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Goddard Tech Trends

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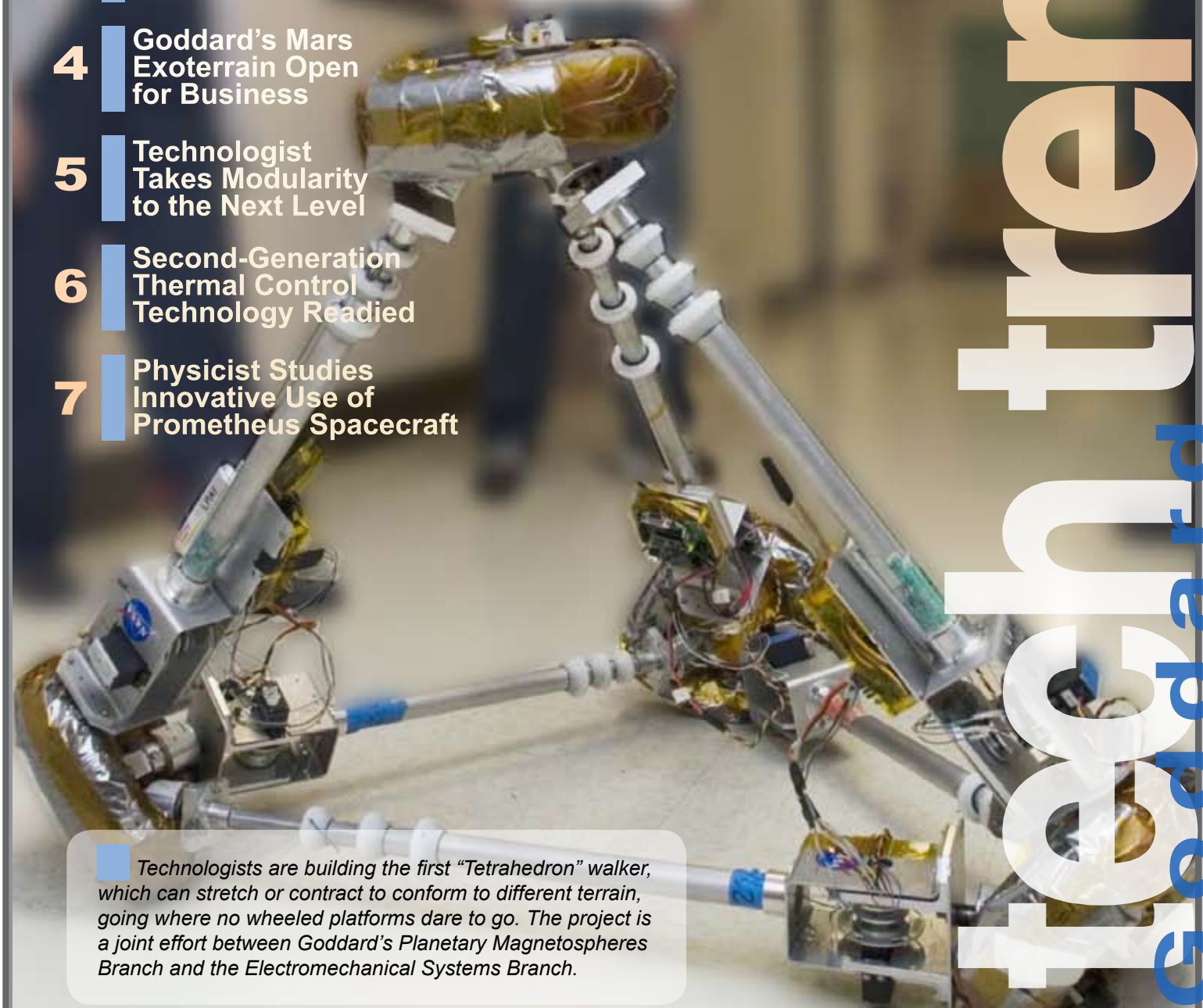
Goddard



Technologists are building the first "Tetrahedron" walker, which can stretch or contract to conform to different terrain, going where no wheeled platforms dare to go. The project is a joint effort between Goddard's Planetary Magnetospheres Branch and the Electromechanical Systems Branch.

http://www.nasa.gov

Goddard to Restore Robotics Capability

Goddard technologists have developed a plan to restore the Center's competency and organization in the burgeoning field of robotics, focusing in specific areas that would benefit NASA's Vision for Space Exploration and science applications.

The thrust for Goddard will be in technologies that allow robots to interact more safely with one another and with humans, particularly where neither has complete control over the environment — often referred to as an "unstructured environment," said Ted Swanson, assistant chief for technology in the Mechanical Systems Division, and a member of the Robotics Formuation Team that developed the plan. This effort is distinct from the possible robotic development work by the Hubble servicing mission, he added.

"There's clearly a role for us that's complementary to what Johnson Space Center and the Jet Propulsion Lab are doing," Swanson said. "We have to be aggressively moving in that direction."

Goddard employees organized the Robotics Formulation Team in November 2004 to reinvigorate robotics research at Goddard. Goddard abandoned robotics research about 15 years ago when NASA Headquarters decided that the work did not directly benefit Goddard missions. However, the Center has carved out a leadership role in the area of on-orbit repair and maintenance primarily because of its work with the Hubble Space Telescope.

Four Specialty Areas Pursued

The plan is to use that expertise and expand into four areas — in-space assembly of large telescopes and instruments; in-space servicing, maintenance, and repair of science satellites (similar to work done under the Hubble program); in-space assembly and docking of large space structures; and in-space and extraterrestrial assembly and operation of equipment and experiments for scientific testing, in-situ resource exploration and use, and possibly operation of nuclear power sources.

To carry out these activities, the Center will have to develop specialized technologies that allow robots to work with one another and with humans in situations where both must react to the unexpected — unlike on assembly lines, for example, where the robot is programmed to carry out a specific task under set conditions.

Other technology goals include developing advanced animation and simulation capabilities, robotic tools and end-effectors, highly adaptive thermal control, vision systems, contact dynamic analysis, and high-performance signal processing and data handling. Goddard also hopes to enhance system modularity

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Robotics Projects Receiving Research Funding

The following robotics projects received research funding under the Internal Research and Development (IRAD) program and the Director's Discretionary Fund (DDF) in FY 2005:

IRAD

- In-space Robotic Integration System (IRIS), Principal Investigator Yury Flom, Code 541
- Reconfigurable Tetrahedral-based Robotic System, Principal Investigator Steven Curtis, Code 695
- Development of a Novel Six Degree-of-Freedom (DOF) High-Precision Alignment Robot, Principal Investigator Farhad Tahmasebi, Code 544
- Tactile Tele-Sensing, Principal Investigator Kate Hale, Code 544, and Ryan Boller, Code 587
- Conformal Gripping Systems, Principal Investigator John M. Vranish, Code 544
- Intelligent, Optimized Thermal Control for Robotic Systems, Principal Investigator Jeffrey Didion, Code 545

DDF

- Virtual Feel Robotic Assembly, Principal Investigator John Vranish, Code 544
- Development of a Novel High-Precision Three DOF Tip-Tilt-Piston Alignment Robot, Principal Investigator Farhad Tahmasebi, Code 544

through its revitalized robotics technology-development efforts.

The effort looks promising, Swanson said. In fiscal 2005, six robotics projects are being funded through the Internal Research and Development program and two under the Director's Discretionary Fund. Altogether, Goddard has invested about $2.5 million in this research. In addition, the Robotics Formulation Team has identified several potential partners and plans to begin discussions with the science missions to determine whether any could be enhanced through advanced robotics.

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High-Tech Skin

Goddard Technologist Proposes Sensitive Skin Covering for Robots

The video shows a ballerina gracefully moving across a small stage. She is followed not by a male partner, but by a robotic arm that seems to sense her every move. For Goddard technologist Vladimir Lumelsky, the performance captures the future of robotics and demonstrates an advanced technology that he hopes to develop as part of the Goddard Space Flight Center's push to restore specific robotics capabilities on campus.

Future skin prototypes, such as the sample shown in this image, likely will have an even higher density of sensors on the skin, providing robots with greater dexterity.

Lumelsky, until recently a professor at the University of Wisconsin-Madison, has begun setting up at Goddard a laboratory to develop a high-tech covering that would enable robots to sense their environment and react to it, much like humans respond when something or someone touches their skin. Such a technology is essential for carrying out the Vision for Space Exploration because the Vision depends heavily on humans and robots working together under a variety of working conditions, many of them highly unstructured, Lumelsky said.

"Robots move well on their own, especially when nothing is in the way," Lumelsky explained. However, they can't react, and "that's got to change for exploration."

Touch Sensing Remains Key

Although progress is being made in the area of computer vision, vision isn't enough, he said. "Humans can survive without sight, but they can't survive without tactile sensing. The skin is the biggest organ in our body. It's nothing more than a huge sensor."

The idea is to develop a "sensitive skin" that technicians could use to cover a robot. This skin will include more than 1,000 infrared sensors that would sense an object by reflecting the light from the object to the sensor detectors, which would pass along the information to the robot's "brain." The brain would digest the information, apply spatial-reasoning strategies, and react within milliseconds by directing the robot to move. Future skin prototypes will likely have an even higher density of sensors on the skin, providing robots with greater dexterity.

The flexible plastic modules that will house the skin's electronics will have to undergo rigorous testing to assure that they're space qualified and able to withstand radiation and extreme changes in light and temperature. In addition, embedding the electronics on a large surface material, or printing the skin like wallpaper, presents another major hurdle, Lumelsky said. Work also is needed in the area of motion-planning algorithm development and intelligence, he added.

Since moving to Goddard, Lumelsky said he's begun identifying resources needed to create his laboratory. In addition, he plans to seek Goddard technology-development funding next fiscal year.

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The sensitive skin was identified as one of the key niche technologies that Goddard wants to develop as part of its effort to restore a robotics capability at the Center (see related story, page 2). It would prove vital in situations where humans and robots work side-by-side in the construction of large telescopes and in the operation of both in-space and extraterrestrial equipment.

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Goddard's Mars Exoterrain Open for Business

Near the picnic tables in the courtyard of the Goddard Space Flight Center's Building 23 is a 30-foot by 40-foot area that only can be described as otherworldly. With its variegated, crater-pocked terrain, this small spot looks a lot like the photos taken of Earth's third closest neighbor — Mars.

That's precisely what the developers of the Multipurpose Exoterrain for Robotic Studies (MERS) were trying to accomplish when they created the facility using Director's Discretionary Fund money last year. The semi-realistic environment was conceived as a testbed so that researchers could demonstrate advanced software control concepts for robotic missions, including optimal path planning and autonomous fleet management, among other things.

Along with the terrain, researchers are allowed to use the facility's three Personal Exploration Rovers (PERS) built by Carnegie Mellon University and a robot locator system for up to 10 robots.

"The purpose of the Building 23 courtyard facility is to provide an environment for Goddard researchers and partners to perform testing relative to surface exploration of the Moon, Mars, and beyond," said Julie Loftis, assistant chief for technology for Goddard's Information Systems Division (ISD), which developed the testbed. "We built MERS so that we would have a local facility to validate Goddard-unique scientific and engineering concepts. We also want to encourage local researchers from industry and academia to use our facility, and partner with us in meeting NASA's exploration challenges."

Two Technologies to Undergo Testing this Summer

This summer, researchers will use the facility to test two different technologies.

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Researchers who want to test advanced software control concepts for robotic missions may now do so at Goddard's recently completed Multipurpose Exoterrain for Robotic Studies (MERS) in the courtyard of Building 23. Researchers also may use the facility's Personal Exploration Rovers, like the one pictured here..

One is Goddard's Adaptive Sensor Fleet (ASF) technology, which ISD technologists originally developed for oceangoing research platforms (see *Goddard Tech Trends*, Winter 2005 at http://gsfctechnology.gsfc.nasa.gov/newsletter/). Technologists have modified the technology for use with the rovers.

With this computer software system, scientists can identify their scientific targets and the system's "fleet manager" divides the work and directs each rover or ocean platform to the target depending its location, obstacles, and the location of other rovers. ASF then displays on a computer screen the progress of each rover or platform as well as the cumulative scientific data. The idea behind ASF is to improve the in-situ data-collection process.

The other prototype subsystems to be tested include vision-navigation guidance and control technology, a boundary-tracking sensor, and a robotic arm.

These technologies are being developed for the Robotic Explorer for Antarctic and Lunar Applications (REAL) project, directed by Mike Comberiate of the Flight Programs and Projects Directorate. REAL is testing new technologies that could be used for planetary surface exploration. The aim is to develop semi-autonomous robotic mechanisms that would allow scientists to do research in hostile and remote environments unattended, yet monitored and controlled by way of Internet-like communications.

The MERS facility is available to NASA, university, and industry researchers. For more information, go to http://mers.gsfc.nasa.gov.

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Technologist Takes Modularity to the Next Level

Engineer Investigates Modular, Adaptive, Reconfigurable Systems

Modular spacecraft aren't new to NASA. In the 1970s, engineers created the Multi-mission Modular Spacecraft (MMS), an engineering concept that resulted in six Goddard-led missions between 1980 and 1992. Now, a Goddard aerospace systems engineer would like to take the concept to the next level and bring about a revolution in the way NASA builds and carries out its missions.

"Everyone thinks that NASA does everything on a grand level," said Jaime Esper, a senior engineer with Goddard's Systems Engineering Services and Advanced Concepts Branch. "The fact is we're trying to simplify systems and build spacecraft and systems not unlike the way you build cars. We need to streamline the process and stop building one-of-kind spacecraft and space systems."

He believes the answer may lie with Modular, Adaptive, Reconfigurable Systems (MARS) — an engineering architectural concept that he began studying 2 years ago.

The Key is Modularity

The key, Esper said, is modularity. Under MARS, mechanical, electrical, and software components would accept "plug and play" standard interfaces, similar to what's available with personal computers (an electrical/software interface analogy). These modular components or systems could offer varying levels of integration, from the chip to card, box, subsystem, system, and system of systems. In effect, they could function by themselves or as part of sophisticated integrated systems, and would be capable of evolving to accommodate new technological advancements.

The second characteristic is its adaptability. An adaptive MARS system would be capable of learning from its environment and reconfiguring its mechanical, electrical or software characteristics to meet changing requirements.

And the third characteristic is its ability to morph into different configurations to meet different missions. It must be easy to produce, integrate, test, and launch, and it must be capable of operating alone or as a collective part, physically detached or attached, Esper said.

Similar to Lego Building Blocks

Esper compares MARS-compatible modules to Lego building blocks. Astronauts living on the Moon, for

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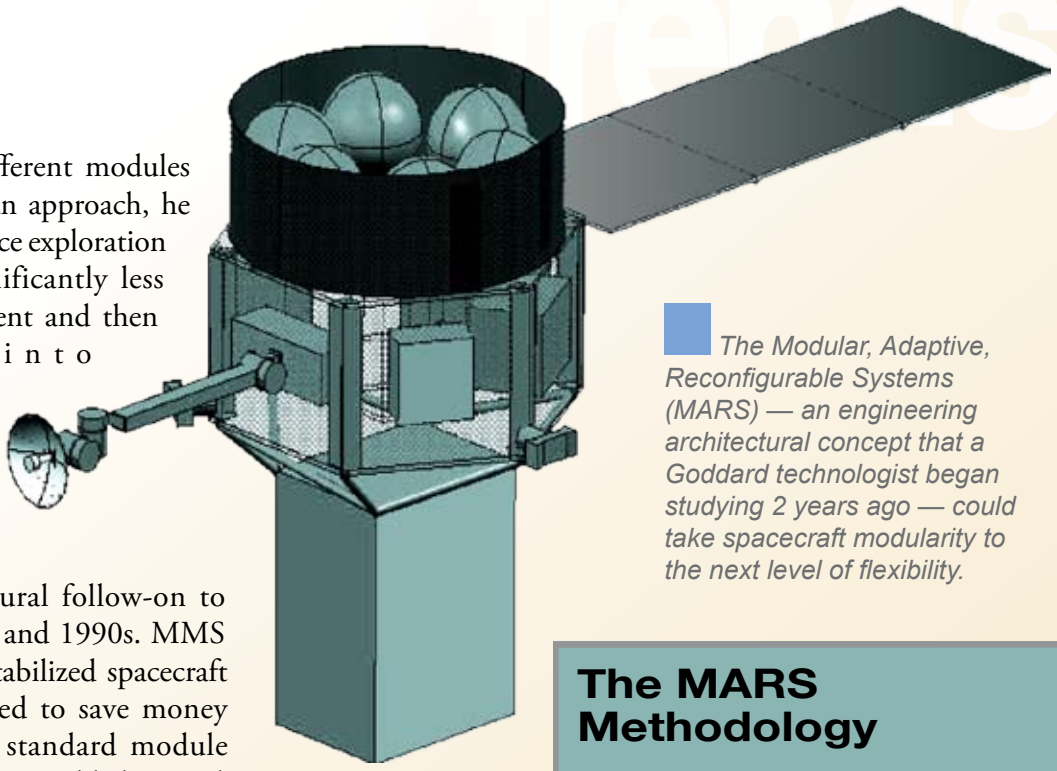
example, could connect different modules to do different jobs. Such an approach, he said, would revolutionize space exploration because it would cost significantly less to uniquely design equipment and then transport that equipment into space. The MARS architecture enables technology that can by its nature be reconfigured in the field.



The Modular, Adaptive, Reconfigurable Systems (MARS) — an engineering architectural concept that a Goddard technologist began studying 2 years ago — could take spacecraft modularity to the next level of flexibility.

Esper said MARS is a natural follow-on to NASA's MMS in the 1980s and 1990s. MMS was a standard, three-axis stabilized spacecraft bus. Mission planners hoped to save money through maximum use of standard module or box components that they could then replace within a structure.

Over the past 35 years, technology has advanced considerably, and now modularity can extend beyond the traditional MMS module or box to cover levels of integration, with application to the chip, card, box, subsystem, to the space system and system of systems.

Since beginning his work, Esper said the concept has attracted the interest of the NASA Exploration Systems Directorate as well as the Air Force Research Laboratory. With limited funding received under an Internal Research and Development award, he's now collecting hardware and other equipment to build a facility where he and his team can test interface standards.

"This is what will bring space home. This is what will bring exploration to reality. One-of-a-kind systems will never be affordable enough to industrialize space, nor will they bring sustainability to the exploration table," he said.

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The MARS Methodology

What makes a MARS-compatible mission? Although different standards are expected as new technology evolves, the following are a few broad principles MARS missions would follow:

- MARS spacecraft and systems should take advantage of commercial manufacturing, computing, and communications technology standards.
- The modular design must allow for technological evolution.
- Standardization is implemented at the interface, not at the subsystem or system level.
- The system should use commercial, open code operating systems.
- The flight software should be based on a layered architecture, with maximum reuse of infrastructure and application modules.
- Communication and information should be distributed through Internet-based operations.

Second-Generation Thermal Control Technology Readied

Goddard Technologists Chosen to Develop ST-8 Experiment

After becoming one of only four winners in a competition to provide a flight experiment for a New Millennium Program mission earlier this

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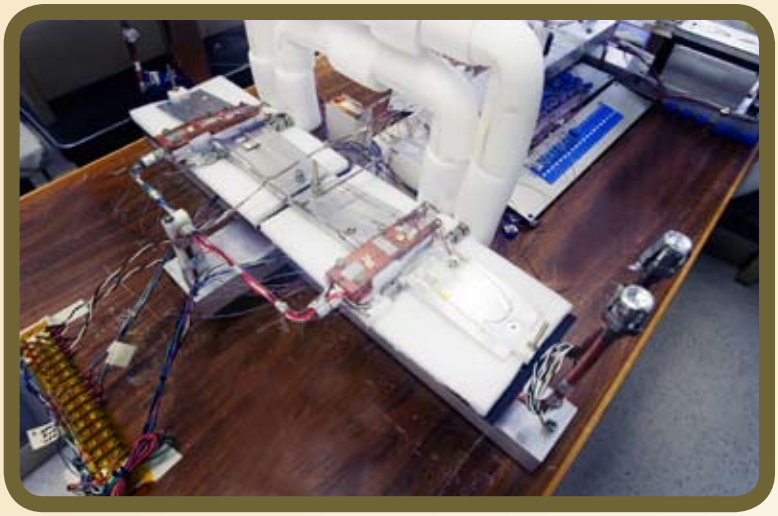
year, a Goddard team has completed the concept design and is preparing to demonstrate its next-generation, two-phase thermal control system during testing early next year.

The experiment, "Miniature Loop Heat Pipe (MLHP) Thermal Management System," is expected to undergo breadboard thermal vacuum testing in early 2006 in preparation for qualification and acceptance tests in late



This breadboard design of the Miniature Loop Heat Pipe Thermal Management System will be tested in early 2006. The technology is one of four technologies selected as part of the New Millennium Program's Space Technology 8 Mission.

2007. Ultimately, the technology, along with three others, will fly as a secondary payload aboard a Delta-II rocket in late 2008 as part of the New Millennium Program's Space Technology 8 (ST-8) mission.

Principal Investigator Jentung Ku who works for Goddard's Thermal Engineering Branch, was the only NASA investigator to be selected in the competition.

The $10 million project, which Ku is developing with support from Swales Aerospace, will demonstrate the transport of large heat loads over long distances without external pumping devices. Key elements in the system include a loop heat pipe with multiple evaporators and condensers, thermal electrical coolers for start-up and saturation temperature control, and deployable radiators layered with variable-emittance coatings.

As designed, the loop heat pipe collects heat generated within a satellite and transmits the heat to radiators, which dissipate the heat into space. Mission designers can place the deployable radiators in different locations on the spacecraft surface, and the variable-emittance coatings can adjust the amount of heat that the radiator emits to maintain a specific temperature. The system can simultaneously cool the instruments that are turned on and heat the ones that are turned off without using auxiliary electrical heaters.

The technology will reduce mass, volume, and power, and simplify integration and testing. It's ideal for small, Earth-sensing satellites, interplanetary spacecraft, and Mars surface rovers, said Laura Ottenstein, project manager.

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Physicist Studies Innovative Use of Prometheus Spacecraft

Scientists believe that asteroids — sometimes referred to as minor planets — are the remnants of the solar system's formation more than 4 billion years ago. Although they number in the thousands, principally in the main asteroid belt between Mars and Jupiter, scientists know little about these objects.

Applied Physicist Sam Floyd and his team from Goddard's Astrochemistry Branch believe they could dramatically enhance their understanding of the solar system and any resources or risks that these objects could present by developing a new instrument that takes advantage of the technological capabilities provided by NASA's Prometheus Program.

NASA established Prometheus in 2003 to develop technology and conduct advanced studies in the areas of radioisotope power system and nuclear power and propulsion for the peaceful exploration of the solar system. The program's goal is to develop the first reactor-powered spacecraft and demonstrate that it can operate safely and reliably in deep space during long-duration missions.

Under Floyd's concept, the neutrons generated by the spacecraft's nuclear reactor would be used the same way that they're used in research reactors on Earth. At research reactors on Earth, scientists use some of surplus neutrons to perform a very powerful analytical

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Project Prometheus
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process called Prompt Gamma ray Activation Analysis (PGAA). The idea behind PGAA is to bleed off neutrons from the neutron-rich core into a long collimating beam line.

The material to be sampled is placed in the beam and the resulting characteristic gamma rays, produced by neutron capture, are analyzed to determine the sample's elemental abundance. Performing PGAA in a similar manner using a Prometheus-type spacecraft reactor is technically possible, Floyd said.

Goddard physicists believe they could dramatically enhance their understanding of the solar system and any resourc es or risks that asteroids could present by developing a new instrument that takes advantage of the technological capabilities provided by NASA's Prometheus Program.

Researchers Develop Chiron Concept

Floyd's team, which includes John Keller and Jason Dworkin, also from Goddard, and David Mildner, who works for the National Institute of Standards and Technology (NIST), have developed a conceptual design for a PGAA instrument that could go onboard a reactor-powered spacecraft flying in formation about 2 kilometers above an asteroid's surface. The instrument, which Floyd named Chiron after the mythical Greek centaur that liberated Prometheus from his bounds atop the Caucasus Mountains, is ideal for missions to near-Earth asteroids, main belt asteroids, comets, and Kuiper Belt objects. Small moons, such Phobos and Deimos, also represent possible targets, he added.

With financial support from the Director's Discretionary Fund in 2004, tests are continuing at NIST's research reactor. Computer modeling of an asteroid mission also is occurring at the University of Maryland. The empirical data and modeling results will determine how much signal scientists could expect from such an experiment. Chiron has attracted much interest and the National Academy of Science, Standing Committee on Planetary and Lunar Exploration. It highlighted Chiron as an innovative Prometheus-enabled idea.

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