National Aeronautics and Space Administration

goddard techtrends

Figueroa: 'Open Our Horizons'

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20% of R&D Funds Committed to Early-Stage Technologies

Orlando Figueroa began his NASA career in 1978, never thinking that he would some day become the Center's Deputy Director for Science and Technology — a position he assumed in February after serving for nearly five years as the Director of the Applied Engineering and Technology Directorate. When nominated for the "Federal Employee of the Year" in 2005, former Goddard Director Ed Weiler described Figueroa's ability to "cut through the tape and get the job done," adding that Figueroa wasn't "afraid to speak his mind." In this interview with Goddard Tech Trends, Figueroa lends credence to Weiler's observations as he shares his vision of technology development at NASA, and Goddard in particular.

What are your reactions to Administrator Bolden's appointment of an Agency-level Chief Technologist?

Throughout the Agency's history, we've gone through cycles of having a Chief Technologist or technology office of varying sizes to not having one at all. During the times we didn't have one, we always conclude that we need a Chief Technologist. Technology investments need a focal point, a champion, someone to oversee the health of near-, mid-, and particularly long-term investments. We need to encourage broader innovation, different approaches, and new ideas not tied to specific programs, where the priority of delivering the mission will always threaten our commitment to and resources for long-term investments in technology. The appointment of a Chief Technologist is a good thing for NASA.

Will this change how we invest in technologies at Goddard?

We have come a long way in focusing our efforts. A few years ago, we were concerned about uncovered capacity. Therefore, we invested money to improve the Center's competitive posture, focusing on near- to mid-term opportunities. Now we are deliberately setting aside part of our technology-investment portfolio for early-stage or long-term investments not tied to any particular mission or opportunity. At least 20 percent of funds will go towards that goal.

What is your advice to technologists in light of your commitment to continue investing 20 percent of R&D funds to early-stage technologies?

Let's be more aggressive about scanning the horizon for technologies outside of the project, outside our close community. When you have a program mentality, you become too risk-averse. You don't look for technologies that can change the game. We must open our horizons to those new ideas. What I hope is that our people will expand their opportunities to interact or "collide" with others outside these walls. We are a very creative community, but we can all benefit by sharing ideas with others. Partnerships and collaborations, therefore, are very important. More can be achieved if we leverage resources.

Are we investing in the right technologies?

I think we have been. We have done a good job at being responsible stewards of our investments and infusing technologies to get the job done. We are incredibly creative and have tackled the most difficult challenges; the COBE (Cosmic Background Explorer) mission is an example of where we did what people thought was impossible, pushing the state-of-the-art. JWST (James Webb Space Telescope) offers many similar examples. We perform technological miracles day in and day out. It is truly inspirational. It's why I come into work each day. Can we do better? Again, the answer is yes. We must be deliberate making long-term investments and providing opportunities for the next generation.

What are your concerns?

This is a challenging period for the Agency. What concerns me during these periods of transition is our ability to keep focus. We need to continually ask ourselves, why are we here? We are here to be enablers, to conceive, develop, launch and operate science missions that answer the most challenging questions in astrophysics, Earth science, heliophysics, and planetary science. We are here to deliver the data and information from those missions to the public in a way people can use it. We need to focus on technology investments and understand that they are part of the foundation of our ability to deliver scientific results. We need to focus on seeking the best ideas, always thinking about the needs of tomorrow. We need to focus on partnerships and collaborations that could lead to truly game-changing technologies. We are stewards for the nation. We have the capability to make it happen. Very few places in the world can claim this. ◆

A Technological Game Changer?

New MicroSpec Instrument Could Revolutionize Far-Infrared Spectroscopy

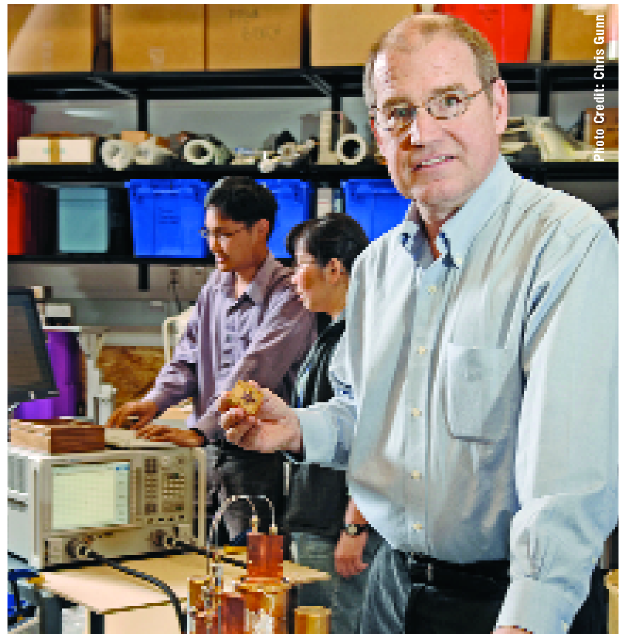
All eyes are on Goddard scientist Harvey Moseley and his team these days as they test the prototype of a ground-breaking far-infrared spectrometer that will be 10,000 times more sensitive than competing instruments, yet infinitely smaller — so small, in fact, that its components fit onto a silicon chip measuring four inches in diameter.

"If there ever were a game-changing concept in submillimeter and millimeter spectroscopy, this is it," Moseley said.

He and his team have begun testing the MicroSpec prototype under cryogenic conditions to gauge the instrument's functionality. After testing the concept under laboratory conditions, the team plans to build a flight-like instrument that it hopes to test at the CalTech Submillimeter Observatory, perhaps later this year. If all goes as planned, the team will have advanced MicroSpec's technology readiness level, making it a strong contender for future flight missions in astrophysics and Earth science.

"If we can prove it, everyone will want it," Moseley said.

His assessment could be an understatement.



Harvey Moseley holds the detector that Goddard technologists developed for a revolutionary far-infrared spectrometer called MicroSpec. Kongpop U-Yen and Wen-Ting Hsieh (pictured in the background) are assisting in the MicroSpec development effort.

Never-Before-Achieved Sensitivity

MicroSpec would replace spectrometers that are thousands of times larger in volume, providing never-before-achieved sensitivity in a wavelength band that would allow scientists to probe a wide range of environments in the universe, from distant galaxies in the early universe and stars forming in our Milky Way, to objects found in our own solar system. Scientists use spectrometers to measure properties of light to identify the composition and physical properties of the object being observed.

Moseley describes his instrument as the logical follow-on to those flown on past missions, including the Kuiper Airborne Observatory, Infrared Astronomy Satellite, Cosmic Background Explorer, Infrared Space Observatory, and Spitzer Space Telescope. All opened the infrared window to the universe, revealing new information about interplanetary dust particles, galactic mergers, and young galaxies — observations largely enabled by observations of the local universe at mid-infrared wavelengths.

Logical Successor to Herschel

MicroSpec also is the logical successor to the Herschel Space Observatory, which the European Space Agency launched last year, Moseley said. Like Herschel, an observatory flying MicroSpec could observe farther back into space and time to see newly forming galaxies that are just beginning to bulk up with new stars. It could sift through star-forming clouds to trace the path by which potentially life-forming molecules, such as water, form. And it could find and observe dust and gas disks around newly forming stars to study the process that gives rise to solar systems and extrasolar planets.

However, it would do so with greater precision. "We can get 10,000 times the sensitivity of Herschel," Moseley said. "The MicroSpec will open new areas of discovery."

Although Moseley had conceived his instrument "a long time ago," he said he did not begin work on the idea until he could "retire a number of the technical uncertainties." In 2009, he applied for and received Goddard Internal Research and Development program funding to begin building the components, which include a Goddard-built 1,500-pixel detector array, coupling optics, dispersive optics, and filters. Researchers from the Jet Propulsion Laboratory and Caltech also are collaborating in the effort.

'Instrument on a Chip'

The challenge was integrating these components into a compact package — specifically onto an easily reproducible silicon wafer. "It is an instrument on a chip — yes, an instrument on a chip," said Wen-Ting Hsieh, a Goddard technologist who helped Moseley in the development of the instrument's detector system. "That's why it's so amazing." ◆

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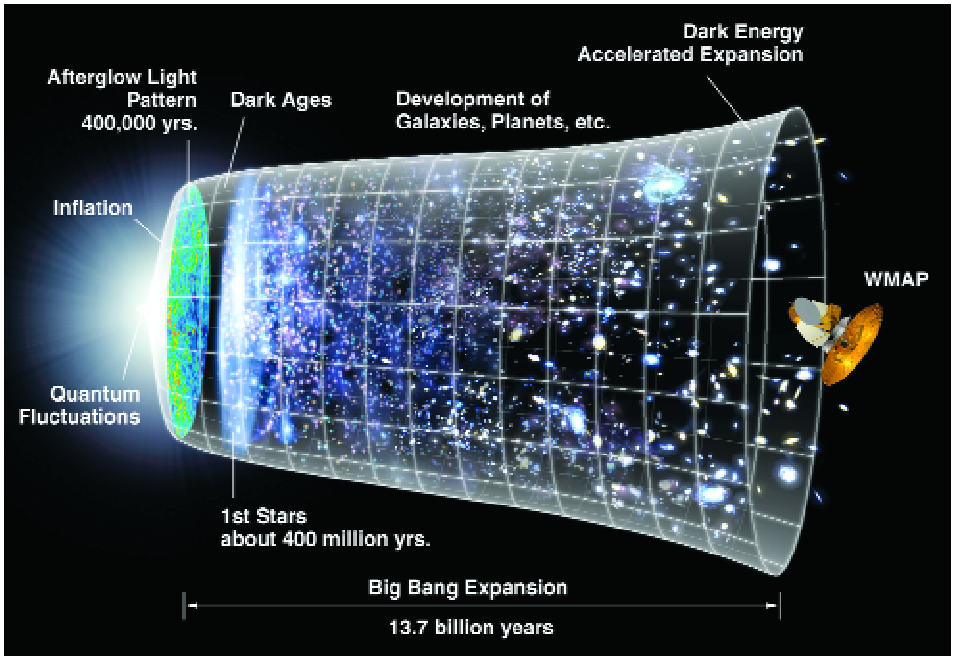
Doubling Down on Efforts to Prove Cosmological Inflation

A long-time partnership between Goddard and Johns Hopkins University (JHU) scientists has resulted in the award of a new instrument designed to search the cosmos for evidence that the infant universe expanded from the microscopic to the astronomical in a fraction of a second after its birth 13.7 billion years ago.



This graphic shows the universe as it evolved from the big bang to now. Goddard scientists believe that the universe expanded from subatomic scales to the astronomical in a fraction of a second after its birth, and are now building, along with their university partner, an instrument that searches for clues that the inflation did, in fact, occur.

Former Goddard scientist Chuck Bennett, now a JHU astrophysicist, won a $5-million National Science Foundation grant to build a new ground-based instrument, the Cosmology Large Angular Scale Surveyor (CLASS). Bennett is building CLASS with his Goddard collaborators, Ed Wollack and David Chuss. Harvey Moseley, Gary Hinshaw, and others also are lending their expertise to the effort.

Goddard will provide most of the sophisticated bolometric detectors and other state-of-the-art technologies that will help the team test the "inflation theory" of the universe's origin. In particular, the instrument will search for a unique polarization pattern in the cosmic background radiation — the remnant light from the first moment of the universe's creation. Because of the size and expansion of the universe, scientists can study this ancient light only if their instruments are tuned to microwave frequencies.

Considered a staggering idea just 30 years ago, the inflation theory postulates that the universe expanded far faster than the speed of light and grew exponentially almost instantaneously. If the cosmic growth spurt really happened, scientists say the event could have created ripples or gravitational waves in the fabric of space. The theory also predicts that these gravitational waves would have caused the background light to be polarized in a particular pattern. The telescope, therefore, will look for this signature pattern.

The CLASS team, which also includes other partner institutions, will complete the instrument in 2014. The team then will ship the instrument to the Atacama Desert in northern Chile where it will observe large swaths of the microwave sky in search of the polarized signature.

Although scientists have yet to find the polarization pattern, they have uncovered tantalizing clues that inflation did, in fact, happen. Scientific results from the Goddard-developed Cosmic Background Explorer (COBE) found tiny temperature differences in the cosmic background radiation. These differences varied by only a few millionths of a degree and pointed to density differences that eventually gave rise to the stars and galaxies seen today.

COBE's successor, the Wilkinson Microwave Anisotropy Probe (WMAP), a mission led by Bennett and launched in 2001, examined the tiny temperature differences in more detail and discovered new evidence for inflation. Among other things, WMAP showed that the geometry of the universe is close to flat — a physical property attributable to inflation. However, other competing theories can explain these dynamics. What the scientific community needs is definitive proof of the primordial gravity waves — a phenomenon that the other theories can't explain.

Another Goddard Mission Complements CLASS

CLASS is not the only effort aimed at finding the same telltale evidence. Another Goddard team now is building

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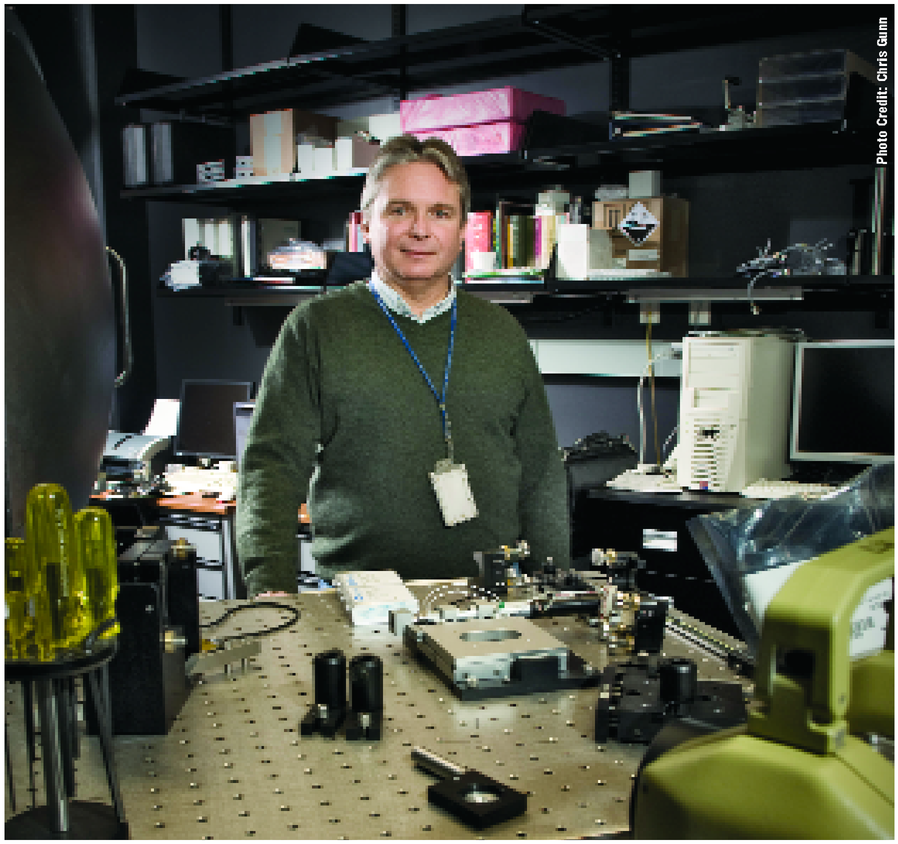
Tracking Alien Worlds

Goddard Team Selected to Advance Planet-Finding Technology



Scientist Rick Lyon is pictured in the lab where he and other team members currently are developing new technologies that would allow scientists to image Jovian-size planets beyond our solar system.

In late 2008, astronomers ignited the scientific world when they announced they had directly imaged the star Fomalhaut b. Although scientists have detected 429 extrasolar planets since discovering the first gas giant in 1995, never before had scientists taken a visible-light photograph of a planet beyond our own solar system.

The hunt has yet to abate.

"The next step is imaging more planets down to Earth size," said Mark Clampin, a Goddard scientist and a member of the team that imaged Fomalhaut b with the Hubble Space Telescope. "NASA wants to search for life; it's the long-term goal. We need to develop technology that would image planets" and analyze their light in search of specific chemicals — oxygen, methane, water, carbon dioxide, and ozone — that might indicate the presence of life.

Clampin and his team have accepted the planet-imaging challenge. In February, the team won about $700,000 in NASA R&D funding to advance an important planet-finding technology called the Visible Nulling Coronagraph (VNC), a hybrid interferometer that could be coupled to a single telescope to suppress starlight and increase the contrast of the circumstellar region surrounding a Jovian-size planet. VNC would allow astronomers to directly image and characterize gas giants, zodiacal light, and the orbits of larger, extrasolar planets — a necessary first step towards the goal of imaging terrestrial planets, Clampin said.

Six other teams also received the funding to advance their planet-finding technologies. The goal is to advance the technologies to a readiness level of about six sometime in 2014, at which time NASA is expected to issue an Announcement of Opportunity (AO) for a planet-imaging mission presumably supported by the National Research Council's Astronomy and Astrophysics Decadal Survey. "The idea here is to invest in technology earlier and retire technology risks sooner," Clampin explained.

Should NASA release the AO, the team plans to use the technology on its proposed Extrasolar Planetary Imaging Coronagraph (EPIC), a probe-class observatory featuring a 1.6-meter primary light-gathering mirror.

September Demonstration Planned

The team is well on its way to proving its technology. With Goddard Internal Research and Development program funding, the team already has developed two VNC testbeds. One operates in a vibration-isolated vacuum tank and is designed to make sure the VNC can achieve a stable level of contrast in white light. The other evaluates the VNC's miniaturized, segmented deformable mirrors that make up the instrument's wavefront sensing and control system. These tiny mirrors, which could number nearly 1,000 on a flight-qualified instrument, tip and tilt to cancel starlight, ultimately creating a coronagraph that blocks direct light from a star so that nearby objects can be resolved.

The team plans to demonstrate the technology in September and use lessons learned from these tests to design a smaller, more compact version of the

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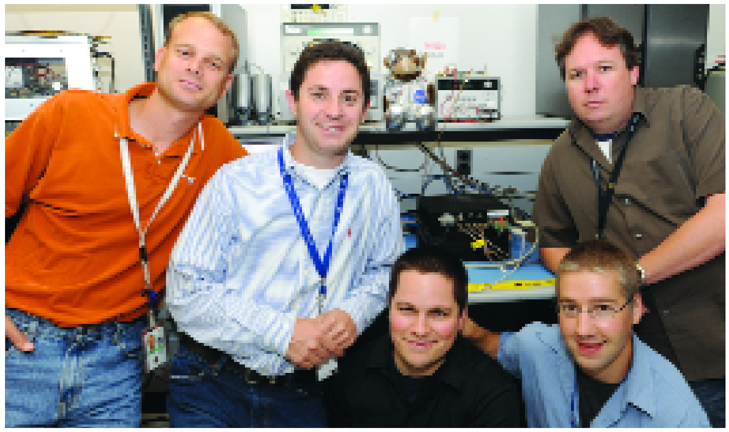
Homegrown Technology Makes Good

Navigator GPS Receiver Advances to Next Level of Functionality

Goddard's homegrown Navigator GPS receiver technology is on a roll, as are the technologists who used R&D funding earlier in the decade to develop the receiver that can quickly find, acquire, and track the GPS radiowave in weak-signal areas. The proof?



A Goddard team (from left to right: Bill Bamford, Steve Sirotzky, Greg Heckler, Luke Winternitz, and Rick Butler) is using R&D funds to advance its Navigator technology to receive GPS signals even at lunar distances.

The Navigator team was nominated to receive NASA's coveted "Invention of the Year" award — an honor bestowed on a patent-protected technology developed by a NASA employee. A decision is expected shortly.

The technology, meanwhile, will serve as the primary navigation sensor on the Goddard-developed Global Precipitation Measurement and Magnetospheric MultiScale missions. The Navigator team also delivered an engineering test unit to the next-generation weather satellite called GOES-R, and the Air Force Research Laboratory (AFRL) plans to fly the technology on two of its spacecraft programs.

In fact, Broad Reach Engineering, an aerospace firm that has offices in Arizona and Colorado, is building the GPS receiver for one of those AFRL missions and is pursuing a commercial license for the Navigator signal-processing technology. The company also plans to use the technology to develop other products geared to commercial satellites and scientific missions, says Dan Smith, a Broad Reach project manager.

And if those successes weren't enough, Navigator proved its mettle during a first-of-its-kind experiment carried out during STS-125, the Hubble Space Telescope Servicing Mission last year (*Goddard Tech Trends*, Summer 2009, page 3). The experiment proved a key relative navigation-sensing technology that could be used in a robotic rendezvous with Hubble in the future.

"No question. The Navigator team has experienced an incredible level of success," says Carl Adams, the assistant chief for technology for the Mission Engineering and Systems Analysis Division. "I attribute their accomplishment to technical know-how, but also to a healthy entrepreneurial spirit. These guys saw a need and developed a solution, which is now driving down mission costs for civilian and military space programs and extending the range of spacecraft GPS sensing to GEO orbits and beyond."

Work began on the Navigator GPS receiver in the early 2000s when a group of Goddard engineers, led by Luke Winternitz, realized that existing GPS receivers could not adequately acquire the weak GPS signals if operating above the GPS constellation, which is about 20,200 km (12,727 miles) above Earth. As a result, spacecraft operating above the GPS constellation could not reliably use GPS for tracking and navigational purposes, forcing them to use more expensive ground-tracking assets.

Seeing an opportunity to help lower mission costs, the Navigator team applied for and received Internal Research and Development (IRAD) funding to develop algorithms and other technology that would allow spacecraft to acquire and track GPS signals at an altitude of 100,000 km (62,137 miles) — well above the GPS constellation, roughly one quarter of the distance to the Moon.

"The investment of previous IRAD funding allowed the weak-signal Navigator GPS receiver concept to come to fruition," Winternitz says. "Proof of the value of this investment lays in the explosion of flight opportunities and commercialization ventures that have followed."

The team is now looking to further improve the technology.

With FY 2010 IRAD funding, Winternitz and his team are developing the next-generation Navigator receiver — one that can acquire the GPS signal even if the spacecraft carrying the receiver is located at lunar distances. Such a capability would reduce mission operational costs because ground controllers could track spacecraft via GPS rather than with expensive ground stations.

"We expect that the evolution of Navigator's capabilities will open up a host of new applications and funding sources, including exploration and high-altitude science missions," Winternitz says. "Navigator's selling points will continue to be that it can offer unparalleled navigation performance in weak-signal and highly dynamic environments." ◆

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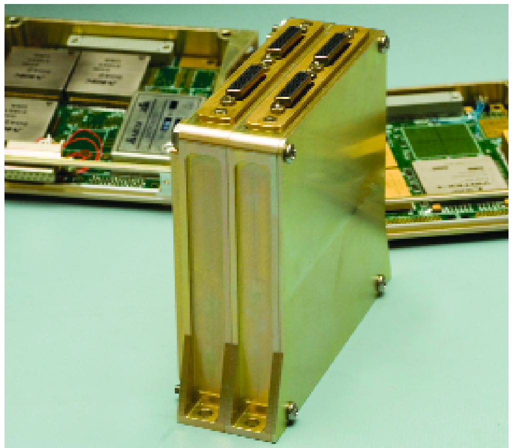
Taking a Page from Apple's Playbook

Goddard Technologist Develops Host of SpaceCube Products

Apple Inc. introduced its first Macintosh computer in 1984, at the time the only commercially successful personal computer to feature a mouse and a graphical user interface. The rest is history. Today, Apple offers all manner of products to meet consumers' needs.



SpaceCube 1.0, a more robust flight processor, is morphing into other products to satisfy different spaceflight applications.

Goddard technologist Tom Flatley and his team seem to have taken a page from Apple's playbook. Buoyed by the success of the team's first model — SpaceCube 1.0 — the group now is creating other products, including the SpaceCube Mini, SpaceCube 1.5, and SpaceCube 2.0, and is considering applying for a trademark to legally identify the brand.

"I talk with a lot of people in different fields," Flatley says. "It gives me ideas on how I can apply the technology to meet their needs. Actually, it just involves listening."

SpaceCube is an experimental, next-generation flight data-processing system that Goddard technologists first flew in May 2009 during the Hubble Space Telescope Servicing Mission (*Goddard Tech Trends*, Summer 2009, page 3). Equipped with four power PCs, a "scrubber," and special algorithms that detect and correct radiation-induced upsets, the computer system is up to 25 times faster than the current state-of-the-art — the RAD750, an expensive radiation-hardened microprocessor currently used on space missions.

The team now is testing a flight spare on the International Space Station as part of the "Materials on the International Space Station Experiment 7" (MISSE 7). MISSE 7 is one of many payloads installed in the Express Logistics Carrier — an unpressurized attached payload on the space station — that astronauts delivered in November.

By the time the experiment ends in two to three years, Flatley says he hopes to advance the technology readiness level of SpaceCube radiation-hardening-by-software techniques to a level nine. Currently at level five, Flatley believes he can achieve these higher levels mainly because he can uplink new variations of the team's radiation-hardened-by-software applications and test them in a spaceflight environment.

So far, SpaceCube has detected a couple upsets per week and its first line of defense, which he calls a "scrubber," has promptly fixed them, Flatley said. If the scrubber fails to correct the upset, SpaceCube's algorithms kick in and fix the error within milliseconds, which means users potentially could lose a pixel or two of data. For the vast majority of NASA's applications, the loss is acceptable, given the trade-off of lower mission costs and significantly increased computing power.

At this point, Flatley says the algorithms haven't been called into action. Even so, he's pleased with the results. "This is great news. With protection, we're showing we can use high-powered commercial processors in spaceflight applications."

He's not resting on his initial success, however. He and his team are using R&D funds to develop SpaceCube 2.0, a next-generation model that combines the radiation-hardened-by-software techniques with both commercial and radiation-hardened semiconductors developed by the San Jose-based Xilinx to create a more robust flight processor. With this version, health and safety applications could run on the radiation-hardened components, while other applications that can withstand the loss of a pixel or two could rely on the commercially available components.

In the fall, the team plans to demonstrate a cross between SpaceCube 1.0 and 2.0 — identified as SpaceCube 1.5 — on a sounding rocket flight in which the computer system will process video monitoring of a parachute deployment — a technique scientists could use to land instruments on planets and other solar system objects.

And last, Flatley and his team have begun work on SpaceCube Mini, a much smaller version of the original that could be installed in unmanned aerial vehicles, robotic servicing systems, landing-system thrusters, or in cameras that could help rovers navigate difficult terrain. "What we're offering with the Mini is a lot of computing power with high-speed data-processing capabilities for a variety of niche applications," he said.

"As a first step, we're not trying to use SpaceCube for man-rated uses, but through the combination of our various SpaceCube technologies, we hope to provide the reliability of full radiation-hardened systems, while offering more computing power at a lower cost. We're very encouraged by our initial success." ◆

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Doubling Down... *Continued from page 4*

a balloon-based instrument, the Primordial Inflation Polarization Exploration (PIPER), that Principal Investigator Al Kogut hopes to launch in 2012 (*Goddard Tech Trends*, Winter 2009, page 4). Although both CLASS and PIPER are looking for the same polarization signature, they will approach the challenge using different detector technologies to study different frequencies.

PIPER will examine the higher frequencies in the microwave band using a planar bolometer array ideally suited for such wavelengths, while CLASS will look at the lower frequencies with feedhorn-coupled transition-edge sensors. Goddard developed both detector technologies with R&D funds. It is considered the leader in both. "The more frequencies you study, the better your chance of detecting the pattern of inflation," Chuss added.

"CLASS and PIPER are perfect partners," Wollack explained. "They share many technologies while spanning a wide frequency range. They will do great science while demonstrating the technologies for a space mission."

The ultimate goal for the team is leveraging its expertise with CLASS and PIPER and winning a possible follow-on space observatory that the scientists call the Cosmic Microwave Background Polarimeter (CMBPol). CMBPol would examine the primordial background with even greater precision. "What we're doing is very much what we need to do to compete for a space mission to measure inflation," Chuss said.

"Goddard's scientific successes with the COBE and WMAP missions, combined with Goddard's broad and deep technical expertise, places Goddard in a unique position for answering the most basic questions we have about our universe," Bennett added. ◆

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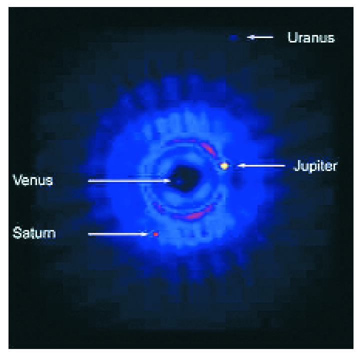
Alien Worlds... *Continued from page 5*

instrument, said Rick Lyon, a Goddard optical scientist developing the VNC. "The trick here is making all this as small as possible," he said. Ultimately, the entire VNC package would be no larger than a textbook.

'Stepping Stone'

Clampin concedes that the scientific community is mixed on what type of mission NASA should pursue should it decide to launch a planet-finding mission in the next decade. "There's a lot of sentiment to go straight to imaging Earth-like planets," he said. To accomplish that, however, NASA would have to fly a six- to eight-meter telescope, which would gather more light, but exceed the $1 billion price cap on probe-class missions. "These missions will be driven by budget and technology. Imaging planets is very hard," he said, adding that a Jovian-size gas giant is a billion times fainter than its parent star.

"EPIC is a stepping stone. It's a way for us to do science" as the scientific community advances technologies to build larger observatories farther into the future, he said. "I believe there are a lot of intermediate steps." In the meantime, he said, work will continue. "We're moving on what we think is a promising technology that will position us for a probe-class mission when it appears," Clampin said. ◆



This artist's rendition shows what the Visible Nulling Coronagraph would see if the instrument were searching for planets around our own Sun.

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Goddard Tech Trends

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