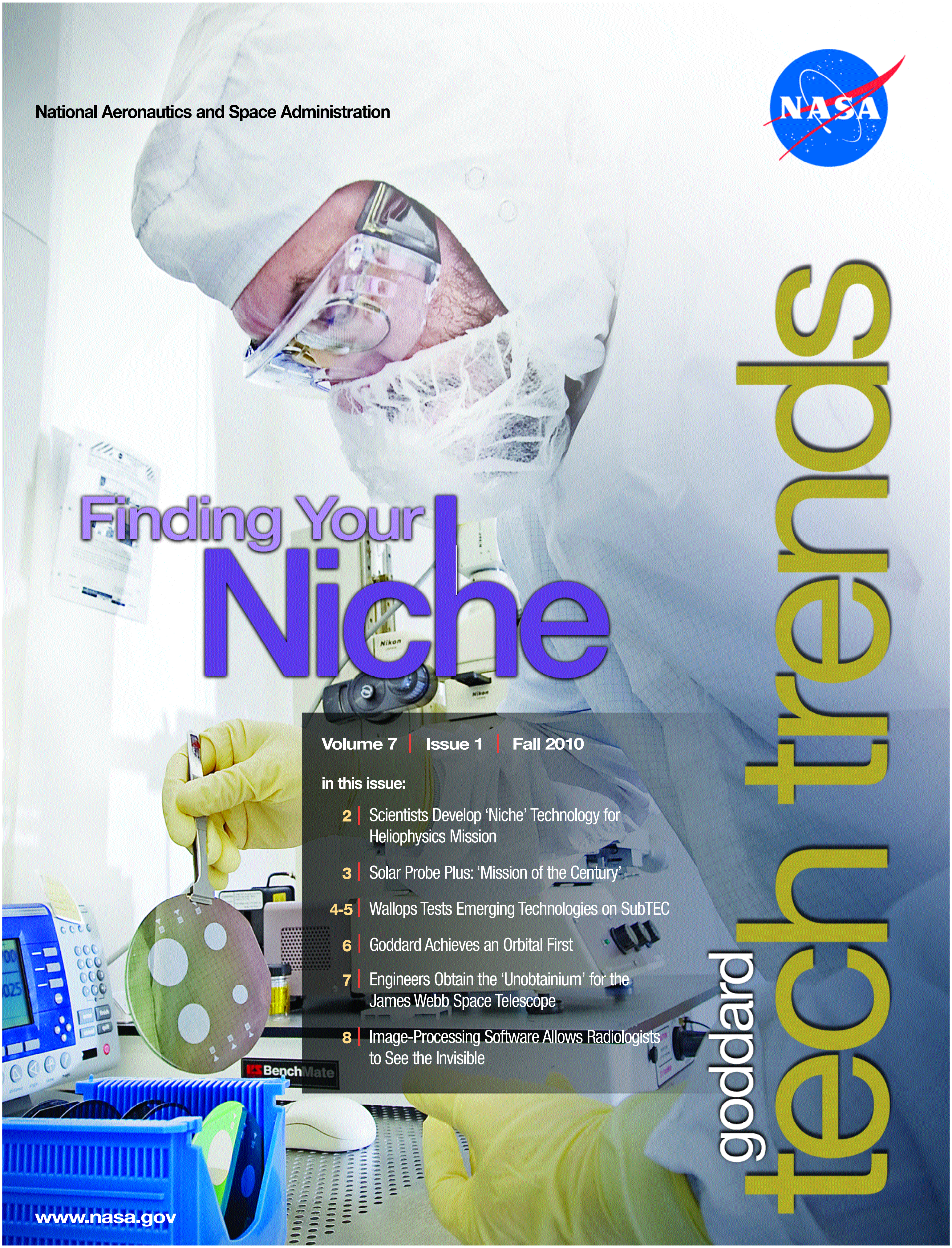
National Aeronautics and Space Administration



goddard tech trends

Finding Your Niche

Volume 7 | Issue 1 | Fall 2010

in this issue:

2 | Scientists Develop 'Niche' Technology for Heliophysics Mission

3 | Solar Probe Plus: 'Mission of the Century'

4-5 | Wallops Tests Emerging Technologies on SubTEC

6 | Goddard Achieves an Orbital First

7 | Engineers Obtain the 'Unobtainium' for the James Webb Space Telescope

8 | Image-Processing Software Allows Radiologists to See the Invisible

www.nasa.gov

Finding Your Niche

Goddard to Provide Unique 'Window' Technology for New Solar Probe Plus Instrument

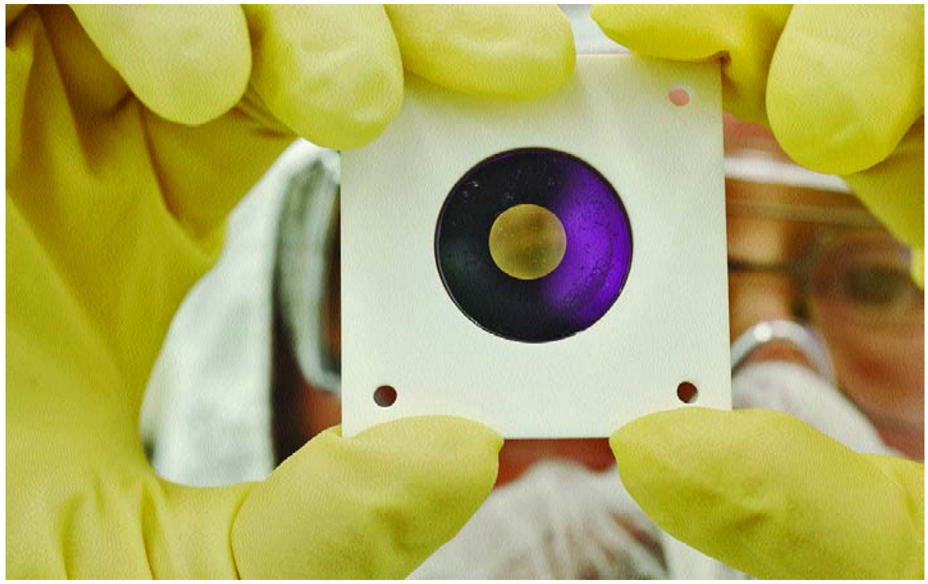


Photo Credit: Chris Gunn

This image shows the new silicon-nitride window that contributed to Goddard winning a prominent role on one of the recently selected Solar Probe Plus instruments. The gold center is the window, which technicians make by etching away silicon from a silicon wafer coated with a thin layer of silicon nitride.

Goddard scientists secured a prominent role on one of the five experiments flying on NASA's ambitious Solar Probe Plus mission by advancing a groundbreaking niche technology that gave them an edge over their competitors, scientists said.

Eric Christian and Tycho von Rosenvinge will be providing windows, mechanical structures, solid-state silicon detectors, and an electronics box for the Energetic Particle Instrument-High (EPI-Hi), one of two instruments flying as part of an experiment successfully proposed by Principal Investigator David McComas of the Southwest Research Institute in San Antonio. The Johns Hopkins University's Applied Physics Laboratory, which also is building the Solar Probe Plus spacecraft and its heat shield, will provide the other instrument, EPI-Lo. Christian will serve as the deputy principal investigator for the EPI instrument suite.

A Competitive Edge

One of the strengths that contributed to EPI-Hi's selection was Goddard's development of ultra-thin windows that instrument developers plan to place in front of a stack of solid-state silicon detectors, whose front detector is only five microns thick, Christian said. Although these thin detectors are robust and can sense particles at lower energies, silicon detectors are prone to stray ultraviolet light and micrometeoroid impacts. To block the contaminants, instrument developers traditionally have placed multiple layers of an opaque window made of aluminized Kapton in front of the first detector.

However, the Kapton windows are twice as thick as the front detector and detract from the detector's overall performance. The quest, then, was to develop an ultra-thin window that would allow particle telescopes to take better advantage of the new thin detectors and therefore cover a larger energy range, Christian said.

Using Goddard Internal Research and Development (IRAD) funding, he and his team created a new window made of silicon nitride that is 10 times thinner than currently available Kapton windows. "With this technology, we will be able to detect twice as many particles," Christian said. "This gave us an edge in a very competitive field. These IRADs certainly helped," he said. With FY 2011 IRAD funding, Christian and von Rosenvinge plan to carry out acoustic tests to make sure the windows can withstand launch loads. The team also will run acoustic tests on the detectors, which are stacked together like a roll of Tums, Christian said.

Continued, Page 3

About the Cover:

Scientist Eric Christian developed ultra-thin windows, which will be used for the first time on the new Solar Probe Plus mission to the Sun. The R&D-funded technology gave Christian and his team a competitive edge in their bid to build one of the mission's instruments. Solar Probe Plus is expected to answer three overarching questions: Why is the Sun's outer atmosphere so much hotter than its visible surface? What propels the solar wind that affects Earth and the solar system? And how are solar energetic particles accelerated to near the speed of light?

Photo Credit: Chris Gunn

Continued from page 2

A Competitive Edge

Using EPI-Hi and EPI-Lo to capture more energetic particles over a broader energy range will help scientists understand the processes that accelerate them to very high velocities — one of the mission's principal objectives (see related story below). Not just an interesting academic question, solar energetic particles, mostly electrons and protons, travel thousands of kilometers per second (tens of millions of miles per hour) and make their presence known across the solar system. On Earth, solar energetic particles can damage satellites and even endanger astronauts' health.

"We really wanted to build the detector technology because it's so groundbreaking," said Adam Szabo, a co-investigator on the Solar Probe Plus mission. "Although Goddard has the lead only on portions of the instrument, we'll actually be deep into all aspects of it partly because of Eric's (Christian) technology."

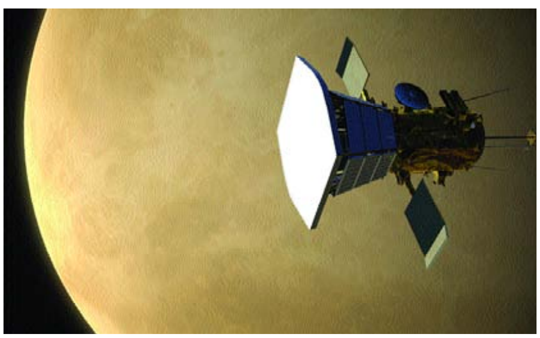
Although the technology benefits heliophysics, its importance isn't limited to studies of the Sun. It has broad application to other space science missions, including a possible mission to Europa, one of the smallest of Jupiter's moons, said John Sigwarth, lead technologist for Goddard's Heliophysics Science Division. NASA is expected to release an Announcement of Opportunity for a Europa mission in January.

"This technology will definitely have applications there," Sigwarth added. "In fact, it is directly applicable to a number of missions coming down the pike."

Contact:

Eric.R.Christian@nasa.gov or 301.286.2919
Tycho.T.Vonrosenvinge@nasa.gov or 301.286.6721

Solar Probe Plus: 'Mission of the Century'



In 2018, the Solar Probe Plus spacecraft will start its plunge directly into the Sun's atmosphere about 6.4 million kilometers (4 million miles) above the star's surface to explore a region no other spacecraft has ever encountered.

By most accounts, the Solar Probe Plus mission is among the most daring NASA has ever attempted — and one that heliophysicists have waited decades to fly. With NASA's recent announcement revealing the five experiments that will fly on the small car-sized spacecraft, the long-awaited mission is that much closer to reality as are answers to three overarching questions: Why is the Sun's outer atmosphere so much hotter than its visible surface? What propels the solar wind that affects Earth and the solar system? And how are solar energetic particles accelerated to near the speed of light?

The answers to these questions are expected to contribute significantly to scientists' ability to characterize and forecast the radiation environment in which human space explorers will live and work. "This is the mission of the century," said Adam Szabo, a Goddard scientist who will serve as co-investigator on several of the mission's instruments. "This has been the dream mission since the 1960s."

To carry out the mission, Solar Probe Plus will swing by Venus on its way to orbit the Sun, where it will fly through the Sun's corona up to 24 times. The probe's first pass will occur three months after launch, at a distance of 24 million kilometers (15 million miles) from the star. Over the next several years, the spacecraft will continue its Venus swingbys to slowly alter the probe's trajectory so that it moves closer to the Sun.

Goddard Plays Significant Role

NASA has tapped several individuals and organizations to provide instruments, components, and scientific leadership. Goddard is well represented, Szabo said.

The Center is managing the development of the spacecraft as well as the all-important carbon-composite heat shield that will protect the spacecraft from the Sun's scorching heat. The Johns Hopkins University's Applied Physics Laboratory is building both, along with one of the instruments. Goddard also is supplying seven science co-investigators — one-third the total science team — on five instruments. Among them are the Fast Ion Analyzer, the Fast Electron Analyzer, the Plasma Wave Instrument, the Energetic Particle Instrument (EPI), and the magnetometer.

Of those instruments, Goddard is either providing the device itself — in particular, the magnetometer based on the groundbreaking designs of Mario Acuna, a Goddard scientist who died in 2009 — or key components, as in the case of EPI (see related story, page 2). "All in all, we did well. We are absolutely, absolutely excited to be a part of this mission," Szabo said.

SPECIAL REPORT

Suborbital Technology Carrier

Wallops Flight Facility's sounding rocket payload canister — the Suborbital Technology Carrier (SubTEC) — tested a new range-safety technology in September and will demonstrate X-band communications and a new microsatellite early next year. In this special report, Goddard Tech Trends examines these technologies and their potential impact on NASA and the scientific community.

Faster Data Rates and Cheaper Access to Space Promised

Two emerging technologies that developers will demonstrate on a Terrier Improved Orion sounding rocket flight early next year may ultimately give researchers what they need most: Faster data rates and less expensive access to space.

Early next year, the Wallops Flight Facility plans to launch its homegrown Suborbital Technology Carrier (SubTEC), the fourth in a series of launches for the payload canister that Wallops engineers developed to help mature emerging technologies faster (*Goddard Tech Trends*, Spring 2006, Page 6).

SubTEC4's primary payload is a high data-rate telemetry system that transmits 384 megabits of data per second using the X-band frequency — a substantially improved rate over the 60 megabits per second now available on the S-band frequency used by sounding rockets. "This is a five- to six-fold increase in the data rate," said Principal Investigator Steven Bundick. "For years, the sounding rocket community has said that it needed higher data rates. With this system, we can meet that need."

A critical component of the system is the Goddard-developed SpaceCube processor, which is equipped with Xilinx Virtex-5 field programmable gate arrays, including two commercially available power PC cores that overcome radiation upsets through software techniques (*Goddard Tech Trends*, Spring 2010, Page 7). Twenty-five times faster than the current state-of-the-art microprocessor, SpaceCube will capture simulated data and transmit it to the ground using an omnidirectional X-band antenna encircling the SubTEC. Data that SpaceCube cannot transmit will be processed and stored onboard at a rate of about one gigabit per second — another capability scientists said they needed to carry out their research.

The demonstration is expected to elevate the system's technology-readiness level to eight, meaning it is operational, said technologist Wayne Powell. Its transition should go smoothly because X-band ground stations already exist at most ranges.

A SMART Way to Fly

The second payload is the Small Rocket/Spacecraft Technology (SMART) platform, created by Goddard technologist Jaime Esper and the Defense Department's Operationally Responsive Space (ORS) Office, which helped fund the platform's development. The platform promises to provide faster, less expensive access to space because of its modular, reconfigurable design that users can adapt to a variety of missions, Esper said.

Comparable in size to an old-fashioned hatbox, the SMART microsatellite can be integrated and readied for launch in as few as seven days for a cost of less than $1 million, Esper said. "We've developed a creative way to reduce mission life-cycle times, with the resulting savings in cost. This enables a new class of researchers who can't afford the high costs of getting into space."

Although Esper is debuting SMART on a suborbital flight, he said his platform is intended for orbital missions, particularly as a freeflyer for planetary missions. To demonstrate that capability, Esper has equipped SMART with three digital video cameras and other equipment serviced by SpaceCube. The microprocessor will process data-heavy video to test high-speed interfaces and monitor the deployment of SubTEC's recovery parachute.

Esper also installed another emerging new technology — an electrohydrodynamic-based thermal control unit developed by Goddard thermal engineer Jeff Didion. "I recognized early that if you want to develop a new type of freeflyer that can travel in different orbits, you have to control the thermal environment," Esper said.

Didion's technology uses electric fields to pump coolant through tiny ducts inside a thermal cold plate. The advantage is that the system requires no moving parts, just electrodes to apply the voltage to move the coolant. Didion now is attempting to further reduce the size of his technology and is investigating ways to take it to the chip level where the ducts would be no larger than 100 microns, or ten-thousands the width of a human hair.

Although Esper's primary objective is demonstrating SMART as a platform for scientific use, he and the Defense Department also want to showcase its capabilities as a platform for testing a space-based range tracking and safety system called the Autonomous Flight Safety System (see related story, page 5).

Contact:

Steven.N.Bundick@nasa.gov or 757.824.1424
Jaime.Esper-1@nasa.gov or 301.286.1124

'Hone' on the Range

Wallops Tests Software to Abort Wayward Rockets

NASA's vision of automating the range and eliminating expensive down-range tracking and command infrastructure to manually abort rockets when they veer off course took a step closer to reality in September.

A Wallops technician puts the finishing touches on the SubTEC-3 payload carrier a few weeks before its launch on a sounding rocket in September. The mission verified new software to autonomously abort wayward rockets.

The Wallops Flight Facility successfully demonstrated the viability of new software that would order a rocket to self-destruct if it swerved off course during launch. The Autonomous Flight Safety System (AFSS) was integrated into hardware that flew on the facility's Suborbital Technology Carrier-3 (SubTEC-3). During the mission, a program sent a simulated signal that the rocket was off course. AFSS acknowledged the signal and then simulated the self-destruct command.

Traditionally, range-safety officials use radar from ground stations to track flight vehicles and ground-based command systems to abort wayward rockets. Due to increasing costs to maintain and staff these systems, NASA created a multi-center engineering effort in 2002 to develop an autonomous system that could migrate flight-safety functions onto the rocket itself. Such a system could replace current systems or could act in parallel with them.

Although Wallops has tested AFSS on two other flights, the launch in September was the first time that the completed software had flown with an inertial measurement unit and GPS receivers.

Technologists also tested another range-safety technology on SubTEC-3 — the Low Cost Telemetry Transceiver (LCT2), which downlinked test data and uplinked commands via the Tracking and Data Relay Satellite System. "Inclusion of LCT2 was a pretty big deal," said Barton Bull, chief engineer of Wallops Research Range. "If AFSS is to be used when the rocket is over the horizon from the launcher, a satellite-based telemetry system will be needed. What we showed is that we could do a handover — launching from a range with radar and command and handing control over to AFSS as the vehicle proceeded over the horizon."

Going into the launch, AFSS had a technology-readiness level of about seven. "With the successful test, we're now ready to turn our attention to readying the software for operational applications," Bull said.

Defense Department to Test Software on SMART

In fact, the Defense Department's Operationally Responsive Space (ORS) Office is planning to test AFSS next year on a sounding rocket flight from White Sands Missile Range. However, it will take the demonstration to the next level by integrating the software onto the Goddard-developed SpaceCube processor and placing the unit inside the Small Rocket/Spacecraft Technology (SMART) platform, also developed by Goddard (see related story, page 4).

SMART is ideal for testing AFSS software because it couples SpaceCube's processing prowess with advanced avionics subsystems, said Goddard technologist Jaime Esper, who teamed with ORS to develop the platform. SMART comes equipped with an inertial measurement unit and a GPS receiver to determine its precise location and velocity at all times during the launch.

With the avionics data, SpaceCube will run the software to analyze whether the rocket has veered off course. If it has, the software will have the ability to initiate an abort command. "All the elements for a space-based range are onboard," Esper said. "This system would effectively free the launch vehicle from human intervention should a problem arise," he added.

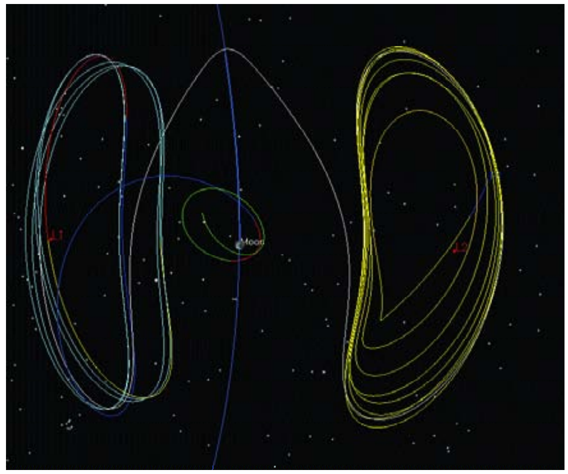
Contact:

James.B.Bull@nasa.gov or 757.824.1893

NASA Achieves an Orbital First

Goddard Engineers Fly Spacecraft in Unusual Lunar Orbit

NASA's decision to repurpose two of five spacecraft originally designed to study auroras in Earth's atmosphere offered a once-in-a lifetime opportunity for Goddard engineers Dave Folta and Mark Woodard. The pair was given a chance to demonstrate for the first time that spacecraft could fly in a unique orbit behind the Moon, but not actually orbit the Moon itself, answering a question that engineers had pondered for half a century.



This image shows the kidney-shaped orbits that two repurposed spacecraft are flying. NASA has never before flown spacecraft at these Earth-Moon libration points.

Working with the Space Sciences Laboratory at the University of California-Berkeley and the Jet Propulsion Laboratory, the Goddard team formulated the orbit design and propulsion maneuvers to send ARTEMIS P1 to Earth-Moon Lagrangian Point 2 (L2), located on the far side of the Moon about 61,300 kilometers (38,100 miles) above the Moon's surface. At the end of October, the team will send a different set of commands to sister spacecraft, ARTEMIS P2, to maneuver that satellite into orbit around the Earth-Moon L1, located between Earth and the Moon.

"In a nutshell, we had this theory but we never had a chance to prove it," Folta said. "No one has ever placed spacecraft at these libration points before."

Kidney-Shaped Orbits

Both distinctive kidney-shaped orbits rely on a precise balancing of the Sun, Earth, and Moon's gravity to allow spacecraft to orbit about a virtual location rather than about a planet or moon. Five Lagrangian points are associated with the Earth-Moon system, but two points nearest the Moon are of particular interest for lunar exploration.

From these locations, NASA will be able to investigate possible regions where it could stage the assembly of telescopes or the human exploration of planets and asteroids. Navigating and controlling the pair of satellites also will supply NASA engineers with important information about propellant usage, required ground station resources, and how to maintain these unique orbits, which are difficult to preserve, Folta said.

The two sister spacecraft, whose name stands for "Acceleration, Reconnection, Turbulence, and Electrodynamics of the Moon's Interaction with the Sun," originally were built for the THEMIS (Time History of Events and Macroscale Interactions during Substorms) mission, which completed its studies of auroras earlier this year.

NASA decided before the mission's conclusion to repurpose two of the five spacecraft to gather additional scientific measurements from a different orbital perspective, giving the Goddard engineers an unprecedented opportunity to navigate in these unusual orbits.

"Maneuvering the two ARTEMIS spacecraft from their original orbits into the lunar Lagrangian orbits was very challenging, but we had an excellent team in place," Woodard said. "The JPL engineers had to design low-energy transfer trajectories using what little propellant was left in the tanks. On paper the design was feasible, but implementing that design took many long hours and lots of analysis to get it just right."

For three months, the two spacecraft will take magnetospheric observations from opposite sides of the Moon. ARTEMIS-P1 then will move to the L1 side, where both will remain in orbit for an additional three months. In particular, the two will provide simultaneous measurements of particles and electric and magnetic fields to produce the first three-dimensional perspective of how energetic particles accelerate near the Moon's orbit, in the distant magnetosphere, and in the solar wind.

The refocused ARTEMIS spacecraft also will collect unprecedented observations of the space environment behind the dark side of the Moon — home to the greatest known vacuum in the solar system. In late March, the Space Sciences Laboratory will send commands maneuvering both spacecraft into elliptical lunar orbits where they will continue to observe magnetospheric dynamics, solar wind, and the space environment over several years.

"The point of this is science and extending the useful life of spacecraft, but at the same time we were able to validate theoretical work that had been done over the past 50 years," Folta said. "I'm hopeful that NASA can use the ARTEMIS paradigm to find creative ways to extend the useful lives of its other space assets," Woodard added.

Contact:

David.C.Folta@nasa.gov or 301.286.6082
Mark.A.Woodard@nasa.gov or 301.286.9611

Obtaining the 'Unobtainium'

Engineers Develop Never-Before-Manufactured Material for Webb Observatory

Imagine building a car chassis without a blueprint or even a list of recommended construction materials.

In a sense, that's what a team of Goddard engineers did when they created the one-of-a-kind Integrated Science Instrument Module (ISIM). Just as a chassis supports the engine and other components in a car, the ISIM will hold four highly sensitive instruments, electronics, and other shared instrument systems flying on the James Webb Space Telescope, NASA's next flagship observatory.


Photo Credit: Chris Gunn

A team of Goddard engineers developed the one-of-a-kind Integrated Science Instrument Module to withstand the super-frigid temperatures it would encounter in space.

From scratch — without past experience to guide them — the engineers designed the ISIM, constructing it of a never-before-manufactured composite material. They then proved through testing that the ISIM could withstand the super-cold temperatures it would encounter when the observatory reached its orbit 1.5-million kilometers (930,000 miles) from Earth. In fact, the ISIM survived temperatures that plunged as low as 27 Kelvin (-411 degrees Fahrenheit), colder than the surface of Pluto, where rubber behaves like glass.

"It is the first large, bonded composite spacecraft structure to be exposed to such a severe environment," said Jim Pontius, ISIM lead mechanical engineer.

The 26-day test culminated years of development, design, analysis, and fabrication and specifically was carried out to test whether the car-sized, 900-kilogram (nearly 2,000-pound) structure contracted and distorted as predicted when it cooled from room temperature to the frigid — very important since the science instruments must maintain a specific location on the structure to receive light gathered by the telescope's 6.5-meter (21.3-feet) primary mirror. If the structure had shrunk due to the cold, the instruments no longer would be in position to gather data about everything from the first luminous glows following the big bang to the formation of star systems capable of supporting life.

Despite repeated cycles of testing inside Goddard's Space Environment Simulator, the truss-like assembly did not crack. It did not shrink — at least by much. In fact, the structure had shrunk only 170 microns — the width of a needle — when it reached 27 Kelvin (-411 degrees Fahrenheit), far exceeding the design requirement of about 500 microns. "We certainly wouldn't have been able to realign the instruments on orbit if the structure moved too much," said ISIM Structure Project Manager Eric Johnson. "That's why we needed to make sure we had designed the right structure."

Obtaining the 'Unobtainium'

Achieving the milestone was just one of many firsts for the Goddard team. One of the first challenges the team tackled was identifying a structural material that would assure the instruments' precise cryogenic alignment and stability, yet survive more than six-and-a-half times the force of gravity experienced during launch.

An exhaustive search in the technical literature for a possible candidate material yielded nothing, leaving the team only one alternative — developing its own as-yet-to-be-manufactured material, which team members jokingly referred to as "unobtainium." Through mathematical modeling, the team discovered that by combining two composite materials — T300 and M55J — it could create a carbon fiber/cyanate-ester resin system that would be ideal for fabricating the structure's square tubes that measure 75 millimeters (3 inches) in diameter.

Through modeling, the team also found it could bond the pieces together using a combination of nickel-alloy fittings, clips, and specially shaped composite plates joined with a novel adhesive process — a difficult engineering challenge because different materials react differently to changes in temperature.

"It passed with flying colors," Pontius said, referring to the negligible shrinkage. With the critical milestone test behind them, team members say their work likely will serve NASA in the future. Missions, such as a next-generation planet finder, for example, also would have to operate in deep space, and therefore would have to be tested under extreme cryogenic conditions. "This test was a huge success for us," Pontius said.

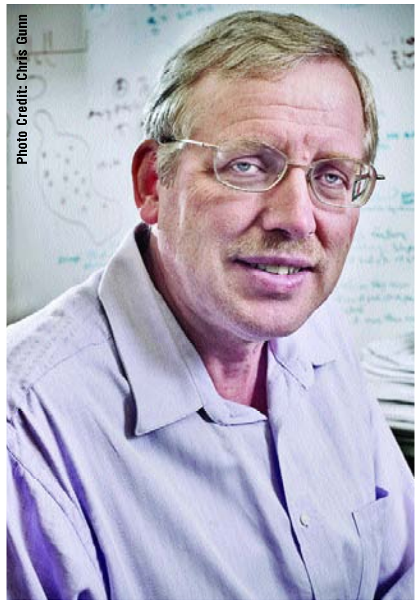
Contact:

James.T.Pontius@nasa.gov or 301.286.2238

NASA Makes the Invisible Visible in Medical Imaging

A technology that Goddard computer engineer James Tilton originally conceived for analyzing remote-sensing imagery could one day aid in the interpretation of mammograms, ultrasounds, and other medical imaging.

A Connecticut-based company, Bartron Medical Imaging, Inc., adapted Tilton's advanced computer algorithm — Recursive Hierarchical Segmentation Software (RHSEG) — for use in its MED-SEG™ system. The Food and Drug Administration (FDA) recently cleared the system for use by radiologists to process images for reports and communications. However, FDA has not yet cleared it as a primary diagnostic tool. Clinical trials are expected to begin shortly. "The use of this computer-based technology could minimize human error that occurs when evaluating radiologic films and might allow for earlier detection of abnormalities within the tissues being imaged," said Thomas Rutherford, director of gynecologic oncology at Yale University.



James Tilton never dreamed that a special algorithm he created could possibly assist in medical diagnoses.

Tilton began working on his algorithm more than 25 years ago. His goal was to advance a totally new approach for analyzing digital images, which are made up of thousands of pixels. Like a single piece of a jigsaw puzzle, a pixel often does not provide enough information about where it fits into the overall scene. To overcome the deficiency, Tilton focused on an approach called image segmentation, which organizes and groups an image's pixels together at different levels of detail.

For example, a remote-sensing image may contain several lakes of different depths. Deep lakes appear dark blue, while shallow lakes are a lighter shade of blue. RHSEG first finds each individual lake; then it groups together all shallow lakes into one class and the deeper lakes into another. Because lakes are more similar to each other than they are to trees, grass, roads, buildings, and other objects, the software then groups all lakes together, regardless of their varying colors. As a result, RHSEG allows the user to distinguish important features in the scene accurately and quickly.

Since Tilton developed the algorithm, scientists have used it to improve the accuracy of snow and ice maps produced from data gathered by NASA's Landsat and Terra spacecraft. Scientists also have used it to find potential archeological sites, the premise being that vegetation covering an abandoned human settlement would look different than surrounding flora.

"My concept was geared to Earth science," Tilton said. "I never thought it would be used for medical imaging." In fact, he initially was skeptical; that is, until he processed cell images and saw details not visible in unprocessed images. "The cell features stood out clearly and made me realize that Bartron was onto to something."

Bartron learned of the patented software through Goddard's Innovative Partnerships Program Office, and in 2003 licensed it to create a system that would differentiate hard-to-see details in complex medical images. Through a NASA agreement, Tilton also worked with the company to develop, test, and document a new three-dimensional version of RHSEG that Bartron plans to incorporate into a next-generation product.

Tilton, meanwhile, said he'll remain focused on applying his technology to other Earth science-related applications and has used Goddard R&D funding to achieve that end. "The main point was and is to help us understand Earth imagery, but knowing that it may help people receive improved health care is very exciting."

Contact:

James.C.Tilton@nasa.gov or 301.286.9510

Goddard Tech Trends

Goddard Tech Trends is published quarterly by the Office of the Chief Technologist at the Goddard Space Flight Center in Greenbelt, Md. The newsletter describes technology developments at Goddard and explains how they are helping NASA to achieve its missions. If you want more information about Goddard technology, contact Chief Technologist Peter Hughes. If you wish to be placed on the newsletter distribution list, contact the editor. NP-2007-10-853-GSFC (revised 10/10)

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

Lori J. Keesey
Editor
301.258.0192
ljkeesey@comcast.net