National Aeronautics and Space Administration

goddard tech trends

Zhang's Glass Kitchen

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Zhang's Glass Kitchen

Goddard Team to Begin NuSTAR MIrror Production this Fall

To produce curved mirrors for NASA's NuSTAR mission, technicians will place a sheet of very thin glass on top of a mandrel and place the assembly into an oven. The heat softens the glass so that it takes the shape of the mandrel.

It pays to persevere. No one knows this better than Goddard astrophysicist Will Zhang.

After 10 years of fine-tuning a technique to efficiently manufacture super-thin, curved mirrors needed to focus X-ray photons, he and his team have won a position on the Caltech-led Nuclear Spectroscopic Telescopic Telescope Array (NuSTAR) mission (see related story, page 3) to provide the telescope's more than 3,000 individual mirror segments.

More significant, however, is the longer-range potential of his mirror technology, he readily concedes.

"NuSTAR will be a precursor to Constellation-X," Zhang said, referring to the proposed flagship X-ray mission that NASA hopes to fly in 2018 to answer the most compelling unsolved problems in astrophysics and cosmology: what happens at the edge of a black hole? What is the mysterious dark energy that is pulling apart the universe? What powered the Big Bang? "This is really an opportunity for us to demonstrate that the technology is flight worthy and is ready for a bigger mission. Producing NuSTAR's mirrors will let us show that we can mass produce the segments."

Testament to R&D Funding

As Zhang and his team gear up to begin the massive production job this fall, Zhang reflected on how he

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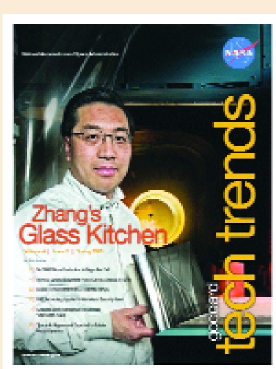

About The Cover:

About a decade ago, astrophysicist Will Zhang conceived an idea for making curved or slumped glass mirror segments to focus highly energetic X-ray photons. Using R&D funding, he perfected his idea and is now gearing up to begin the production of 3,120 mirror segments for NASA's Nuclear Spectroscopic Telescope Array mission. Without Goddard R&D funding, Zhang says his work would have taken much longer and he might have been beaten by the competition. In this image, Zhang stands in front of one of the ovens he will use to create the mirror segments. He holds one of the sample mirrors.

Photo Credit: Chris Gunn

Zhang... *Continued from page 2*

eventually earned a position on the NuSTAR mission. Until just a few months ago, he wasn't even on the team.

Initially, Caltech had chosen Columbia University to produce the mirror segments. In 2006, NASA cancelled the mission due to funding shortfalls. When it became obvious that the Agency needed the mission to bridge the gap between the 2009 launch of the Wide-field Infrared Survey Explorer and the 2013 launch of the James Webb Space Telescope, the Agency restarted NuSTAR in 2007. By then, Goddard had pulled ahead of Columbia in fine-tuning the production technique.

"There are two reasons why we pulled ahead," Zhang said. "Number one, we started out with the right idea; and two, we had more money and professionals than Columbia." Money and personnel were initially provided through Goddard's Director's Discretionary Fund (DDF) in 1998 and subsequently through the Internal Research and Development (IRAD) program in 2004-2007. Zhang's team also received support from the Constellation-X project, he said.

"Without DDF and IRAD funding, our work would have taken much longer and we might have been beaten by the competition," Zhang said. "It sometimes takes a decade to bring an idea to the point where you have something to show. The R&D funding gave us time and money. It gave us encouragement and legitimacy. To get an idea like this going, you need both. Now, we're talking about flying this by 2011."

A Good Idea

Just as important is the idea itself.

X-ray mirrors must be curved and nested inside an optical assembly so that the highly energetic X-ray photons graze their surface, instead of passing through them — much like a stone skimming the surface of a pond. To make these curved segments, Zhang will use flat sheets of smooth, lightweight glass measuring only 200 microns thick — the thickness of three sheets of paper.

His production team will place the commercially available glass on a mandrel or rounded mold that provides the exact optical prescription for NuSTAR's mirrors. Technicians will then place the entire assembly inside an oven that heats the glass to about 593˚C (1,100˚F). As the glass heats, it softens and folds over the mandrel to produce a curved mirror that is an accurate copy of the mandrel's surface.

In contrast, Columbia University slumped the glass into the mandrel, not over it, Zhang said. "Our approach is more controllable. Furthermore, we use a release layer that prevents the glass from sticking." This proprietary preparation technique preserves the mirror's surface quality. "Our yield is almost 100 percent," he said.

Production Begins in the Fall

Production begins this October after Zhang's team installs 10 large ovens in his laboratory. Once Goddard technicians finish the job in November 2009, they will ship the 3,120 pieces to the Danish Space Research Institute, which is responsible for coating the segments with 300 alternating layers of tungsten and silicon. From there, the coated mirror segments will be shipped back to Columbia University where they will be placed and aligned in a nested configuration inside two 10-meter-long assemblies to form the telescope's grazing-incidence optics.

"This will be a revolutionary mission," Zhang said. "It would have been a shame for Goddard to sit by and not be a part of it." ◆

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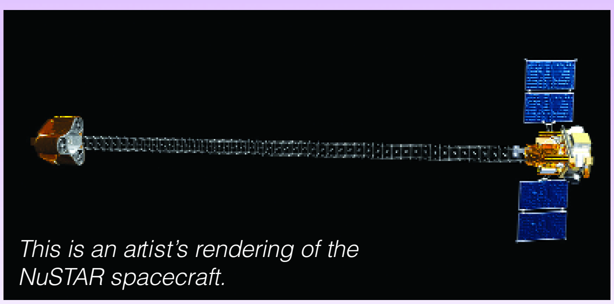
NuSTAR: A Mission of Firsts

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission is the first to use grazing-incidence focusing optics to open a new observing window into the poorly studied hard X-ray band.

The ability to collect and focus "hard X-rays," with energies as high as 80,000 electron volts, will allow this small Explorer-class mission to study black holes of all sizes and make observations that were beyond the reach of currently operating X-ray observatories. The Chandra X-ray Observatory, for example, can only sense less energetic "soft" X-rays, and therefore, cannot pierce the dust that frequently enshrouds black holes. NuSTAR also will study stellar explosions and galactic nuclei.



This is an artist's rendering of the NuSTAR spacecraft.

NuSTAR is slated to launch on a Pegasus rocket. To fit inside the rocket's fairing, the spacecraft must be compact. To accommodate the size restrictions, the two optical assemblies are attached to the end of mast that is stowed inside a canister. Once NuSTAR reaches its orbit, a motor deploys the mast to its observing configuration. ◆

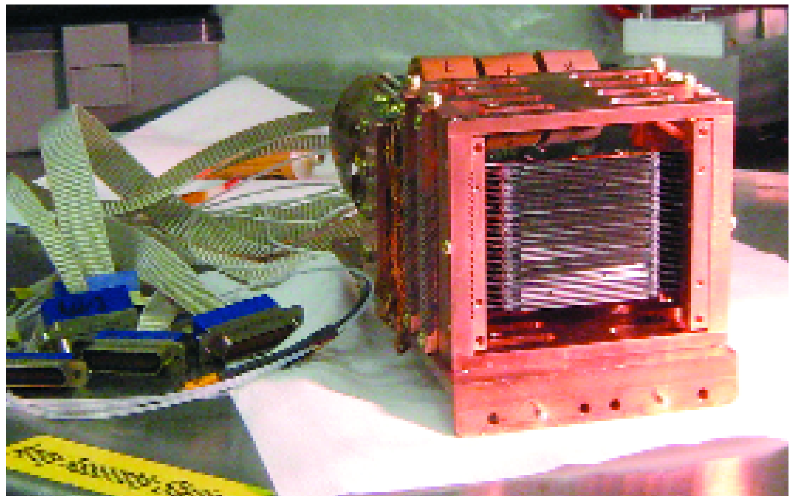
SPECIAL REPORT: DETECTOR TECHNOLOGIES

Maintaining Goddard's Preeminence in Detector Technologies

For years, Goddard has invested in detector technologies that have maintained the Center's preeminence in the field, leading to scientific discoveries literally across the electromagnetic spectrum. Here, Goddard Tech Trends showcases a few of those technologies, including one that the Department of Homeland Security could use to prevent illicit nuclear material from being shipped into the country.

World's Largest Bolometer Array Camera Debuts in Chile

Goddard technologists have tripled the size of a detector array that will fly on NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) to create the world's largest bolometer array camera, which is now observing the afterglow light — the so-called cosmic microwave background — that was created during the first moments of the universe's creation billions of years ago.



This image shows one of three fully assembled kilopixel arrays that a Goddard technologist developed for the Millimeter Bolometer Array Camera, an instrument that is now observing the afterglow light — the so-called cosmic microwave background — that was created during the first moments of the universe's creation billions of years ago.

The Millimeter Bolometer Array Camera (MBAC), which traces its heritage to SOFIA's High-resolution Airborne Wideband Camera (HAWC), was installed in the Atacama Cosmology Telescope in Chile late last year and has produced high-resolution, high-sensitivity data that scientists are now analyzing, said Principal Investigator Jay Chervenak. Scientists are expected to report the results in scientific journals shortly.

"It's exciting," Chervenak said, referring to the camera's results. "This has been in development for a long time."

Ideal for Observing Background Radiation

The bolometer camera is a radiant-heat detector. It is ideal for observing the changes in the microwave background radiation — the oldest light in the universe — as it passes through and around galaxy clusters that began to form in the early universe. When combined with optical and X-ray data, MBAC's high-angular-resolution data will provide insights into the mechanics that drove their formation.

This particular camera-development effort is the result of a partnership involving Goddard, Princeton University, the National Institute of Standards and Technology, and the National Science Foundation. Under the collaboration, Chervenak and his team developed three detector arrays capable of making simultaneous observations in three microwave wavelength bands.

Advances in 'Pop-Up' Technology

Like HAWC, MBAC makes use of the Goddard-developed "pop-up" detector technology that a team led by technologist Christine Allen (see related story, page 5) began developing in the late 1990s under R&D funding.

However, MBAC represents a significant advance over its predecessor. Using Internal Research and Development funding, Chervenak increased the size of the detector array to include 1,024 pixels, resulting in the largest array of pop-up detector bolometers ever fielded. In comparison, HAWC hosts a 384-pixel array. For microwave measurements, more pixels mean faster and a more detailed mapping of the sky.

"The big challenge for us was making the larger arrays," Chervenak said. Array assembly was simplified by using low power and superconducting circuits that could be arrayed lithographically. Chervenak added that his team developed the techniques to produce the thousands of elements needed.

The Chilean observatory made its initial observations in November. Full science observations with the three detector arrays are expected to begin this summer.

Chervenak's work does not end here. The next step is developing and demonstrating a "scalable" array that offers even higher sensitivity, he said. ◆

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It's Not a Whachamacallit...It's a GISMO!

Prototype Camera Using New Detector Arrays Demonstrated in Spain

This 30-meter telescope operated by the Institut de Radio Astronomie Millimétrique in Spain used GISMO to observe nearby to very distant galaxies that formed less than a billion years after the creation of the universe. GISMO will do follow-up observations in June.

A prototype camera that employs a large-format, faster, and more efficient detector array developed in part with Internal Research and Development (IRAD) funding has gathered high-quality infrared data on nearby to very distant galaxies that formed less than a billion years after the creation of the universe.

The instrument, the Goddard-IRAM Superconducting 2-Millimeter Observer (GISMO), observed these objects in late 2007 after being installed in a 30-meter telescope operated by the Institut de Radio Astronomie Millimétrique (IRAM) in Spain. The instrument will do follow-up observations in June.

Brainchild of Goddard Technologist

GISMO is the brainchild of Goddard technologist Christine Allen. Her team used NASA Headquarters funding to develop the instrument as a way to validate a next-generation detector architecture she created with Goddard IRAD funding. The detector architecture — called the backshort-under-grid (BUG) — allows easier assembly of the instrument's bolometer array because the array's three individual components are merged into a single working unit.

That contrasts sharply with the level of effort she invested into building a similar array now used in a bolometer camera at the Caltech Submillimeter Observatory in Hawaii.

The 384 detectors in the Caltech instrument were made using 12 individual rows of 32-pixel arrays, requiring a significant amount of handwork for assembly. "This was quite an undertaking," Allen said. By constructing the pixels on a single silicon wafer bonded onto a read-out circuit, however, the new BUG architecture is scalable, which means Allen can easily increase the size of the detector array. The larger the detector array, the better the sensitivity and resolution of data.

The more efficient fabrication technique also contributed to GISMO's relatively low cost and speedy development. It took Allen's team just a year to build the entire instrument, which was designed specifically to observe in the 2-millimeter bands because this wavelength regime allows observations of objects in the distant universe.

'On Our Way'

During the demonstration in Spain, GISMO observed in the far-infrared wavelength bands some of the oldest galaxies in the universe. Enshrouded in dust, they are of particu-

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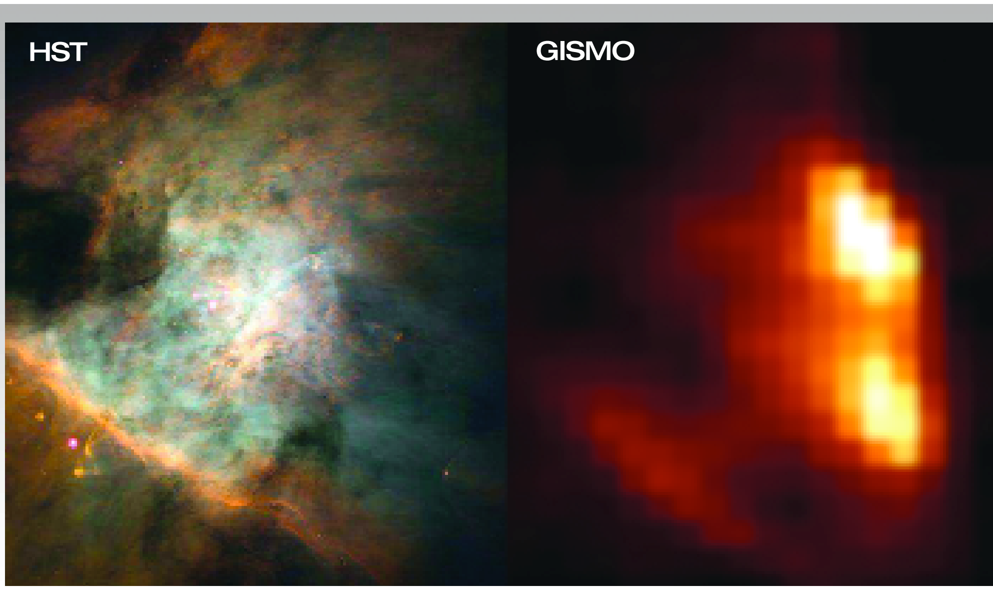
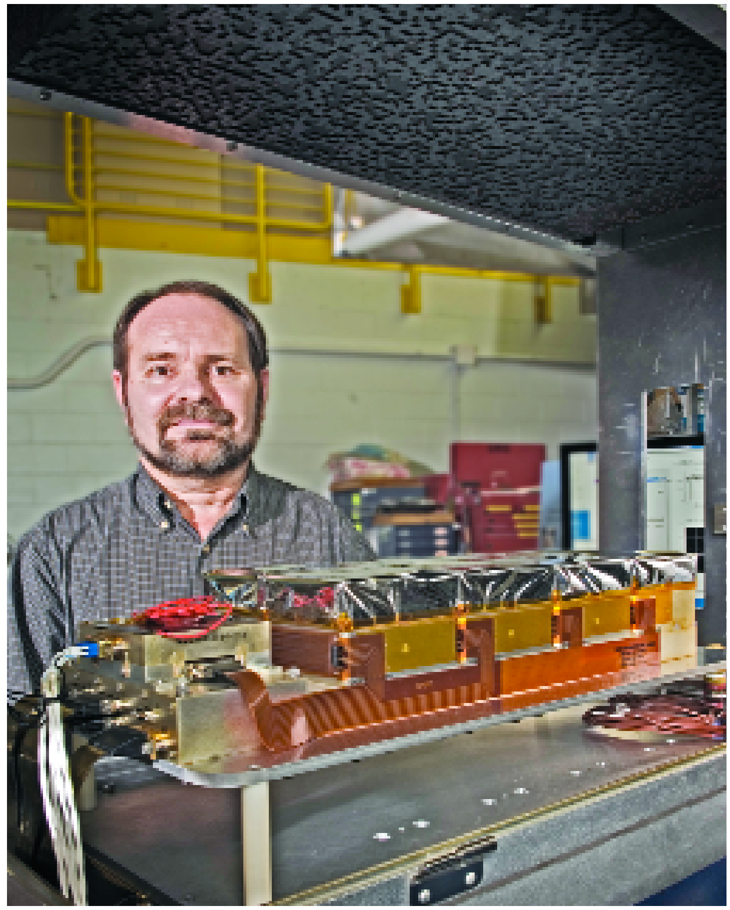


These two images, taken with the Hubble Space Telescope and the Goddard-developed GISMO, show the Orion Nebula, the closest region of massive star formation. Because GISMO views objects in the infrared, it was able to penetrate the dust to pinpoint the most active star-forming areas.

BAT Technology Applied to Homeland Security Need

Detecting gamma-ray bursts from space is really no different than finding and intercepting nuclear material illegally stowed inside shipping containers or even trains — at least that's the view of the principal investigator who created Swift's Burst Alert Telescope (BAT) that has detected hundreds of gamma-ray bursts from all directions in the sky.

To prove his point, Principal Investigator Scott Barthelmy received Department of Energy funding to cobble together a prototype system using leftover components from the BAT-development effort. Although his prototype would have to be smaller and more mobile to operate as a counterterrorism tool, the same principles are at play, he said. He hopes to make the case and win Department of Homeland Security (DHS) funding to build a second-generation detection system equipped with even more capable detectors now being developed under Goddard's Internal Research and Development (IRAD) program.



Technologist Scott Barthelmy believes this instrument prototype would be useful for detecting nuclear material hidden in shipping containers and trains. He developed it using leftover components from Goddard's Burst Alert Telescope.

The instrument that inspired the potential spin-off application is now flying aboard NASA's Swift mission, which as it name implies, swiftly detects gamma-ray bursts and then targets itself toward the event in about one minute to make detailed observations. Gamma-ray bursts are the most powerful explosions in the universe — second only to the Big Bang in terms of total energy output. They occur randomly about once per day, lasting only a few milliseconds to tens of milliseconds in duration.

Scientists strongly believe these split-second flashes of gamma-ray light signal the collision of a black hole and a neutron star or the collision of two neutron stars that then create a black hole. Hypernova, the explosion of massive stars, also are believed to cause the bursts.

First Line of Defense

BAT is the instrument that detects and locates the burst. Developed with Goddard R&D funding several years ago, BAT carries out its job using a technique called a "coded aperture mask" that creates a gamma-ray shadow on its 32,768-pixel, cadmium-zinc-telluride (CZT) detector plane. The mask itself contains 52,000 randomly placed lead tiles that block some gamma rays from reaching the detectors. With each burst, some of the CZT detectors light up while others remain dark, shaded by the lead tiles. The angle of the shadow points to the direction of the gamma-ray burst.

The same instrument concept is ideal for homeland security, Barthelmy said. "We've already produced an instrument that has a 100-degree field of view and can pinpoint the location of a gamma-ray source," Barthelmy said. "It's what you would need to find and intercept nuclear material stowed inside shipping containers and trains."

A new generation of CZT detectors and electronics, which Barthelmy is developing under current IRAD funding for possible use on NASA's proposed Energetic X-ray Imaging Survey Telescope (EXIST), would further improve the prototype. "They really need the ability to distinguish legitimate sources," he said. The new CZT technology would do just that. It could distinguish isotopes and determine whether the detected nuclear material were medical in nature or posed a national security threat, he said.

His goal is to get DHS funding to develop a second-generation prototype using the EXIST detectors. "We really want to move into the second stage," he said.◆

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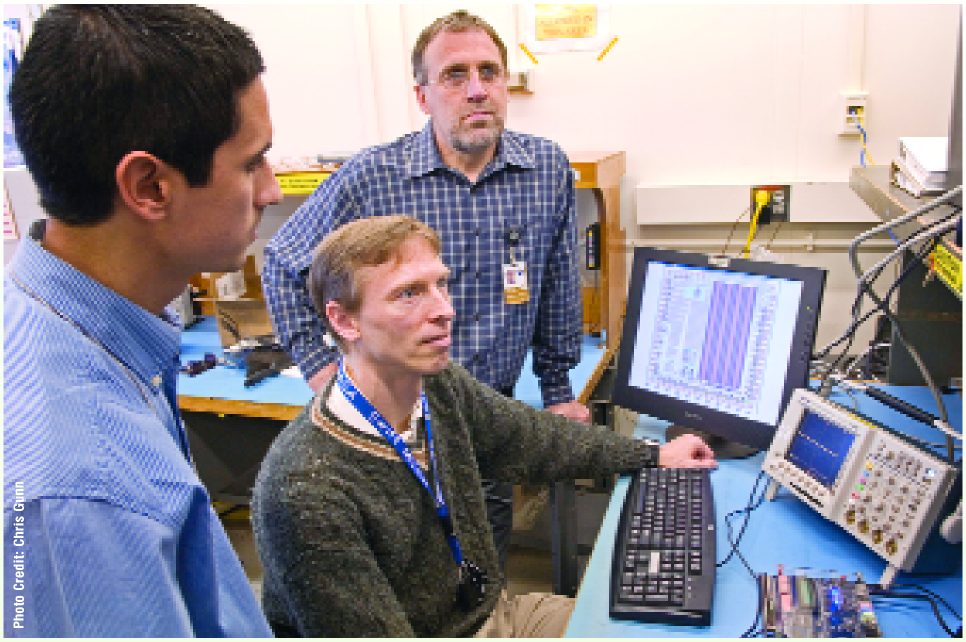
Goddard Joins Consortium to Develop 'Rad-Hard' ASICs



Goddard's Mixed-Signal Application-Specific Integrated Circuit Group (from left to right, George Suarez, Jeff DuMonthier, and Gerry Quilligan) have joined a consortium with the Air Force Research Lab and Jazz Semiconductor to develop radiation-hardened application-specific integrated circuits — a mainstay of all spacecraft systems. LaVida Cooper, another team member, is not pictured.

Integrated circuits — the ubiquitous chips of silicon found in computers, autos, and virtually every other electronic gadget on the marketplace — may be as commonplace as fast-food restaurants. But try finding one that can withstand the rigors of spaceflight and still carry out a very precise job onboard an orbiting spacecraft. It's not easy.

Gerry Quilligan, an electronics engineer and member of Goddard's Mixed-Signal Application-Specific Integrated Circuit Group, knows this well.

That's why he and his team have joined a consortium with the Air Force Research Laboratory (AFRL) and Jazz Semiconductor, a California-based company, to design and manufacture two particular types of space-worthy application-specific integrated circuits (ASICs). Unlike general-purpose circuits, such as microprocessors, mixed-signal ASICs are customized for a particular use, and therefore, help to increase the performance and decrease the size and power needs of an electronic device. Virtually all spacecraft platforms and instruments rely on them.

In this case, both of Quilligan's chips would digitize amplitude and time-of-flight signals; in other words, measure the size of a packet of photons along with the time it takes to reach a detector while traveling over a varying distance — an important capability for three-dimensional imaging, autonomous landing and hazard avoidance, and laser communication.

Currently, Goddard scientists must rely on external "off-the-shelf" parts, which, in most cases, are not designed for exposure to space radiation. In fact, only a few companies in the nation actually manufacture "radiation-hardened" circuits that carry out these very precise jobs. Quilligan hopes to end the dependence on these few companies, advance the state-of-the art, and acquire the ability to tailor integrated circuits to scientists' needs.

He says he's well on the way.

One of his circuits will be able to measure time intervals with a sensitivity of 33 picoseconds, which is 33 million millionths of a second. "That would push the boundaries," Quilligan said, referring to the so-called Multi-Channel Charge Amplifier Time-of-Flight circuit. "That is state of the art," not only for radiation-hardened time-of-flight circuits, but even those developed for ground-based use.

Partnership Responsibilities

Under the partnership, Quilligan and his team will design and lay out the circuits, equipping each with 16 independent channels that can be scaled up to at least 64 channels in the future. AFRL, meanwhile, will provide unique radiation-modeling design tools and Jazz Semiconductor will manufacture the circuits on a multi-product wafer (MPW), also subsidized by the Air Force. Because circuit fabrication costs are high, the MPW provides a relatively inexpensive way to manufacture several products on a single silicon wafer. This is especially ideal for researchers who need smaller batches for testing purposes. Quilligan hopes to have chips by October.

"We get low-cost manufacturing and design tools," Quilligan said, "and they get feedback on performance." What they all get — at least that's the goal — are "real world circuits that will fly," he said. ◆

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Gismo... Continued from page 5

lar interest to scientists because they all experienced a phase of violent star formation and a large number of them host quasars, indicating the presence of super-massive black holes at their centers. GISMO's observations are aimed at giving scientists insights into their evolution on cosmological time scales and the physical processes that formed them.

"With a successful ground-based demonstration, we hope to be on our way to building large-format arrays that can be tailored to operate at a wide range of wavelengths," Allen said.

Although GISMO's principal investigator for science, Johannes Staguhn, says he's still processing the data, he is pleased with the results. "We got some real science out of our first observing run. They're eager for us to come back and do more science with GISMO in June," he added, referring to IRAM. "This is really saying something since getting an invitation (to install a new instrument and carry out observations at IRAM) is not common procedure at this observatory."

"We're hopeful that this opens the doors to other observing opportunities," he said. ◆

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Space Act Agreement Expected to Bolster the Center's Radar Expertise

Although Goddard has for years developed aircraft-borne radar instruments to validate data collected by Earth-orbiting spacecraft, the Center has never considered itself a radar powerhouse. Under a new Space Act Agreement with Northrop Grumman Electronic Systems, the Center hopes to bolster its expertise and become more competitive winning future Earth-observing and planetary missions.

"What interested us in creating this partnership is that Northrop Grumman was willing to work with us to incorporate our technologies into their systems, and vice versa," said Cathy Long, chief of the Microwave Instrument Technology Branch, which oversees the Center's radar technology-development efforts. "Our goals are to improve our in-house capabilities, to become smart buyers, and push the state-of-the-art."

Both Organizations Benefit

The partnership could not have come at a better time for both partners, she conceded. The National Academy of Sciences last year issued its first-ever decadal survey of future Earth-observing missions. Many of the 17 recommended missions call for measurements of cloud composition, sea-surface winds, water levels, snow accumulation, and other characteristics — measurements best obtained with radar-based instruments. Planetary missions also will require smaller, lighter, and less costly radar systems.

Goddard wants to bolster its chances of winning these missions and Northrop Grumman would like to apply its considerable expertise in military-based radar systems to civilian-space applications, she said.

To do this, Goddard plans to leverage Northrop Grumman's radar technology and combine it with its own remote-sensing expertise, testing facilities, and insight into applications that would help scientists answer key space and Earth science questions.

Although details are still being worked out, one of the first activities could be to apply Goddard-developed algorithms to one of Northrop Grumman's existing radar systems and fly the instrument on one of the company's research aircraft, Long said. "There are more people who want to fly than what NASA can accommodate. Flying our technologies on Northrop Grumman's aircraft would open up our options for demonstrations." ◆

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Goddard Tech Trends

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