National Aeronautics and Space Administration

Goddard Tech Trends

Volume 2 | Issue 4 | Summer 2006

tech trends

On The Cover:

Goddard Space Flight Center Director Ed Weiler holds a piece of the Space Cube, a next-generation command, data, and handling system that is faster than the current state-of-the-practice — the RAD750. See interview on page 2.

Photo Credit: Chris Gunn

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The State-of-Technology at Goddard: Center Director Ed Weiler Speaks Out

Goddard Space Flight Center Director Ed Weiler recently shared his views on the state-of-technology at the Center in an interview with Goddard Chief Technologist Peter Hughes and the editor of Goddard Tech Trends. In an era of shrinking budgets and resources, Weiler offered a no-nonsense assessment of the role of technology at Goddard.

What is the future of technology development at Goddard?

We need to continue pursuing only those technologies that are critical to potential missions or instruments. The 'good old days' of playing in the sandbox are over. I also think that it takes big flagship programs, like [the Hubble Space Telescope] and the [James Webb Space Telescope], to make the big, fundamental discoveries. These are the missions that people will remember in 100 years. The reality of this is that the price tag on these big missions begins at $1 billion. The challenge now is how do we keep them from costing significantly more than that? I believe the money will flow to those technologies that make things cheaper and enable missions.

But flagship missions aren't the whole story, of course. A healthy science program requires a mix of small, medium, and large missions. The trouble these days is finding compelling science that still can be done, especially by the smaller missions. This is where technology will play a role in various ways… innovative ideas in detectors, light-collecting systems, lightweight components, and such can help us get more science for the dollar and put us in position to win scientific competitions.

What is your advice to Goddard technologists?

People who think that Agency-level, mission-independent research funding is coming back had better get real. Those days are over. But that doesn't mean money isn't available. For instance, the R&A [Research and Analysis] funding at Headquarters is an undertapped chunk of money for specific, mission-related technologies. Hundreds of millions of dollars are available in R&A and a significant part of that is available for technology grants!

So, people need to become more aggressive about writing proposals. They need to differentiate their technology from others. They need to become more imaginative and entrepreneurial. If they have connections with others doing complementary work, they need to use them to build partnerships. I'd also like to get Codes 500 and 600 — the engineers and scientists — working more closely together on proposals. We have a unique capability here at Goddard and we need to use it to our competitive advantage. Another thing to remember is that we don't have to develop everything ourselves. We should always be looking to apply and use technologies developed by other agencies. HST, for example, certainly was enabled by technologies flowing out of the work of other agencies. That's no secret.

What are your priorities for internal technology-development funds?

Internal research and technology-development funding will be more focused in the future. I will give priority to those efforts that target realistic funding sources. Having spent years at Headquarters, I have a good idea of which future missions have a chance. I'm looking for investments that will clearly improve our competitiveness in the short- to mid-term. I also will

Photo Credit: Chris Gunn

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Interview with Ed... *Continued from page 2*

approve a portion of our investments targeting the longer term; that is, those that create realistic opportunities 10 to 20 years from now.

What specific areas do you think Goddard should more assertively pursue in the Science Mission and Exploration Directorates?

For starters, lasers. We need to consolidate and leverage our world-class capabilities in laser technologies for unique scientific measurements. We need to aggressively pursue all opportunities in this area. Optical communications and other space communications technologies are another important area. I see them as a real growth area. Eventually, NASA will have to replace its TDRS system. As for detectors, absolutely — across the board — they are important to us. Peter, as Chief Technologist, you know these technologies and you know as well as I that they're too numerous to list. But I might mention avionics and robotic end effectors. We excel in tools and Johnson [Space Center] needs them. Also important are many other technologies that will reduce the mass, cost, and risks of next-generation missions.

Photo Credit: Chris Gunn

Historically, instruments are our strength. However, I'd like us to win some planetary missions with greater involvement than simply providing the instrument. I'd also like to see us fly low-cost missions out of Wallops. Most people don't realize this, but Wallops is NASA's only launch range. The Air Force owns Cape Canaveral and provides the launch-range support for the Shuttle. Think about it, Goddard has its own dedicated launch range at Wallops. It should be used more aggressively to carry out NASA's low-cost missions. For that matter, Goddard should creatively use all of its unique capabilities to carry out NASA's mission. ◆

Space Cube to Debut in 2007

Goddard Space Flight Center Director Ed Weiler and others frequently cite the "Space Cube" as one of Goddard's strategically important technologies. But what is it?

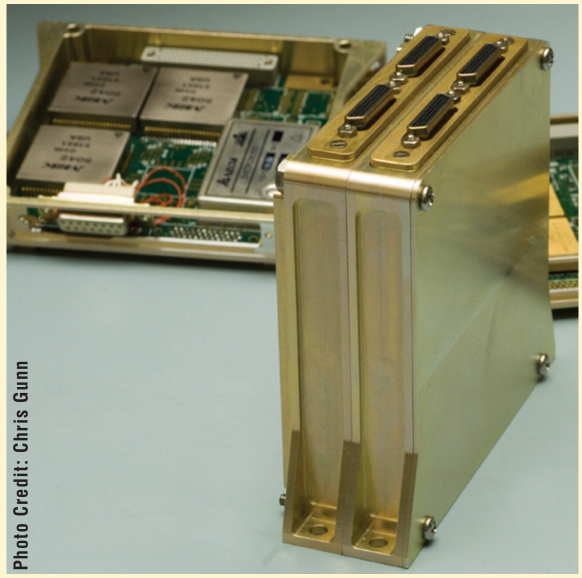

Photo Credit: Chris Gunn

This command, data, and handling system is smaller and more powerful than current technologies.

Space Cube is a next-generation command, data, and handling system; in other words, the brains of a spacecraft. It controls all spacecraft functions. "It's a very powerful processing engine," explained John Godfrey, a Goddard technologist who began working on the technology 1-1/2 years ago. He said each of the Cube's four power PCs is four times faster than the current state-of-the-practice — the RAD750, a radiation-hardened microprocessor currently used on space missions.

The technology will make its debut in late 2007 or early 2008 when astronauts are scheduled to visit the Hubble Space Telescope to change instruments and components that will keep the observatory alive and well until 2013. During that mission, astronauts will demonstrate image recognition and the viability of autonomous, robotic servicing. That experiment couldn't be done without Space Cube's enormous processing power, Godfrey said.

Completely reconfigurable, Space Cube also is slated to fly as a Space Station payload in 2008. ◆

Contact:

John.s.godfrey@nasa.gov or 301.286.7566

The Devil's in the Details

Goddard-Developed Mars Rover Instrument Offers Design Challenge

For engineers who thrive on challenge, Patrick Jordan and his team have a dream job. Their assignment: Designing and building a soda can-sized oven that can heat to a scorching 1100˚C (2000˚F) using only 25 watts of power.

The "pyrolysis oven" is just one of several challenging technologies now being developed for the Sample Analysis at Mars (SAM), one of 10 instruments flying on NASA's next-generation Mars Science Laboratory (see related story on page 5). When SAM begins operations in 2010, the Goddard-developed chemical processing lab will analyze gases in the atmosphere and those that are produced when the oven heats soil and rock samples to temperatures that would melt metal. The detailed analyses of these gases are expected to answer the question that has so far eluded scientists: Did microbial life ever exist on Mars?

Since winning a spot on the Mars rover in late 2004, the Goddard team has refined and tweaked SAM's design to accommodate science requirements. The team passed the Preliminary Design Review in March and is now preparing for the Critical Design Review in December. To assure the instrument's delivery for a 2009 launch, the team is expected to begin building the engineering test unit this year and the flight model in 2007. Work is progressing with those milestones in mind.

Complex Instrument

"This is one of the most complicated experiments that's ever landed on the surface of another planet," said SAM Principal Investigator Paul Mahaffy, whose team includes Goddard and other NASA center employees as well as industry, university, and international partners.

The instrument's complexity is in large part due to how it's expected to carry out its job. Before SAM's three instruments — a gas chromatograph, a quadrupole mass spectrometer, and a tunable laser spectrometer — can identify a wide range of organic compounds and determine the ratios of different isotopes, it must do a little preparatory work, particularly on the soil and rock samples.

The general idea is that the rover's robotic arm would scoop up the soil and rock samples and a separate mechanism would grind and deliver the samples to SAM's "sample manipulation system." Built by Honeybee Robotics, the subsystem is a carousel-like device that contains two concentric rings holding 74 tiny tubes that each are about an inch high and a quarter-inch wide. Once the tubes were filled with the finely

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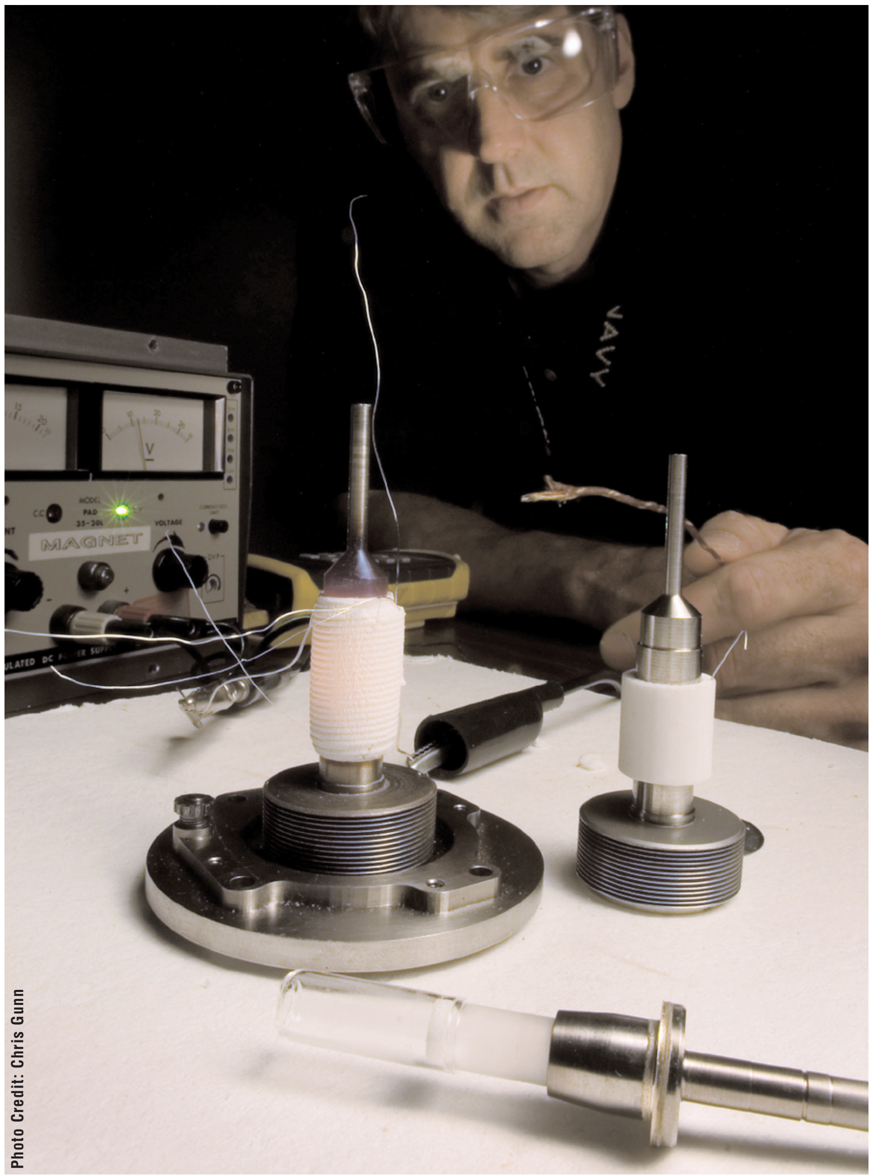


Photo Credit: Chris Gunn

Mechanical engineer Pat Jordan heats a prototype of his pyrolysis oven. To the right of the oven is another design that will be used on the actual instrument. In the forefront is one of the tiny cups that will deliver Martian dirt and rock samples to the oven.

Details... Continued from page 4

ground samples, the carousel would rotate and insert the tube inside the oven. Ten of the cups would contain extraction solvents and derivatization agents to bring about chemical reactions in otherwise difficult-to-analyze polar compounds, such as organic acids.

As the oven heated slowly — 90 degrees every minute — the hermetically sealed sample would begin to break down, releasing gases that SAM's instruments could then analyze. These gases would then be carried by inert helium through stainless-steel plumbing that connects the oven to the instruments. By heating the sample slowly, Mahaffy and other scientists can get a more complete picture of the sample itself. Minerals release specific molecules at characteristic temperatures. As a result, the pattern of gases released over time as the oven heats would tell them which minerals the sample contained.

Tricky Business

"But it's tricky," said SAM Thermal Lead Rob Chalmers. "You have to electronically adjust the power that gets into the oven so that it doesn't get too hot, too quickly." And if the gases get too cold as they travel from the oven to the instruments, they'll condense and the instruments won't be able to measure them. As a result, "all the plumbing — about 100 linear inches of stainless steel tubing — needs to be heated to nearly 400˚F. And, because of the high temperatures involved, it's been a research project finding which heaters we could use," Chalmers added.

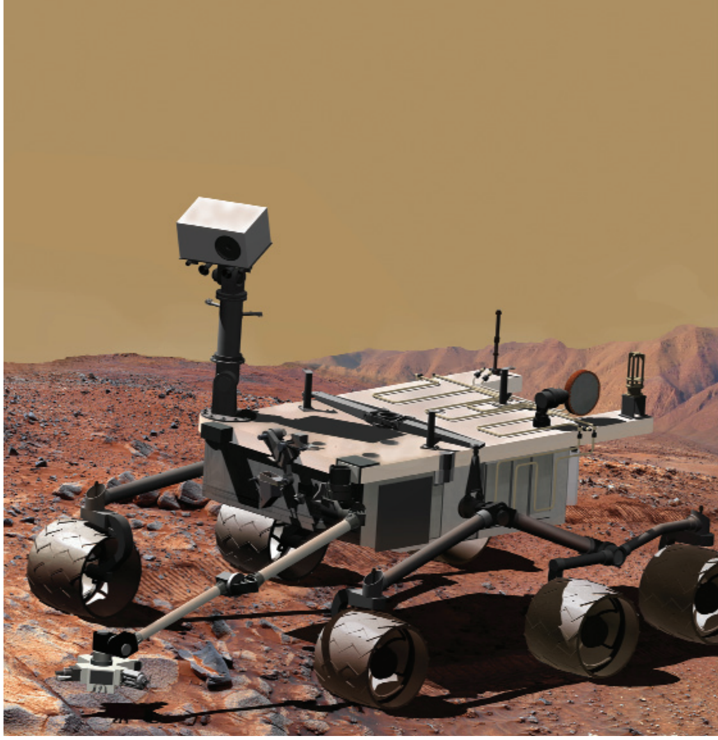
But those are just a few of the challenges that Jordan and his team have encountered. Since beginning the project more than 3 years ago, Jordan, a mechanical engineer who designed the oven and sample cups with a team of engineers at Goddard and the National Institute of Standards and Technology, said he's evaluated materials that can handle the oven's high-temperature and cleanliness requirements. He's also identified materials that he can use for both the oven's thimble-sized heating element that's situated outside the oven chamber and the oven chamber itself. He's now in the process of building an engineering unit.

But he still needs to tackle what he considers the largest challenge of all: Successfully heating the oven to 1100˚C with a power budget of only 25 watts. Detailed thermal analysis performed by Thermal Engineer Janelle Vorreter shows that the design should use only 22 watts. In laboratory tests, he's come within striking distance. He used 35 watts of power, and believes he can whittle down the remaining 10 watts through enhanced thermal insulation and shielding. "This is a thermal and material design challenge," Jordan conceded, referring to the oven's relative complexity. "If you're working on this project, it has all the challenges you could possibly want." ◆

Contact:

Patrick.J.Jordan@nasa.gov or 301.286.2434

Going Where No Rover Has Gone Before



Similar in size to a Mini Cooper, the Mars Science Laboratory (MSL) will go where no Mars rover has gone before to analyze soil, rock, and the atmosphere to determine whether the red planet now or ever sustained life.

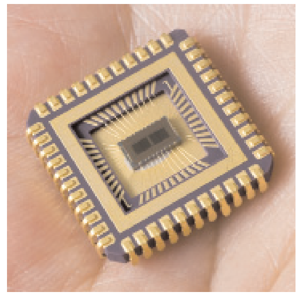
In addition to the Sample Analysis at Mars (SAM) instrument, which Goddard is contributing to the JPL-led mission (see related story on page 4), the next-generation rover will carry nine other instruments, including two from Spain and Russia. NASA plans to launch the mission in 2009, with operations to begin after the rover arrives on Mars in 2010.

During its 2-year sojourn, the nuclear-powered rover is expected to travel about 12 miles in a geographical area that scientists will choose after analyzing images from the Mars Reconnaissance Orbiter.

CULPRiT Technology Successfully Demonstrated On Orbit

Development Could Lead to More Efficient Spacecraft Design

Goddard technologists have successfully demonstrated a radiation-hardened computer chip that consumes significantly less power than traditional chips, opening the door to more efficient spacecraft design in the future, say the technology's developers.



The CMOS Ultra-Low Power Radiation Tolerant (CULPRiT) technology, developed by Goddard Scientist Pen-Shu Yeh and the University of Idaho's Center for Advanced Microelectronics and Biological Research (CAMBR), flew on NASA's Space Technology 5 (ST-5) mission. Sponsored by NASA's New Millennium Program, the mission assessed state-of-the-art miniaturized subsystems on three micro-satellites.

"The ST-5 validation is a milestone for ultra-low power technology because they've demonstrated it on orbit," said Mike Johnson, Assistant Chief for Technology at Goddard's Electrical Engineering Division. "It's a step in the right direction."

For the ST-5 demonstration, Yeh and CAMBR applied the CULPRiT technology to a Reed-Solomon encoder. Encoders modify scientific data from data systems, thereby creating the

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Goddard Laser Physicist Develops Robotic Laser

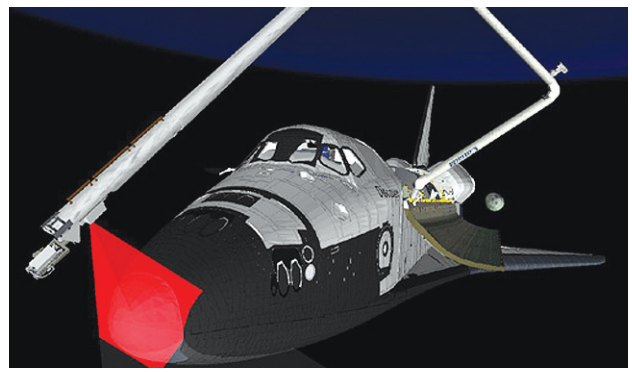
When NASA launched Space Shuttle Discovery last summer, the Agency used a three-dimensional laser camera system attached to Discovery's robotic arm to inspect the underside to make sure the protective tiles suffered no external damage during launch. Although effective, the process took all day and required that an astronaut operate the Shuttle's robotic arm.

Goddard laser physicist Barry Coyle believes he has a better solution.

Using Goddard's Internal Research and Development (IRAD) funding, Coyle is working to develop a robotic laser system that could perform the same task, except that it would perform it without the use of moving parts or human oversight. Coyle's system would create images by firing thousands of laser pulses at an object and then measuring how quickly the pulses returned, making it ideal for vehicle inspections, robotic assembly, maintenance activities, and docking maneuvers.

The concept of laser ranging and laser surface imaging is not new, and in fact, commercial units can be purchased at some expense, Coyle said. However, these units lack either resolution or pixel size, and usually rely on mechanically driven scanning optics to point the laser over the target. "We will perform all these functions, including surface imaging and target ranging to the centimeter level or less, with no moving parts," Coyle said. "The goal is to have an automated system so that you can remove human error and reduce decision times." Coyle said.

In his laboratory, Coyle has begun building a breadboard system that mates an electro-optic scanner to a variable output laser transmitter (VOLT), which Coyle developed under a Director's Discretionary Fund investigation in 2002-2003. The VOLT is reliable, compact, immune from



This artist's rendition shows the 3-D laser camera inspecting the Shuttle's protective tiles. Coyle's technology would do the same job, but without moving parts or human oversight.

contamination, and capable of making trillions of laser shots, Coyle said, adding that it's currently under a NASA-sponsored patent application.

The laser's main advantage is that the operator can vary the pulse-width, pulse energy, pulse shape, and pulse repetition frequency "on the fly" and not degrade pointing accuracy or beam quality. No other laser offers these capabilities, he said. Furthermore, the operator can adjust the repetition rate.

With the IRAD funding, Coyle is adding the second dimension to Goddard's scanner, which will give the system the ability to fire laser pulses at different angles to create the multi-dimensional image. He's also repackaging the VOLT with custom electronics to lock together and synchronize the two subsystems.

Coyle expects to demonstrate the system by late summer. ◆

Contact:

Donald.B.Coyle@nasa.gov or 301.614.5859

Detector Sees The Invisible, In Color

QWIP Technology Advances to Next Level

The Quantum Well Infrared Photodetector (QWIP), which was hailed as the world's largest infrared array when it debuted 3 years ago, can now see invisible infrared light in a range of "colors," or wavelengths.

The new QWIP array is the same size as the original at 1 million pixels, but it can now sense infrared between 8 to 12 micrometers, which greatly enhances the array's utility particularly in the area of spectroscopy. The original QWIP array could detect infrared light with a wavelength of between 8.4 and 9.0 micrometers.

"The ability to see a range of infrared wavelengths is an important advance that will greatly increase the potential uses of the QWIP technology," said QWIP Principal Investigator Murzy Jhabvala, who also is leading Goddard's effort to build a microshutter array for the James Webb Space Telescope (see related story below).

A conventional infrared detector has a number of cells or pixels that interact with an incoming particle of infrared light. The cells convert the light to an electric current that can be measured and recorded. The QWIP detector is a Gallium Arsenide (GaAs) semiconductor chip, which has more than 100 layers of detector material placed on top of it. The layers are extremely thin, ranging from 10 to 700 atoms thick, and are designed to act as quantum wells.

This false color image of a Goddard engineer was taken in the far infrared (8-12 micro-meter spectral band) with the 1-megapixel GaAs QWIP camera.

Of particular interest is the thermal handprint left on her lab coat as she removes her hand from her pocket.

Quantum wells employ the bizarre physics of the microscopic world, called quantum mechanics. They trap electrons — the fundamental particles that carry electric current — so that only light with a specific energy can release them. If light with the correct energy hits one of the quantum wells in the array, the released electron flows through a separate chip above the array, called the silicon readout. There, it is recorded. A computer then uses this information to create an image of the infrared source.

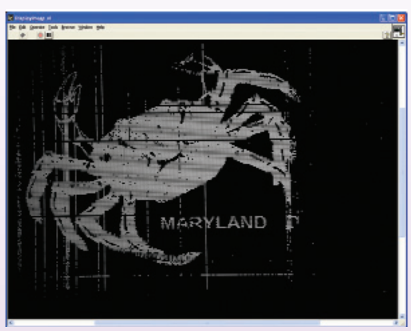
The advance was possible because quantum wells can be designed to detect light with different energy levels. Fabricators achieve this by varying the composition and thickness of the layers. ◆

Contact:

Murzy.D.Jhabvala@nasa.gov or 301 286-5232

Technology Update: Microshutter Array Undergoes Testing

The Goddard-developed microshutter array, a pioneering technology that will give astronomers the ability to produce at least 100 simultaneous spectra of astronomical objects, is undergoing environmental and other rigorous testing that will determine whether the technology can advance to the next stage of development.



The shutters are opened and closed to depict a Chesapeake Bay blue crab.

The array, an enabling technology for the James Webb Space Telescope's Near-Infrared Spectrograph (NIRSpec), is made up of 62,415 tiny shutters precisely aligned on a silicon grid. Through magnetic actuation and electrostatic latching, these shutters — each about the width of a human hair — open or close to allow or prevent starlight from entering the spectrograph. This way, astronomers can gather light from only those objects they want to study.

Since the beginning of the project nearly 6 years ago, the technology has advanced through various levels and is now poised to achieve Technical Readiness Level 6, which means that the team will have demonstrated the prototype in a relevant environment. Relevant in this case means subjecting the arrays to vibration testing and a "life test." During the life test, the shutters are opened and closed 50,000 to 100,000 times under cryogenic temperatures (35 Kelvin or -396˚F). To pass the test, only one shutter in any column can remain open when commanded to close.

Getting to this point has taken patience. To develop one useable array, fabricators must make at least seven and it takes about 3 months to fabricate seven, said Project Lead Murzy Jhabvala. Ultimately, the project will require eight arrays — four for the actual instrument and four for backup. When the arrays pass the testing, Jhabvala said the team would then begin building flight hardware. JWST is slated to fly no earlier than 2013. ◆

CULPRiT... Continued from page 6

ability to correct communications errors when the information is received on the ground. Data can be corrupted by any number of reasons, including space radiation and severe weather. To determine the effectiveness of the chip, code word produced by the CULPRiT Reed-Solomon encoder was compared with that of a standard logic radiation-tolerant Reed-Solomon encoder.

An analysis determined that the CULPRiT encoder performed the same as a standard encoder but used only .5 volts of power — a 100 to 1 reduction in power consumption. "The validation data came back clean. It works perfectly," Yeh said. "This chip in ST-5 is much more powerful in functionality than anything available commercially."

Quest Began 10 Years Ago

The quest to design and build a radiation-tolerant, ultra-low power (ULP) chip began more than 10 years ago when Goddard began funding CAMBR, headed by Gary Maki. Developing a circuit chip that could withstand the effects of space radiation and still be fabricated in a commercial foundry represented the first major breakthrough, Maki said. To take the concept to the next level, Maki's group married the radiation tolerant technology to ULP electronic circuitry to produce CULPRiT, he said, adding he built the technology based on mathematical models developed by Yeh.

"We knew that CULPRiT devices were more efficient than other available flight technologies," said Johnson, referring to the efforts that led up to the successful demonstration. "Maki also showed theoretically that the chip could be radiation tolerant. But he needed more than theory and ground tests." He needed a flight opportunity, which ST-5 afforded.

Although challenges remain, the technology has the potential to significantly reduce electrical power requirements on space missions, Yeh said. For solar energy-

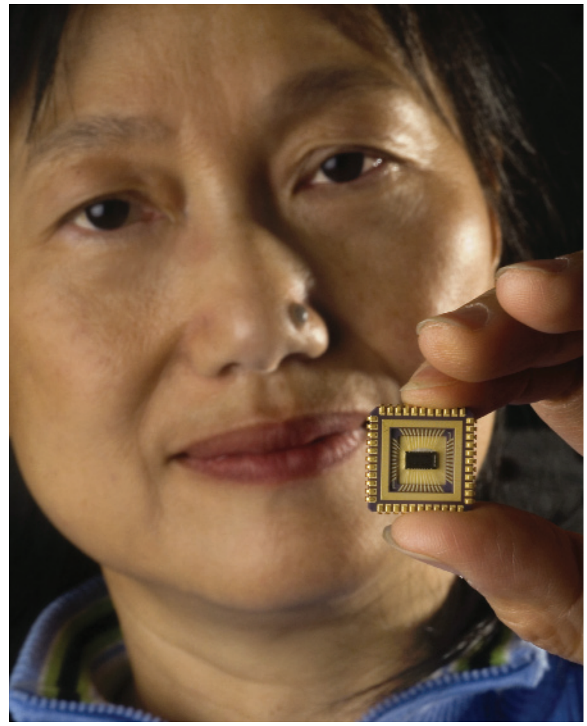


Photo Credit: Chris Gunn

Pen-Shu Yeh created the algorithms used to build the Ultra-Low Power Radiation Tolerant technology.

powered spacecraft, for example, a reduction translates into smaller solar panel, mass, and battery requirements. "Considering the difficulty and the cost associated with developing photo-voltaic technology to increase the efficiency of solar cells by merely a few percentage points, NASA simply cannot afford overlooking the potential payoffs that this technology provides," Maki said.

In addition to supporting the ST-5 encoder development, Goddard also is funding an effort to apply CULPRiT to a Motorola microprocessor in a project called ColdFire. ◆

Contact:

pen-shu.yeh-1@nasa.gov or 301.286.4477

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, 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 Code 502 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 6/06)