted radiation-hardened hardware critical for operating an onboard Ethernet network, said Jane Marquart, a technologist with Goddard's Software Branch who participated in the demonstrations. In particular, the team demonstrated Goddard-developed Ethernet cards, which allow onboard computers to talk with a network, and switches, which transfer packets of data between computers onboard a spacecraft.

## High-Fidelity Testbed Used

"What's significant about our demonstration is the level of fidelity in the testbed. We used flight-compatible hardware in a flight development environment to prove the viability of an end-to-end Internet Protocol system — from a flight operations center on the ground to a receiving payload on a spacecraft — all communicating by way of Internet technologies," Marquart said.

In addition to the Ethernet cards and switches, developed by Goddard's Flight Data Systems and Radiation Effects Branch, Cisco Space Systems developed and tested a prototype for a radiation-hardened router. The company performed the work under a Space Act Agreement with the Goddard Space Flight Center. Routers allow messages to be sent between two or more networks.

"Now a mission has the hardware infrastructure for a fully compatible Internet Protocol network that will satisfy radiation requirements for any type of mission," Marquart said. "There are no restrictions where this hardware can go."

The demonstrations took place during the summer and represented the next step in NASA's continuing efforts to extend Internet Protocol (IP) into space — a development that holds the promise of reducing mission costs as well as the time it takes to develop them.

Marquart said her team's efforts were similar to what Goddard technologists demonstrated in 2003 when they flew the Communication and Navigation Demonstration on Shuttle (CANDOS) experiment aboard Space Shuttle Columbia. The equipment that flew on the Shuttle, however, was not space qualified to the degree necessary for a mission that lasted longer than a Space Shuttle mission.

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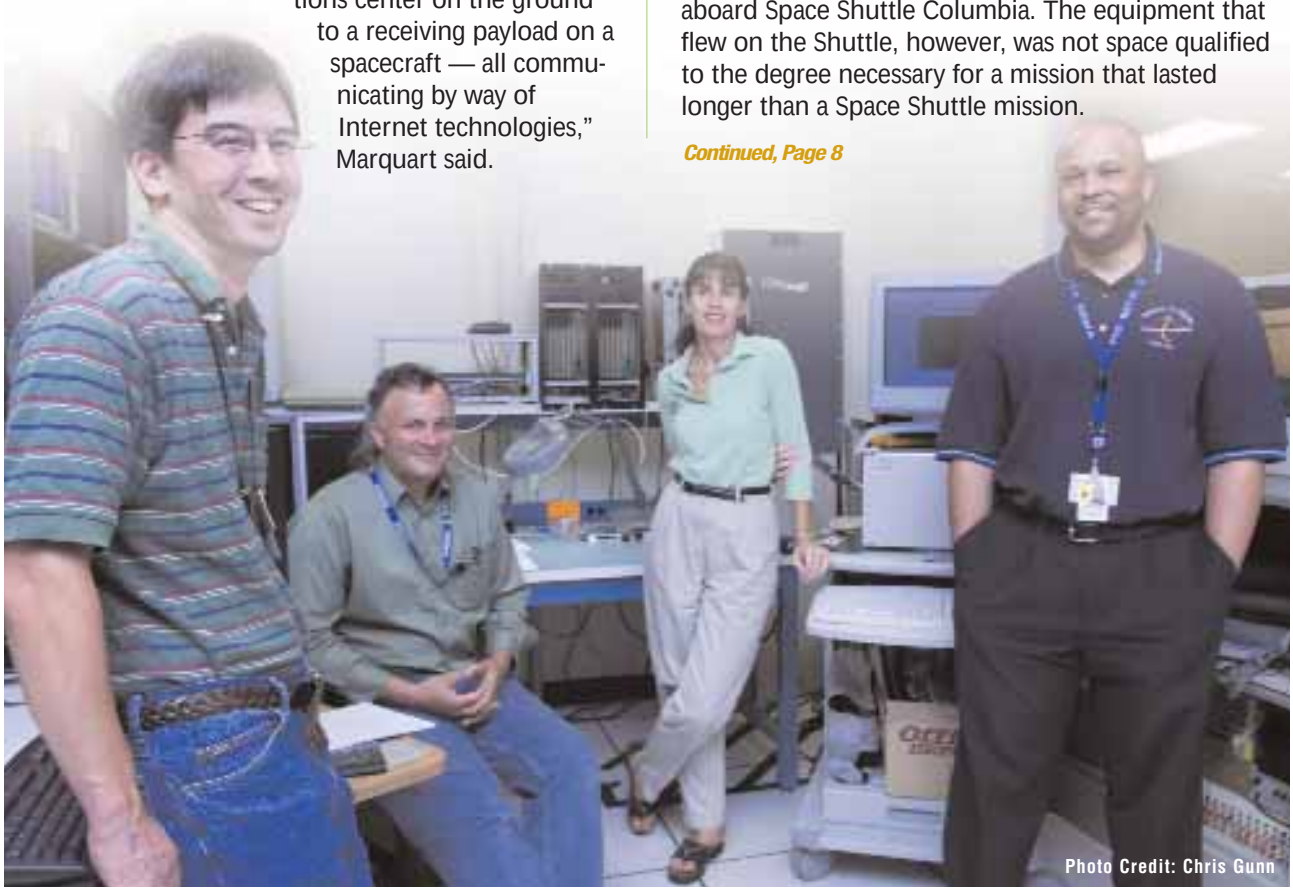


*Goddard technologists developed and demonstrated radiation-hardened hardware critical for operating an onboard Ethernet network. From left to right: Mike Lin, Greg Menke (Raytheon), Jane Marquart, and Freemon Johnson.*

# Inspiration from a Computer Chip

## *Goddard Technologist Delivers First Single-Crystal Silicon Mirrors*

A few years ago, Goddard technologist Vince Bly participated in a series of brainstorming sessions looking at how NASA might use thin silicon wafers — like those used in Pentium IV computer chips — to build ultra-lightweight mirrors for space telescopes. Although it soon became clear to him that the idea probably wouldn't work, it did get him thinking about silicon as a mirror material.

After 3 years of research and development, in part using Director's Discretionary Funding, Bly's idea paid off. Just a few weeks ago, he delivered the first two curved single-crystal silicon mirrors to Goddard Earth scientist Scott Janz who plans to use them in Geostationary Spectrograph (GeoSpec), an experimental instrument he's developing under NASA's Instrument Incubator Program (see related story).

Bly says he's pleased so far with the mirror's initial test results and optimistic that he'll find other applications for his technology. He plans to conduct more validation tests at Goddard and the Marshall Space Flight Center and design additional single-crystal silicon mirrors of varying shapes and sizes. "Most likely, the best way to do this is to provide mirrors for other projects," he said. "My belief is that single-crystal silicon mirrors are a

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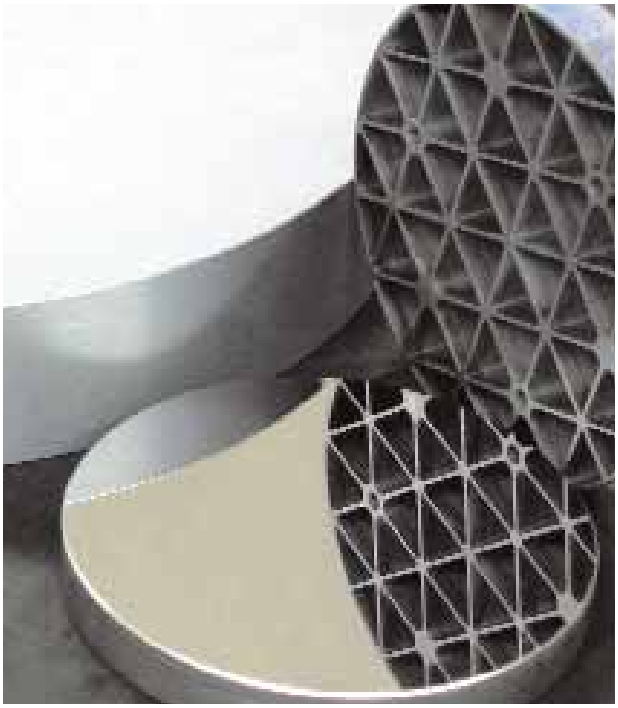


*This image shows the optical surface of a single-crystal silicon mirror reflecting the light weighted, honeycombed backside.*

# GeoSpec to Use New Mirror Technology

The Geostationary Spectrograph (GeoSpec) — the first project to use mirrors made of single-crystal silicon — is being developed under NASA's Instrument Incubator Program to support several possible mission concepts in the atmospheric and land and ocean sciences.

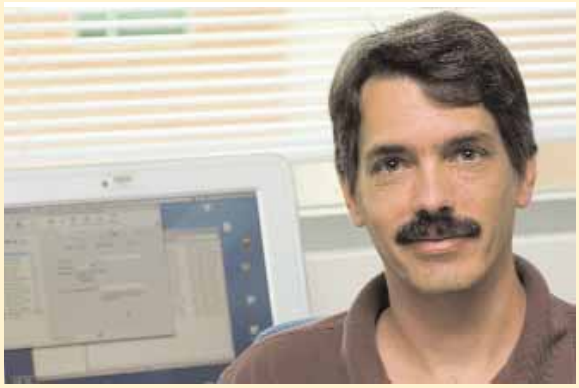


Photo Credit: Chris Gunn

*Goddard Earth Scientist Scott Janz, who is building the Geostationary Spectrograph under NASA's Instrument Incubator Program, is the first to use single-crystal silicon mirrors developed by Goddard technologist Vince Bly.*

Developed by Scott Janz and colleagues in the Atmospheric Chemistry and Dynamics Branch (Code 613.3), the instrument will become part of an Earth Science System Pathfinder mission proposal, with a target launch date of 2012.

Janz says the single-crystal silicon mirrors appealed to him because he needed to reduce the instrument's weight, which would reduce the cost of placing the instrument in a geostationary orbit. He also said the technology's thermally stable optics help maintain the high-spatial resolution needed for his observations.

The instrument will measure both chemically linked atmospheric trace gases and important molecules, such as nitrogen dioxide, ozone, sulfur dioxide, and formaldehyde. It also will monitor coastal and ocean pollution events, tidal effects, and aerosols in the ultraviolet-, visible-, and, possibly, shortwave infrared-wavelength bands.

The Instrument Incubator Program fosters the development of innovative remote-sensing concepts and the assessment of these concepts in ground, aircraft, or engineering model demonstrations. For more information about the program, visit: **http://esto.nasa.gov/programs/iip.** ◆

Contact:

Scott.Janz@nasa.gov or 301.614.5987

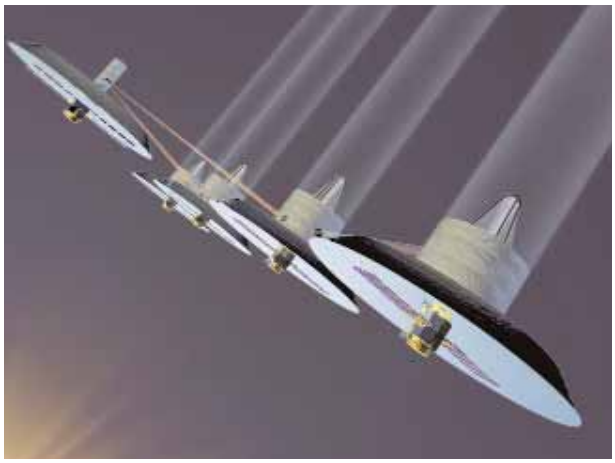
# Goddard Technologists Lead Three ST-9 Concept Definition Studies

Three Goddard technologists are leading yearlong concept studies to define space experiments that demonstrate and validate advanced technology for future science missions.

The effort began August 23 after a formal kick-off meeting and is a part of the New Millennium Program's Space Technology-9 (ST9) project, which is testing system-level technologies in five technical concept areas.

The concept areas include system technologies for solar sails (Tim Van Sant, Code 460), precision formation flying (Jesse Leitner, Code 591), and large space telescopes (Chris Schwartz, Code 502). Technologists from the Jet Propulsion Laboratory (JPL), meanwhile, are leading similar efforts in the areas of terrain-guided automatic landing systems for spacecraft and an aerocapture system technology for planetary exploration.

By the end of September 2006, the teams will submit study reports describing a technology-validation experiment and its rationale, a development schedule, and cost plan. The Science Mission Directorate will then evaluate the proposals to select the concept area that will proceed into "formulation refinement" as the ST9 mission. A flight is scheduled for 2010.



*The proposed Terrestrial Planet Finder will use multiple telescopes working together to take family portraits of stars and their orbiting planets and determine which planets may have the right chemistry to sustain life. The mission may employ formation-flying techniques.*

Joining all five team leads are 11 recently selected technology providers who will conduct studies and gather data needed to support the proposals. The technology providers represent both NASA Centers and private industry. ◆

## ST9 At-A-Glance

### Solar Sail Technology

- **Study Lead:** Tim Van Sant (Solar Terrestrial Probes Program)
- **Partners:** L'Garde, Inc., Tustin, Calif.
- **Purpose:** To study a flight experiment that would deploy and operate a steerable solar sail, made of very thin, reflective membranes about 1/50th of the thickness of a human hair. The sails would be used to propel spacecraft into otherwise inaccessible orbits.
- **Possible Missions:** Heliostorm, the Solar-Polar Imager, and the Interstellar Probe

### Formation Flying

- **Study Lead:** Jesse Leitner (Guidance, Navigation & Control Systems Engineering Branch)
- **Partners:** JPL and General Dynamics Decision Systems, Arizona
- **Purpose:** To study technologies that would continuously and collaboratively control multiple spacecraft flying in formation and validate advanced inter-satellite communication and sensor technologies.
- **Possible Missions:** Terrestrial Planet Finder-Interferometer, the Stellar Imager, MAXIM, the Submillimeter Probe of the Evolution of the Cosmic Structure, the Magnetospheric Multi-Scale Mission, and the Solar Imaging Radio Array

### Large Telescopes

- **Study Lead:** Chris Schwartz, (Goddard Technology Management Office)
- **Partners:** Northrop Grumman Space Technology, Lockheed Martin Space Systems, Goddard, and JPL
- **Purpose:** To examine the technologies required for large, deployable, actively cooled sunshields and cryogenically cooled telescopes needed to detect and analyze the composition of planets outside our solar system and study the formation of the first galaxies, stars, and planetary systems.
- **Possible Missions:** Single Aperture Far-Infrared Observatory (SAFIR) and Cosmic Background Polarization (CMBPol) experiment

## Looking for Life

### *Technologist Study New Instrument Concept*

Astrobiologists looking for evidence of life on Mars may find NUGGET to be one of the most useful tools in their tool belt.

As conceived by scientists at the Goddard Space Flight Center, the proposed Neutron/Gamma ray Geologic Tomography (NUGGET) instrument would be able to generate three-dimensional images of fossils embedded in an outcrop of rock or beneath the soil. NUGGET could help determine if primitive forms of life took root on Mars when the planet was awash in water eons ago.

Similar to seismic tomography used by the oil industry to locate oil reserves beneath Earth's surface, NUGGET would look instead for evidence of primitive algae and bacteria that had fossilized along the edges of extinct rivers or oceans. As on Earth, these remains could lie just a few centimeters beneath the surface, compressed between layers of silt. If a rover were equipped with an instrument like NUGGET — capable of peering beneath the surface — then it might be able to reveal evidence of astrobiological life.

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## Proposed Earth Science Platform Shows the SHAPES of Things to Come

Although Unmanned Aerial Vehicle (UAV) platforms are becoming de rigueur with both NASA and the Defense Department, the concept of a hybrid airship that uses electric propulsion to propel itself remains a largely unexplored technology. Previous ventures involving hybrid airships, primarily based in Europe, dealt with high-altitude, heavy-lift applications.

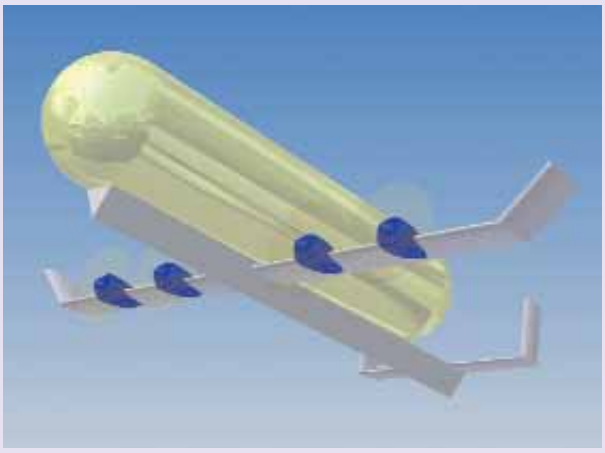
However, the Scalable Hybrid Airship Platform for Exploration and Science (SHAPES) project is changing that.

The project, managed by principal investigators David Wilcox and Geoff Bland at the Wallops Flight Facility, hopes to develop an initial pathfinder platform that could fly lightweight, miniaturized Earth science payloads at low-speed and low-altitude. Such a vehicle might prove especially useful for coastal-zone research, and ultimately planetary exploration.

Initially funded by the Director's Discretionary Fund, the project ultimately plans to prototype and test a platform and begin to answer the hard questions associated with developing an alternative technology platform, including launch, recovery, stability, and control. Currently, the prototype design is based on a 5.5 lb. scientific payload. The proposed platform is 27 feet long, 5 feet in diameter, with a wingspan of 20 feet.

Because of the complexity of integrating a craft that large, Bland and Wilcox said they are now investigating different aerodynamic and structural engineering issues using smaller-scale test vehicles. "This approach will minimize the risks as we determine the best next steps for realizing a fully capable Earth science measuring system and evaluating the craft's potential use for planetary exploration," Bland said.

In addition, he and Wilcox are studying lightweight construction techniques and new methods for fabricating



*A hybrid airship uses a combination of static lift from an airship-like envelope and dynamic lift from an aircraft-like wing. Advantages of the hybrid airship over the traditional "blimp" are that the craft would be somewhat negatively buoyant, reducing the need for large ground handling crews and alleviating the hazards associated with the loss of powered flight or control*

materials so that SHAPES can accommodate varying payload sizes and masses.

Once these issues are decided, the pair said they would like to fly an initial SHAPES vehicle that uses electric propulsion, powered by a lithium-polymer battery and controlled by radio. They also would like to use the new UAV runway on Wallops Island to conduct flight tests. Initial science instrumentation packages for the SHAPES pathfinder mission could include an infrared video/high-resolution digital imaging package used to study coastal waterways and a carbon-dioxide sensor for observing gas distribution in a marsh environment.

### Contact:

David.A.Wilcox@nasa.gov or 757.824.1314
Geoff.Bland@nasa.gov or 757.824.2855

## Inspiration... Continued from page 3

natural — especially for telescope spectrometers and similar instruments that operate in deep space and must endure super-cold temperatures," he said, adding that those missions include everything from a Terrestrial Planetfinder to a large telescope that studies the very early universe.

### The Appeal of Silicon

What initially attracted Bly to the material is its high-thermal conductivity and low expansion, which make it less likely to distort when exposed to extreme swings in temperature — especially compared with more traditional mirror-making materials like quartz or glass. In addition, silicon is extremely pure and crystalline, making it more uniform and stable. And last, silicon is commercially available. The semiconductor industry now can manufacture boules that are nearly 20 inches in diameter. "That's certainly large enough for most optical instrument applications," Bly said.

The question that remained was how to fabricate a lightweight mirror from the material.

### Reversing the Process

In conventional lightweight mirror making, technicians remove portions of the mirror blank before they polish the optical surface. The technique creates a honeycomb that maintains the mirror's strength while significantly reducing its weight. But with single-crystal silicon, which isn't as stiff as other materials for lightweight mirrors, the approach wouldn't work, Bly said. "If the light weighting were too aggressive, then the pattern of the supporting ribs would print through to the mirror surface," Bly said. The resulting mirror would have a poor optical figure or would have to be significantly heavier.

But Bly had another idea. He figured that because single-crystal silicon is so pure and homogeneous, he could light weight the mirror after he polished the optical surface. This approach wouldn't work with conventional materials because the removal of so much material would unbalance the material's internal structure and distort the optical surface.

He has continued to improve the process and now his mirrors distort no more than about one-fiftieth wave after light weighting, which is good enough for even the most critical applications, he said. In fact, a recent mirror he created was so flat that — if stretched to one mile in diameter — the highest bump on the mirror would be less that the width of a human hair. ◆

Contact:
Vince.Bly@nasa.gov or 301.286.1580

## Work Progressing on TETWalker

What started out as a pyramid-shaped robot that could change its shape and move by tumbling is beginning to evolve into a more complex machine that its creators believe will one day navigate the lunar surface, going where no wheeled robot would dare to go.

With the help of summer interns, Goddard principal investigator Steve Curtis has begun construction of the 12-Tetrahedron Walker (12-TETWalker), which offers greater flexibility and locomotion than the initial 1-TETWalker he conceived and built a couple years ago using Director's Discretionary Funding.

Under Curtis's unusual robot design, nodes and struts — reminiscent of Hasbro's Tinkertoys™ — form the pyramid shape of the 1-TETWalker. The struts are equipped with electric motors that expand and retract to change the length of the sides. The changing length alters the pyramid's center of gravity, causing it to topple over and move. Because the nodes pivot, the robot has even greater flexibility.

Once completed, the more sophisticated 12-TETWalker will look more like a tower made up of 12 tetrahedron units. Because of the additional struts, the robot will be able to reconfigure itself into a greater variety of shapes, giving it the ability to navigate difficult terrain. The tetrahedron concept has a variety of applications and potential, Curtis believes. Work currently is underway to develop a robotic arm as well as more advanced command and communication technologies.

*The 1-TETWalker is the basis for the 12-TETWalker.*

For more information, see www.nasa.gov/vision/universe/roboticexplorers/ants.html. ◆

Contact:
Pamela.E.Clark@gsfc.nasa.gov or 301.286.7457

## Looking... Continued from page 5

"This is a brand new idea," said Sam Floyd, the principal investigator on the project funded this year by Goddard's Director's Discretionary Fund. When developed, NUGGET would be able to investigate important biological indicators of life, and quickly and precisely identify areas where scientists might want to take core samples or conduct more intensive studies. "It would allow us to do a much faster survey of an area," Floyd said.

The proposed instrument, which could be carried on a rover or a robot lander, is made up of three fundamentally distinct technologies — a neutron generator, a gamma-ray detector, and a "polycapillary" optical lens. This is the first time that these three technologies have been brought together for consideration as one scientific instrument system.

At the heart of the instrument is a three-dimensional scanning subsystem, which focuses a beam of neutrons into a rock or other object under study. When the nucleus of an atom inside the rock captures the neutrons, it produces a characteristic gamma-ray signal for that element, which the instrument's gamma-ray detector then analyzes. By moving the neutron focal point within the object and knowing its location, it's then possible to plot the location of the elements measured by the gamma-ray subsystem.

Photo Credit: Chris Gunn

*Goddard scientist Sam Floyd holds a device he used to test his concept for a Neutron/Gamma ray Geologic Tomography (NUGGET) instrument, a concept instrument that may help astrobiologists search for evidence of life on Mars.*

Photo Credit: Chris Gunn

*Jason Dworkin, a Goddard astrobiologist, holds a stromatolite, a layered sedimentary rock formed by bacteria eons ago. If such a rock were discovered on Mars, it could indicate that primitive life had once taken root on the red planet.*

This information can then be turned into an image of the elements within the rock. Imaging the existence of certain types of elements can tell scientists whether a certain type of bacteria may have become fossilized inside the rock.

Although the concept of focusing neutrons isn't new, the ability to focus them is. Thanks to a Russian scientist who devised the method in the 1980s, scientists can today can direct a beam of neutrons through an optical lens made up of thousands of long, slender, hair-size glass tubes. The bundle of tubes is shaped so that the neutrons flowing down the tubes can converge at a focal point. Since the method's invention in the 1980s, manufacturing practices have made these so-called "polycapillary" optics a feasible part of space exploration.

The advantage of this is that the system can create a higher intensity of neutrons at the location being studied. This increased intensity allows a higher- resolution image to be produced.

Floyd said that his research could give Goddard the lead role in developing a new class of instrument to support NASA's astrobiology missions in the future. ◆

### Contact:

Samuel.R.Floyd@nasa.gov or 301.286.688

## Technologists... Continued from page 2

### Other Demonstrated Capabilities

In addition to demonstrating the radiation-hardened hardware, Marquart said the team made sure that they wouldn't encounter hardware or software problems integrating standard commercial IP applications, including Voice-over IP and Mobile IP. In addition, they addressed security issues and overcame timing issues within the onboard network itself. Any one of these could have jeopardized their efforts to create a flight-ready, end-to-end system. "About the only thing we didn't tackle was the operations issues, which can be very mission dependent," she said.

Although CANDOS demonstrated Mobile IP, it didn't do so with flight-ready hardware. With mobile IP, a spacecraft equipped with a router or any other device with an IP address would be able to communicate with an IP-compatible ground station within range, reducing the level of set-up activity required to schedule and process satellite communication in advance.

The team also incorporated security protocols developed by the Internet Engineering Task Force to demonstrate how it would secure data and prevent hackers from tampering with the network. The protocol is currently used by e-commerce and the banking industry and is considered the safest for securing packets of information over the Internet. "This technology is proven in traditional terrestrial networks and its user-space can now span into flight mission environments here at NASA," said Freemon Johnson, another Goddard technologist who participated in the demonstration.

"The point here is that we didn't have to customize or invent any new technology. We simply took the commercial versions and integrated them onboard the spacecraft," Marquart said.

### Overcoming Onboard Timing and Reliability Issues

To successfully demonstrate the flight-ready system, Goddard technologists also had to resolve timing and reliability issues associated with transporting data across the onboard network. The most commonly used technology is Transmission Control Protocol (TCP), which assures that data is reliably transmitted and received through a network by requiring that the sending computer receive a confirmation from the receiving computer once it receives a packet of information. In some instances, TCP acknowledgments would not be received within the strict time constraints of an onboard network.

Goddard technologists resolved the timing problem by using User Datagram Protocol (UDP), another transmission protocol that doesn't require receipts after sending packets of information. Because UDP is unreliable, Marquart said the group added a layer of reliability into the Ethernet link by using another common protocol called Logical Link Control. She said the fix proved reliable, met the onboard timing requirements, and didn't require any customized code.

"Our effort was demonstrated in a high-fidelity, mission-compatible environment," Marquart said, describing the demonstrations. "Now we have radiation-hardened Ethernet hardware that can fly beyond low-Earth orbit. We believe this advances the state-of-the-art for Internet Protocols in space." ◆

**Contact:**

Jane.Marquart@nasa.gov or 301-286-7851


## Goddard Tech Trends

*Goddard Tech Tends* is published quarterly by the Goddard Technology Management Office (Code 502) at the Goddard Space Flight Center in Greenbelt, Maryland. The newsletter describes technology developments at the Center and explains how they are helping NASA to achieve its missions. If you wish to be placed on the newsletter distribution list or if you want more information about Goddard technology or the Goddard Technology Management Office, contact:



Peter M. Hughes
Chief Technologist
Goddard Technology Management Office
301.286.2342
Peter.M.Hughes@nasa.gov

Lisa W. Callahan
Deputy Chief Technologist
Goddard Technology Management Office
301.286.1212
Lisa.WCallahan@nasa.gov

Lori J. Keesey
Editor
301.258.0192
ljkeesey@comcast.net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