National Aeronautics and Space Administration

Goddard Tech Trends

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tech trends

On The Cover:

A Goddard technician examines a thin, curved mirror before coating it. See story on page 2.

Photo Credit: Chris Gunn

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Goddard's Investment in Technology Pays Dividends

Results from a recent survey conducted by the Goddard Technology Management Office (GTMO) confirmed that Goddard's technology-investment programs are making a significant impact on the amount and value of new business coming into the Center.

In August, the Goddard New Opportunities Office reported the award in FY05 of 26 new proposals, valued at about $234 million. Sixty-five percent of the winners attributed their success to having previously received Goddard technology-development funding, which they used to advance key technologies and capabilities necessary for capturing the new business, according to the survey. The corresponding contracts are valued at $176 million or 75 percent of the total of new business.

After the New Opportunities Office released its report, GTMO conducted its informal survey and found that Goddard principal investigators had won at least an additional $11.5 million in new business. That would bring the total of new business attributable to prior technology investments to about $187.5 million in FY05.

> "...Our results validate what we long believed – we are seeing strong returns on our technology-investment programs."

GTMO conducted the informal survey in October to assess the impact of the Center's technology-investment programs on new business wins. In addition to contacting the FY05 new contract winners, GTMO sent survey questions to past winners of its Internal Research and Development (IRAD) program, which Goddard created in the late 1990s to help make the Center more competitive. Of the 88 principal investigators contacted, 46 responded.

"Because not everyone participated in our informal survey, it's possible that Goddard's IRAD, Core Capabilities, and Bid and Proposal funding played an even greater role in the award of new business," said Goddard Acting Chief Technologist Peter Hughes, who manages IRAD and oversees Goddard's other investment programs. "Even so, our results validate what we long believed — we are seeing strong returns on our technology-investment programs."

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The Secret's in the Sauce

Scientist Develops Technique to Manufacture Super-Thin Curved Mirrors

Although some thought it couldn't be done, a Goddard scientist has invented a technique to mold lightweight commercially available glass into high-quality mirrors capable of focusing X-rays and satisfying the demanding technical specifications of NASA's next-generation Constellation-X.

From a laboratory in Building 22, astrophysicist Will Zhang and two technicians are producing several mirrors a week in an effort to fine-tune a technique that Zhang hopes a private company will eventually use to mass produce the estimated 16,000 mirror pieces needed for Constellation-X, NASA's next-generation X-ray observatory slated for launch in 2018 (see related story, page 3).

Like many X-ray telescopes, Constellation-X will use a Wolter Type I mirror design, distinguished by its nested mirrors that are curved so that highly energetic X-ray photons graze their surface, instead of passing through them — much like a stone skimming the surface of a pond. In particular, Constellation-X's mirror will include four mirror assemblies, each containing 230 nested shells for a total of 16,000 mirror pieces. The nested configuration increases the mirror collection area, and therefore the telescope's sensitivity.

What stands out is the size of the actual mirrors. In contrast to the mirrors on the Chandra X-Ray Observatory,

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Photo Credit: Chris Gunn

To produce curved mirrors, Goddard contractors Marton Sharpe (front) and Jim Mazzarella place a sheet of very thin glass on top of the mandrel and place the assembly into an oven. The heat softens the glass so that it takes the shape of mandrel.

Curved Mirrors... Continued from page 2

Photo Credit: Chris Gunn

In contrast to the X-ray mirrors on the Chandra X-Ray Observatory, which are an inch thick, these Goddard-developed curved mirrors are only 400 microns thick. Contractor Jim Mazzarella lifts the glass from a mandrel he uses for cutting.

which are an inch thick, the mirrors specified for Constellation-X are only 400 microns thick. This "terrifically thin" mirror, however, cannot be shaped, polished and ground under traditional manufacturing practices.

Zhang's technique offers a solution. In his laboratory, he uses flat sheets of smooth, lightweight glass measuring about 400 microns in thickness and places them on a mandrel or rounded mold that provides the exact optical prescription for Constellation-X's mirrors. He then places the entire assembly inside an oven that heats the glass to about 1,400°F. As the glass heats, it softens and folds over the mandrel to produce a perfectly curved mirror. Eventually, he will be able apply the same process on bigger and thinner sheets of glass.

The Secret

The secret, Zhang said, lies in the preparation. "What we've learned is how to treat the mandrel and the glass sheet before we heat them in the oven," he said. Though he cannot offer specifics for proprietary reasons, he said the approach preserves the mirror's surface quality, which otherwise would be compromised in the process. Technicians then analyze the mirrors to determine their micro-roughness and to make sure that they are exact replicas of the mandrel itself.

So far, the tests have revealed that the mirrors essentially meet the technical specifications required of Constellation-X. "We've shown that we can meet Constellation-X's technical requirements. The skeptics are even saying that this is really possible," Zhang said. "But the key is whether we can mass produce the mirrors."

And that, Zhang said, is the problem he's now attempting to solve. "We need to further develop and refine the technique so that we can make copies and copies of these mirrors at the lowest possible cost and in the shortest possible time," he said. ◆

Photo Credit: Chris Gunn

Marton Sharpe holds one of the curved mirrors he's produced in the laboratory.

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Flagship Mission Considered High Priority

Constellation-X — one of two flagship missions in NASA's Beyond Einstein program — is expected to answer a few of the most compelling unsolved problems in astrophysics and cosmology: What happens at the edge of a hole black? What is the mysterious dark energy that pulling apart the universe? What powered the Big Bang?

The four satellites that make up the high-resolution spectroscopy mission will together provide 100 times greater sensitivity than any past or current X-ray satellite mission and allow scientists to collect more data in an hour than they would have collected in days or weeks with current X-ray telescopes. The scientific community considers it a high-priority mission, second only to the James Webb Space Telescope in the most recent Decadal Survey Report ranking of space-based missions. ◆

Turning Moon Dust into Oxygen

Producing a bountiful supply of oxygen will be a top priority for astronauts when they return to the Moon and begin setting up living and working quarters. The question is, of the more than 20 different technologies capable of extracting oxygen from lunar soil, what's the best approach?

Goddard technologist Eric Cardiff believes he has the answer. He's put his money on a technology called vacuum pyrolysis and has used Internal Research and Development (IRAD) funding to build a prototype system that he hopes will advance the technique and ultimately lead to a technology-demonstration mission in 2010 or 2012.

Principal Investigator Eric Cardiff uses a mirror to direct sunlight into a vacuum chamber, where he vaporizes and decomposes lunar-like material to produce oxygen.

"There's really nothing mysterious about the technology," Cardiff said. "Researchers have long known that moon rocks and soil contain 45 percent oxygen bound up in various minerals, and vacuum pyrolysis is potentially the most efficient technique to extract oxygen from the lunar regolith. Unfortunately, very little research has been done. My team hopes to change that."

Unlike some techniques, which use a complicated chemical process to reduce the oxygen inside rocks and soil, vacuum pyrolysis incinerates the rock to release oxygen bound up in the material, Cardiff said. With pyrolysis, a lunar processing facility would collect the oxygen-rich soil or regolith, place the material inside the plant's reactor, and use solar flux, or concentrated sunlight, to heat the soil to about 4700°F (2600°C). Under such extreme temperature conditions, the soil would vaporize, releasing gaseous oxygen that would then be pumped into a holding tank and stored.

In addition to supplying breathable oxygen, the technique could produce oxygen for rocket propulsion. This would save NASA additional time and money because the cargo space needed to transport fuel instead could be used to ferry other equipment. Furthermore, the incinerated remains or metallic slag could be used for other purposes, like spare parts.

"Pyrolysis is more efficient, especially when you put it up against the other techniques that have gotten more attention in the past," Cardiff explained. "It doesn't require as much infrastructure to build a processing plant. Therefore, it would take fewer flights and less assembly time to get a plant up and running. But perhaps more important is the fact that vacuum pyrolysis takes complete advantage of the lunar environment," he said. "Any kind of regolith can be used and the Moon has a natural vacuum and a high solar flux. In addition, you don't need additional fuel from the Earth to begin the processing, just the resources on the Moon itself."

Prototype Developed

To take the technique to the next level of technical sophistication, Cardiff developed a prototype to conduct experiments. The current model is equipped with a large Fresnel lens that concentrates solar light before it passes through a window and into a vacuum chamber where it heats the regolith. The soil vaporizes and decomposes, ultimately releasing oxygen. Cardiff also plans to complete a larger prototype system that uses a large parabolic reflector to concentrate light from the Sun.

Since completing the Fresnel prototype, Cardiff said he has demonstrated run times of up to one hour, successfully vaporizing and condensing several different lunar "simulant" materials, including ilmenite — a metal-rich mineral that is very common on the Moon. Measurements taken by a mass spectrometer and an electron-scanning microscope indicate that small quantities of oxygen are being extracted.

Cardiff is taking his preliminary success in stride. "We still have a long way to go," he said. "Our performance predictions indicate that vacuum pyrolysis could produce more than 1 kilogram of oxygen per 10 kilograms of regolith processed, which is 10 times more than with reduction techniques. But this technique is still much less mature and we still need to prove its value. My hope is that we can create a flight experiment using the basis of our work here." ◆

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Driving Down Mission Costs

New Flight Software Package Delivered to Lunar Mission

The Lunar Reconnaissance Orbiter (LRO), the Goddard-developed mission that will map the lunar surface and characterize future landing sites when it's launched in 2008, is the first to fly a new software package that promises to significantly reduce flight software costs and development time in the future, its creators say.

Goddard's Flight Software Branch (Code 582) delivered the Core Flight Executive (cFE) to the LRO flight software team a few months ago. The delivery represents the first step in a much larger effort to provide an automated, platform-independent system that offers reusable software to all types of missions, said Maureen Bartholomew, Product Development Lead. "In the past, we always had the greatest intentions of reusing software from one mission to the next, but it always seemed that we ended up reinventing the wheel."

The Core Flight System

The delivered product is the first element in an overarching effort to streamline the software-development process and manage previously flown software that handles routine spacecraft tasks, such as telemetry, health and safety, stored commanding, to name just a few. Called the Core Flight Software (CFS), system, the still-evolving capability isolates platform-dependent interfaces, provides a reusable plug-and-play software component library controlled by Code 582, includes an integrated development environment, and features a graphical interface that allows mission planners to peruse a catalog and select the components they want for their mission. The cFE is the base on which the mission components sit.

The obvious benefit is that missions don't have to dedicate valuable resources to developing commonly reused software, said Jonathan Wilmot, who leads the CFS program. Instead, they can use their resources to develop greater functionality onboard their spacecraft or keep down costs. Furthermore, development systems can be up and running in just a few weeks, not months as was the case before, he said. The hope is that the system will reduce time to flight, reduce the risks, and allow future missions to choose from an ever-expanding catalog of reusable components.

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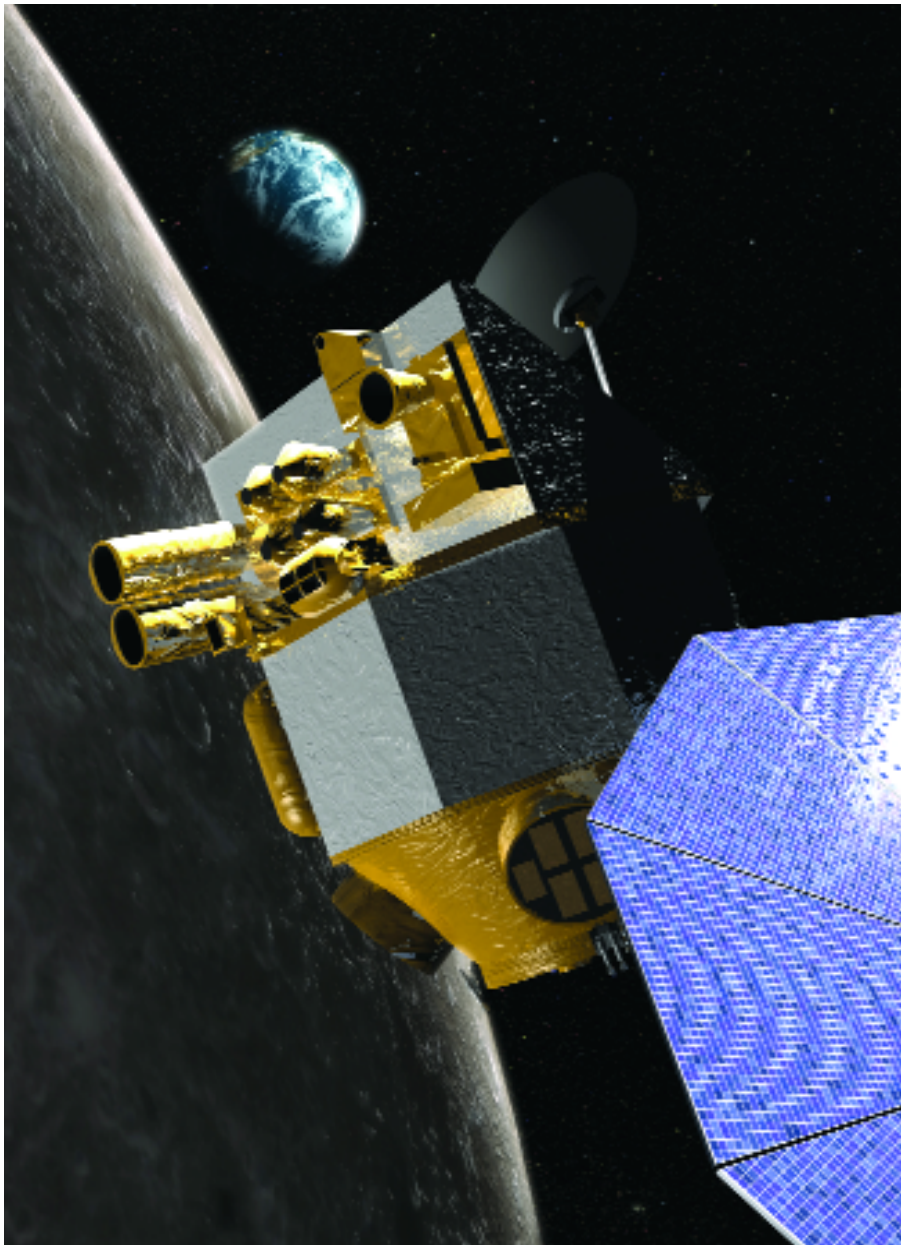

The Lunar Reconnaissance Orbiter is the first mission to use the Goddard-developed Core Flight Executive, a new software package that promises to reduce flight software development costs in the future.

NASA Prepares for Launch of Micro-Satellites

Effort Culminates Years of Research and Coordination

What began as a series of workshops in the mid-1990s to assess the state-of-the-art in miniaturized subsystems and satellites is expected to advance to the next stage of technology development when NASA launches three experimental micro-satellites aboard a Pegasus XL rocket from Vandenberg Air Force Base in California at the end of February

The satellites, which are the result of years of Goddard-funded research and coordination across the science and engineering directorates, will test and validate new technologies as part of NASA's Space Technology 5 (ST5) mission, sponsored by the New Millennium Program.

"The hope is that the 90-day mission will demonstrate the capabilities of micro-satellites and their miniaturized components, and eventually lead to the launch of 'constellations' of these spacecraft to carry out scientific missions," said ST5 Project Scientist Jim Slavin.

Weighing 55 lbs. when fully fueled and measuring only 21 inches wide and 19 inches tall, the micro-satellites represent a significant departure from the larger and heavier spacecraft NASA has flown in the past. Because of their relatively diminutive size, mission planners are able to stack them in a specially designed launch rack

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60s-Era Facility Gets New Lease on Life

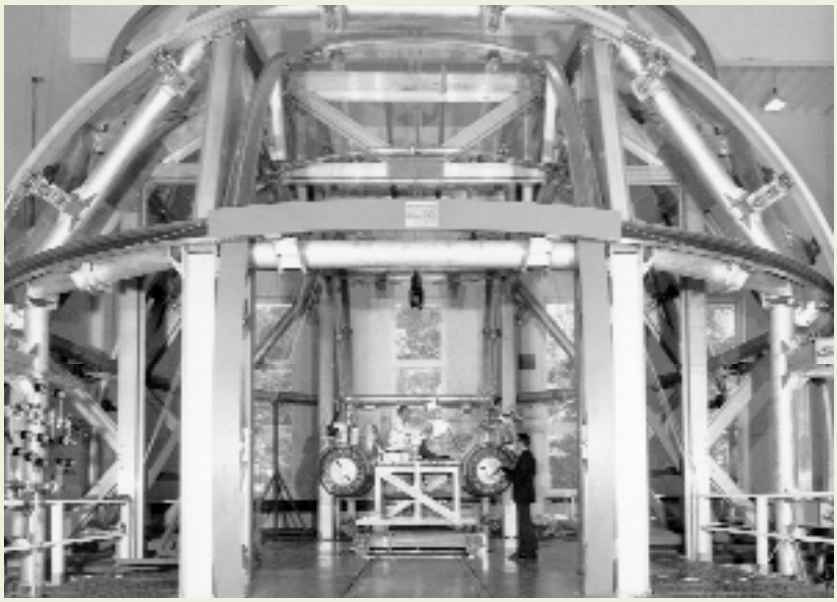
The last stop that Goddard's one-of-a-kind micro-satellites made before technicians shipped them to Vandenberg Air Force Base in early December was a nearly forgotten, 1960s-era facility that could perform a task like no other in the U.S. — thoroughly cleanse the spacecraft of a magnetic field.

That facility — Goddard's Spacecraft Magnetic Test Facility — is now in the middle of a multi-million-dollar refurbishment begun largely in part because of Space Technology 5 (ST5) requirements that the satellites be thoroughly cleansed of a magnetic force, which could interfere with their ability to gather highly precise measurements of the Earth's magnetic field.

Originally built in the mid-1960s, the facility features a 42-foot diameter, 3-axis coil system that negates Earth's magnetic field. Only two other facilities in the world match its size and precision, said Bob Vernier, Chief of the Environmental Test Engineering and Integration Branch.

Although the facility's coil system was in good shape, its heating and air conditioning system needed upgrading; so did its electronic control system, which was vintage 1960s, Vernier said. With the renovation funding, his group developed an engineering model of the new electronic control system and fashioned a breadboard system to be used during the ST5 testing. The renovations and installation of the new equipment are expected to be finished in 2006.

With its new equipment, the facility is expected to get busy. NASA has planned several spacecraft, including the Magnetospheric MultiScale Mission that will require a level of accuracy and resolution that only the facility can provide, Vernier said. ◆



This vintage photograph taken in the late 1960s shows the 3-axis coil system that distinguishes Goddard's Spacecraft Magnetic Test Facility. Inside the chamber is one of the Apollo-era lunar buggies.

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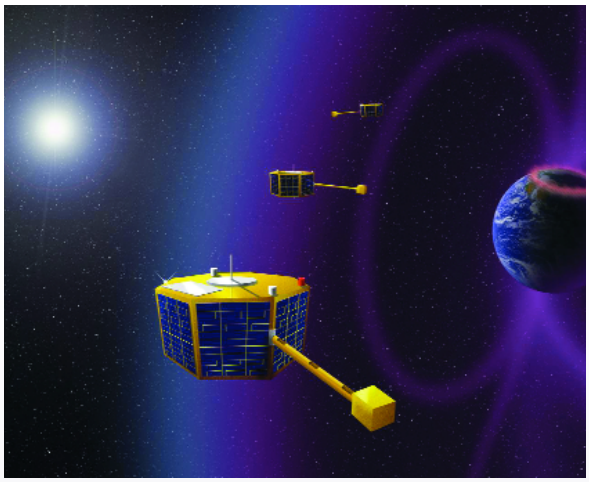
Micro-Satellites... Continued from page 6

that allows the relatively inexpensive Pegasus rocket to deploy them individually in a Frisbee-like spinning motion.

After their launch, they will be positioned in a "string of pearls" constellation about 25 to 90 miles apart to carry out multi-point measurements of the Earth's magnetic field using a highly sensitive miniaturized magnetometer. The principal goal of the science demonstration is to validate how a constellation of micro-satellites might be used for science.

The behind-the-scenes work that led to the upcoming launch began a decade ago after the failure of NASA's high-profile Mars Observer mission, Slavin said. "Interest in smaller satellites surged as a means of better controlling cost and reducing the risk of total mission failure due to the loss of a single spacecraft," he recalled.

Goddard's Laboratory for Extraterrestrial Physics and the Applied Engineering and Technology Directorate took the lead, sponsoring workshops and carrying out internally funded research efforts to advance the state-of-the-art. By 1999, the Goddard team had convinced the New Millennium Program to fly a micro-satellite constellation as part of its ST5 announcement of opportunity. The same year, the program selected Goddard's winning proposal. "And as they say, the rest is history," Slavin said. "This mission just goes to show you what Goddard can accomplish for the scientific community when everyone works together toward a common goal," he added. "This is really a great Goddard success story. ◆



The Space Technology 5 (ST5) mission consists of three micro-satellites — each about the size of a microwave oven — that will explore the Earth's magnetic fields.

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Helen Johnson, a Goddard Thermal Design Technician, works on one of the micro-satellites before it and two others were shipped to Vandenberg Air Force Base for launch.

Technologies Onboard the Micro-Satellites

The micro-satellites also are carrying the following New Millennium Program-selected miniaturized technologies:

Low Voltage Power System – Triple Junction Solar Cells and Lithium Ion Batteries

Cold Gas Micro-Thruster • X-Band Transponder Communication System

Variable Emittance Coatings for Thermal Control • CMOS Ultra-Low Power Radiation Tolerant Logic

Investment... Continued from page 1

A majority of the awards came in the area of new instrument development. As would be expected, the majority of IRAD and other technology investments also are instrument-related, Hughes said. "Given Goddard's success in new instrument development, our investments in that area should remain robust," he said. "However, we need to make sure that we are adequately investing in all areas important to our future."

Other Demonstrated Capabilities

In addition to bringing new work into the Center, the survey indicated that Goddard's technology investments are maintaining or developing competencies and reputations for excellence in key technologies and technical fields and allowing principal investigators to apply what they've learned to other projects and proposals. "We developed interferometric technology for LISA, but it also turned out to be useful for TPF-C (Terrestrial Planet Finder-C)," said Jordan Camp, who works at Goddard's Gravitational Astrophysics Laboratory (Code 663).

Added Geary Schwemmer, who works at the Laboratory for Atmospheres (Code 613) and won a Research Opportunities in Space and Earth Sciences Advanced Component Technology (ROSES/ACT) award last fiscal year: "IRAD support had a direct and major impact. The engineers helped by producing some conceptual designs, and the technician helped to gather more laboratory data. Both of these efforts provided me with material that gave my proposal more depth and credibility."

Other researchers reported that the funding had given them an opportunity to build testbeds, or co-author peer-reviewed articles, which increased Goddard's visibility and reputation, and resulted in technology transfers to private industry.

"Now that we understand the impact of our programs, I think we now must make sure that we continue to invest in our technologies and at the right funding level," Hughes said. ◆

Mission Costs... Continued from page 5

Layered Architecture

The effort began a couple years ago when a group of Goddard flight software engineers outlined components needed for all missions, regardless of mission size, and determined the requirements for a generic onboard executive system that would allow missions to truly reuse software components. The group demonstrated a prototype in 2004 and formal development began in 2005.

The cFE is the first out of the gate and is the cornerstone of the system. It offers generic onboard software services, including time management, event handling, table management, file management, and network services. Because its internal workings are carefully layered and use run-time interfaces, users enjoy a "plug and play" environment where they can swap or update software and hardware without shutting down the entire system. "This means you can start and stop an application or fix something in the software while the system is running," Bartholomew said.

Although the goal is to eventually offer users a suite of software applications as part of the reuse library, Bartholomew said the project is continuing and that only the cFE is available now. Even so, projects can still enjoy the plug-and-play capability using their own flight software components. In fact, she said, flight software developed by the Lunar Reconnaissance Orbiter might one day find a home in the reuse library. ◆

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Goddard Tech Trends

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