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Cutting edge
Goddard's Emerging Technologies

NASA's Technology Renaissance

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Mason Peck: NASA's Technology Renaissance Man

INTERVIEW

On Jan. 1, 2012, Cornell University Professor Mason Peck became NASA's chief technologist, bringing a wealth of experience to the job as the Agency's top technology advocate. In a wide-ranging interview with CuttingEdge, he discussed NASA's Space Technology Program and how it will return the Agency to its technology roots.

The accomplished Peck offers NASA a broad background in aerospace technology, which comes from nearly 20 years in industry and academia. Among many other professional achievements, he has worked with NASA as an engineer on a variety of technology programs, including the Tracking and Data Relay Satellite System and Geostationary Operational Environmental Satellites. The NASA Institute for Advanced Concepts sponsored some forward-reaching research in modular spacecraft architectures and propellant-less propulsion, and the International Space Station currently hosts his research group's flight experiment in microchip-size spacecraft.

Prior to his NASA appointment, Peck also worked as an engineer and consultant with Boeing, Honeywell, Northrop Grumman, Goodrich, and Lockheed Martin. He has authored 90 academic articles and holds 17 patents in the U.S. and European Union. Peck earned a doctorate in aerospace engineering from the University of California-Los Angeles as a Howard Hughes Fellow and a master's degree in English literature from the University of Chicago.

You spend a lot of time on Capitol Hill. What kind of response have you gotten about the Office of the Chief Technologist's Space Technology Program?

I have good news about that. The fact is, we have bipartisan support from Congress and the administration for what we're doing. So the general architecture of the technology program — that is to say, the range of technology-readiness levels and the fact that we're investing in cross-cutting technologies — all play well. Also, the fact is, we are returning NASA to its technology roots. And that return is welcome. From the NRC's (National Research Council) report, the consensus view is that NASA needs to be investing in technologies to make its future missions possible. Their view is that this isn't just an essential enterprise for NASA; it's a direction we need to take to have a positive impact on the economy.

The President's proposed budget is very generous to your program. Provided Congress approves the budget, how do you plan to invest it? What are your priorities for keeping NASA's technology pipeline filled?

First of all, the $699-million budget requested for 2013 is at a level that allows us to maintain a minimally viable technology program. In fact, it's less than the amount authorized for 2012 and more than the enacted amount for 2012. The request represents the phased growth of the program and a few of what we call 'the big nine' projects we're taking on this year. So the key thing to keep in mind is that many of the investments we're making in 2013 continue 2012 investments. As for how we plan to invest in the future, we'll balance our investments according to guidance we've gotten from the National Research Council's assessment of our technology roadmaps. That assessment is

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About the Cover

NASA Chief Technologist Mason Peck recently shared his views about the value of the Agency's Space Technology Program. The wide-ranging interview covered everything from the organization's proposed $699-million budget to the challenges he sees on the horizon.

Cover Photo Credit: Chris Gunn

Photo Credit: Chris Gunn

"One really important message is that we're experiencing a renaissance in technology at NASA and the Space Technology Program is open for business."

— Mason Peck, NASA Chief Technologist

essential because it provides a consensus view of what our higher-priority technology areas should be. We'll take that advice, along with other factors, and develop a strategic investment plan that will shape what we invest in.

Can you tell me more about this strategic technology investment plan?

The plan is meant to be comprehensive. It's meant to address space technology across the Agency, including those needed by aeronautics. What we'll see in that plan are technology priorities. It won't specify the level of individual projects, but it will provide a strategic direction. That direction will primarily come from the NRC, but it will also include input from the mission directorates. It will come from our awareness of what other government agencies are doing and what opportunities industry and academia bring. We'll revisit our strategic plan every couple years and we'll redo our technology roadmaps every four years.

How should the technology community respond to those who might question the requested budget increase? Why is this investment important?

NASA's missions have always been based on new technology. We can't do what we need to do in the future with yesterday's technology. That's especially true for the challenges that lie ahead, including humans visiting an asteroid or Mars and some of the next-generation science activities. We need, for example, better storage for cryogenic propellants, better communications, and solar sails. All these technologies — three of the 'big nine' I mentioned earlier — are being advanced through our Technology Demonstration Missions, or TDMs. They are at the tipping point and could tip us over the edge. When they do, we'll be able to infuse them into future missions.

That is essential. It's not enough to focus on some early-stage ideas and then let them languish. We have to have a chain, like a supply chain, that goes through every stage. Our program provides that. We have a pipeline that starts with early stage and ends in TDMs. We can take those early-stage technology ideas and make them real.

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Tiny Mirrors for Detecting Extra-Solar Planets Promise to Revolutionize Space Observatories

NASA's next flagship mission — the James Webb Space Telescope (JWST) — will carry the largest primary mirror ever deployed. This segmented behemoth will unfold to 21.3 feet in diameter once the observatory reaches its orbit in 2018.

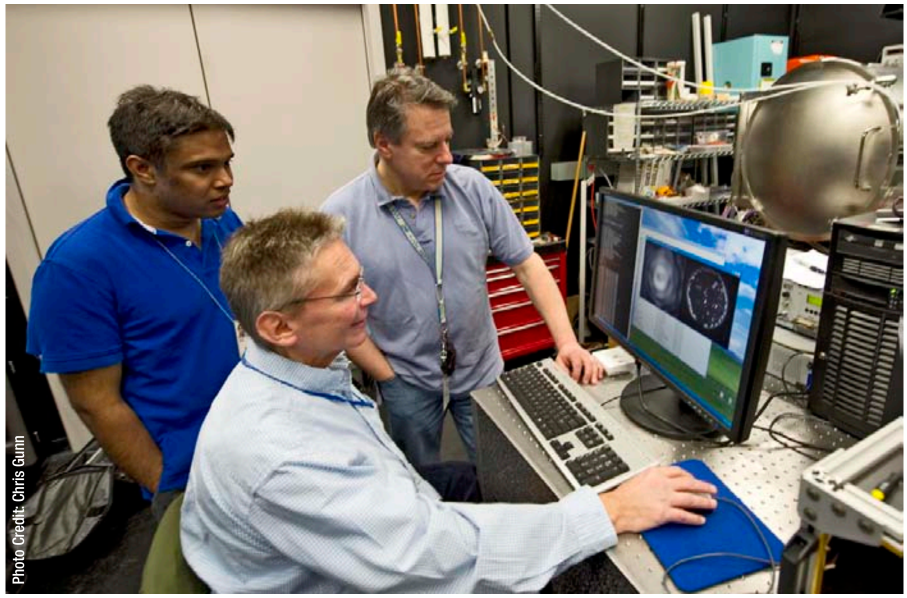

Photo Credit: Chris Gunn

The Visible Nulling Coronagraph (VNC) combines an interferometer with a coronagraph to image and characterize Jovian-size planets. In this photo, Rick Lyon (foreground), Udayan Mallik (left), and Sigma Space's Pete Petrone (right) are monitoring the progress of wavefront control using the VNC, which is operating inside a vacuum tank.

A Goddard team now developing an instrument that would image and characterize Jovian-size planets beyond the solar system possibly from a high-altitude balloon (see related story, page 5) has borrowed a page from JWST's playbook. It has created an infinitely smaller segmented mirror that currently measures less than a half-inch in diameter and promises to revolutionize space-based telescopes in the future.

The multiple mirror array (MMA), now being developed by the Berkeley, Calif.-based Iris AO, Inc., under a NASA Small Business Innovative Research grant, is one of the enabling technologies on the Visible Nulling Coronagraph (VNC), a hybrid instrument combining an interferometer with a coronagraph — in itself a first.

Since work began on the VNC more than three years ago, a team led by Principal Investigators Rick Lyon and Mark Clampin has made significant progress maturing the technology. With its VNC testbeds, the team has proved in laboratory tests that the instrument can detect, image, and characterize likely targets. "Nearly all the technologies are completed or are on track," Lyon said.

"MMA is a legacy of JWST," he added. "Segmented mirrors are the future, not only for traditional observing missions like JWST, but also for non-traditional uses, like the one we've developed for planet finding. No other coronagraph has segmented mirrors."

However, the technology's potential isn't limited to the different types of science it could execute.

The mirror array, currently comprised of 169 individual segments each measuring the width of three human hairs, could drive down the costs of observatories relying on robust wavefront-sensing-and-control techniques to assure the collection of sharp, perfectly focused light.

The Concept

Under the VNC concept — whose development NASA currently supports through several technology-development programs — starlight collected by a primary mirror or telescope travels down the instrument's optical path to the first of two beam-splitters within each arm of the interferometer. The MMA is located in only one arm. A second beam-splitter recombines the beams into two output paths known as the "bright" and "dark" channels. The starlight passes to the bright and the planet light to the dark.

Because MMA is a mirror image of the telescope, it can see wavefront and amplitude errors caused by vibration, dust, and turbulence that prevent the light from being perfectly focused as it's collected.

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The MMA not only senses those errors, but also takes care of those issues. Algorithms that Lyon developed calculate errors in the telescope's wavefront and instruct MMA's 169 tiny mirror segments — each perched atop tiny finger-like devices — to piston, tip, and tilt up to thousands of times per second to precisely correct the distortions and then cancel the starlight in the dark channel. A second technology, the spatial filter array, passively acts in concert with the MMA to further correct both amplitude and wavefront errors. Combined, these technologies allow the mirror array to create an internal coronagraph to suppress starlight and increase the contrast of the circumstellar region surrounding a star, thereby allowing scientists to detect planets and dust disks.

Applications Abound

While unique in its application as a coronagraph, MMA and its associated wavefront-sensing-and-control technologies, hold great promise for other applications, including medical imaging, LASIK eye surgery, and even military gun sights, Lyon said. But for NASA, the benefit lies in being able to fly less expensive telescopes.

"Ultimately with this technology, you can get away with a low-cost, low-risk primary mirror," Lyon said. In contrast, JWST's much larger segmented mirror was expensive to build. Technicians carefully constructed the mirror segments to an exact optical prescription and then mounted them on a mechanism that positions each to perfect alignment, much like the tiny fingers on MMA.

To assure a perfect focus, however, JWST will first image a target. After ground controllers have analyzed the image with multiple algorithms, they then can send commands to tweak the mirrors' alignment. This compares with MMA's ability to perform up to thousands of wavefront calculations per second, position the mirror segments, and then maintain a tight alignment — all from onboard the instrument.

"The idea is can we come up with something that is up to hundreds of times more precise than JWST's wavefront control? I think we can. We're doing it now in a standard lab. If you can do wavefront sensing and control fast enough, which we've proven, you can get away with a not-so-great telescope," Lyon said. ❖

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The BigBENI Solution

Novel Planet-Finding Technology Provides Viable Alternative for Long-Sought Science Goal

Due to budget constraints, NASA has delayed for now an ambitious mission to image Jovian-size planets and eventually those as small as Earth. However, a Goddard scientist believes it's time to look at an alternative strategy that would achieve the same science, but at a significantly reduced cost.

"We're not going to get a big exoplanet mission for quite a while," said Principal Investigator Rick Lyon. "That got us thinking. What could we do with a balloon?"

His solution? BigBENI.

Also known as the Big Balloon Exoplanet Nulling Interferometer, the instrument, as currently conceived, is actually a hybrid of both a coronagraph and an interferometer. Carried on a gondola attached to a high-altitude balloon, the hybrid instrument would be able to suppress starlight and increase the contrast of Jupiter-size planets, allowing scientists to detect, directly image, and characterize these gas giants and the dust disks of nearby stars.

Advances in the instrument's primary component — the Visible Nulling Coronagraph (VNC) — are happening incrementally and will likely lead within the next two years to suppression levels allowing the imaging of Earthlike planets, he said (see related story, page 4).

Switching Gears

Lyon and co-Principal Investigator Mark Clampin began working on the VNC more than three years ago when a dedicated spacecraft for photographing and taking spectral measurements of extrasolar planets was still a possibility — at least in the relatively near term. At the time, the team, which also includes Lockheed Martin and Ball Aerospace Technology Corp., hoped to use the technology on the proposed Extrasolar Planetary Imaging Coronagraph, a probe-class observatory.

Given cutbacks in science missions, Lyon said it became clear that a large planet-finder mission "is

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Measuring Transient X-rays with Lobster Eyes

New Detector Technology Promises Dual-Use Applications

A technology that mimics the structure of a lobster's eyes is now being applied to a new instrument that could help revolutionize X-ray astronomy and keep astronauts safe on the International Space Station.

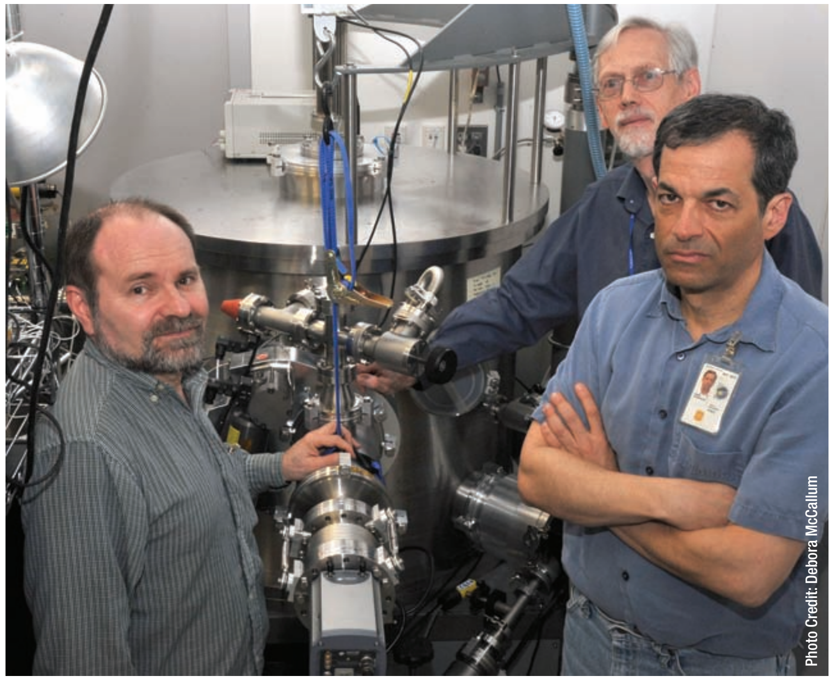

Photo Credit: Debora McCallum

Scientists (clockwise) Scott Barthelmy, Gerry Skinner, and Jordan Camp are shown here with their prototype "Lobster Transient X-ray Detector," a cross-cutting instrument that would detect transient X-rays and ammonia leaks on the International Space Station.

Scientists Jordan Camp, Scott Barthelmy, and Gerry Skinner are developing the "Lobster Transient X-ray Detector," which they hope to deploy on the space station in three to four years. From its perch on the orbiting outpost, the cross-cutting instrument would detect with unprecedented accuracy transient X-rays — those fleeting, hard-to-capture high-energy photons produced during black-hole and neutron-star mergers, supernovae, and gamma-ray bursts created much farther away in the early universe.

But the lobster-eye technology also could carry out another much-needed job.

It could check for ammonia leaks on the International Space Station — a problem Johnson Space Center engineers have identified as needing a solution. Anhydrous ammonia, a toxic compound of nitrogen and hydrogen, is used as a coolant that helps regulate onboard temperatures. Currently, leaks are at acceptable levels, but a sudden increase could pose serious risks to astronauts.

New Application for Established Technology

Lobster technology isn't new. First conceived as an X-ray all-sky monitor by University of Arizona scientist Roger Angel in the 1970s, it mimics the structure of the crustacean's eyes, which are made up of long, narrow cells that each captures a tiny amount of light, but from many different angles. Only then is the light focused into a single image.

The Lobster X-ray instrument's optics would work the same way. Its eyes are a microchannel plate, a thin, curved slab of material dotted with tiny tubes across the surface. X-ray light enters these tubes from multiple angles and is focused through grazing-incident reflection, giving the technology a wide field of view necessary for finding and then imaging transient events that cannot be predicted in advance. The Lobster detector is unique in that it is highly sensitive and provides a wide field of view and high-angular resolution.

Since Angel first conceived the concept, astronomers at the University of Leicester have matured the technology and have built an instrument to fly on BepiColombo, a mission to Mercury developed jointly by the European Space Agency (ESA) and the Japan Aerospace Exploration Agency. ESA plans to launch the spacecraft in 2014.

What's new is "what we want to do with it," Camp said. "The innovation is using the Lobster technology for a cross-cutting application. We want to use the technology in a new way to promote both astrophysics and human spaceflight."

To advance the dual-use concept, the team is using Goddard Internal Research and Development (IRAD) and NASA Office of the Chief Technologist's Center Innovation Fund support to assemble and test a prototype equipped with a commercially available microchannel plate, a charged-coupled

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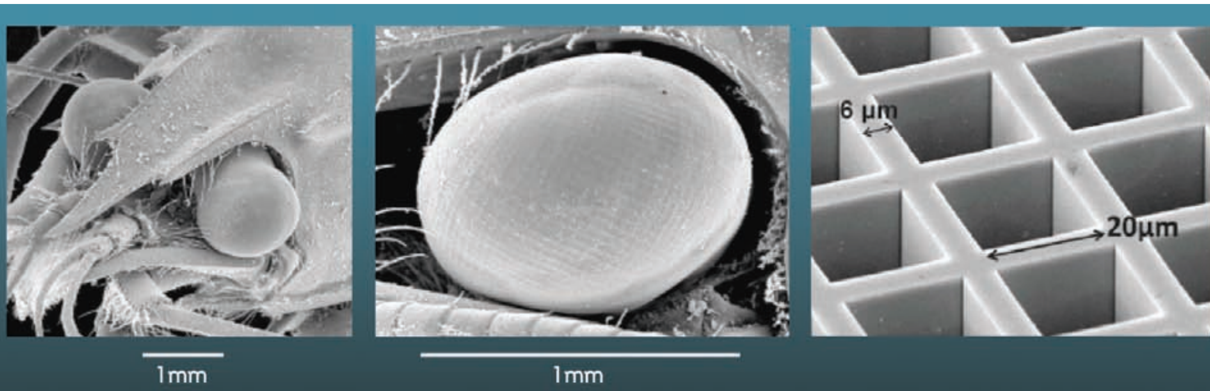

The Lobster Transient X-ray Detector borrows from nature. The images on the left and center show close-up views of a crustacean's orb; the image on the right shows a man-made microchannel plate. In addition to looking the same, the Lobster technology works like the lobster 's eye, providing a wide field of view necessary for detecting transient high-energy events that cannot be predicted in advance.

device detector, and associated electronics. The hope is to raise the technology-readiness level of a dual-use Lobster detector to at least six, making it a viable contender for an Explorer-type mission, Camp said.

Wide Field Collection of Transient X-rays

With its increased sensitivity and wide field of view, Camp said the instrument would be able to detect transient X-ray emissions from a large portion of the sky, giving scientists an unprecedented view of black-hole mergers, supernovae, and even gamma-ray bursts in the very distant universe. Transient X-rays are now difficult to detect because these sources brighten without warning and then vanish just as quickly.

He also believes the instrument could work in conjunction with and even extend the sensitivity of the Laser Interferometer Gravitational-Wave Observatory (LIGO), a National Science Foundation-funded experiment that has searched for gravitational waves since 2002. Gravitational waves, first postulated by Albert Einstein, are faint ripples in space-time that theoretically happen during massively powerful events, such as black-hole or neutron-star binary mergers.

Gravitational-wave detectors don't localize well. Used in conjunction with the focusing Lobster detector, however, scientists would be able to zero in on the location of the source, Camp said.

Detection of Ammonia Leaks on Space Station

Just as exciting, Camp said, is how he could use the technology to detect ammonia leaks. Anhydrous ammonia runs through tubing connected to huge radiator panels located outside the space station. As the ammonia circulates through the tubing, it releases heat as infrared radiation. In short, it helps to regulate onboard temperatures. Possibly because of micrometeorite impacts or thermal-mechanical stresses, these lines currently leak.

The Lobster technology could help, Camp said. With this application, however, the instrument would require the addition of an electron gun designed to bombard surfaces with electron beams at specific energy levels. Elements that come into contact with these electron beams are excited, producing X-rays at specific energy levels.

In this case, the instrument, once attached to the space station's robotic arm, would sweep over the coolant lines and radiator panels in search of nitrogen, and more specifically the X-rays generated by the element. If nitrogen X-rays are detected, their presence could indicate leaks since ammonia is a compound of nitrogen and hydrogen.

Skinner has taken the lead in assembling and testing a leak-checking detector prototype and has recently succeeded in producing an X-ray image of a small nitrogen leak in a laboratory vacuum system. Barthelmy, meanwhile, is studying the system issues involved in deploying a dual-use Lobster system on the space station.

"Many people are excited about the possibilities of this quintessentially crosscutting instrument," Camp said. "With help from our IRAD program and support from NASA's Office of the Chief Technologist, we plan to advance the technology-readiness levels of our proposed instrument. We'll see where it goes. We believe it has great potential." ❖

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Photon Sieve to Fly on Cubesat

Technology Demonstrated for the First Time in Solar Observation

Some of the more intriguing components of the sun's chromosphere can't be resolved with existing spacecraft or ground-based telescopes. However, a new imaging technology — the so-called photon sieve — promises to bring these structures to light and help scientists better understand this irregular layer above the photosphere that contributes to the formation of solar flares and coronal mass ejections.

Goddard scientists Adrian Daw and Douglas Rabin are collaborating with researchers at the U.S. Air Force Academy and other Air Force-affiliated organizations to build a small solar observatory equipped with an eight-inch (20-centimer) diffractive optic called the photon sieve. Its flight on a three-unit Cubesat in 2014 — the Air Force-sponsored FalconSat-7 mission — will demonstrate the practicality of deploying this emerging technology in space and possibly paving the way for a larger heliophysics mission in the future.

"We've studied the sun's corona for years and it's complicated. But the chromosphere, which can be seen as a thin pink layer during a total solar eclipse, is even harder to understand," Daw said. "Things are happening there at spatial scales we can't currently resolve with existing space- or ground-based telescopes."

Although a large observatory comparable in size to the Hubble Space Telescope could resolve magnetic flux tubes and filamentary plasma within coronal loops, the costs to build a conventional large-aperture solar telescope is cost prohibitive, Daw said. "The photon sieve could help us overcome this obstacle and help us provide a game-changing technology for high-resolution imaging in space," he said.

A Variant of Fresnel Zone Plates

The technology that could help bring these details to light is a variant of the Fresnel zone plate, which focuses light through diffraction rather than refraction or reflection. These devices consist of a set of alternating transparent and opaque concentric circular rings. Light hitting the plate diffracts around the opaque zones, which are precisely spaced so that the diffracted light interferes at the desired focus to create an image taken by a camera.

The sieve operates largely the same. However, the rings are dotted with millions of holes, whose sizes and positions are configured so that the light diffracts to a desired focus. As a result of its design, the sieve can be patterned on a flat surface and can be easily scaled up in size — particularly if constructed of a polyimide film similar to the ubiquitous Kapton, which spacecraft and instrument developers commonly use because it can withstand extreme temperatures and vibration.

But perhaps the most significant advantage is that the lightweight, easily rolled and deployed film

Principal Investigator Adrian Daw used IRAD funds to design and construct a ground-based breadboard imaging system shown here to test a glass version of a photon sieve. Laura Dunlap, a student at the University of Maryland-College Park (in the foreground) and Juliana Vievering, a student at the College of St. Benedict in St. Joseph, Minn., helped carry out the observation.

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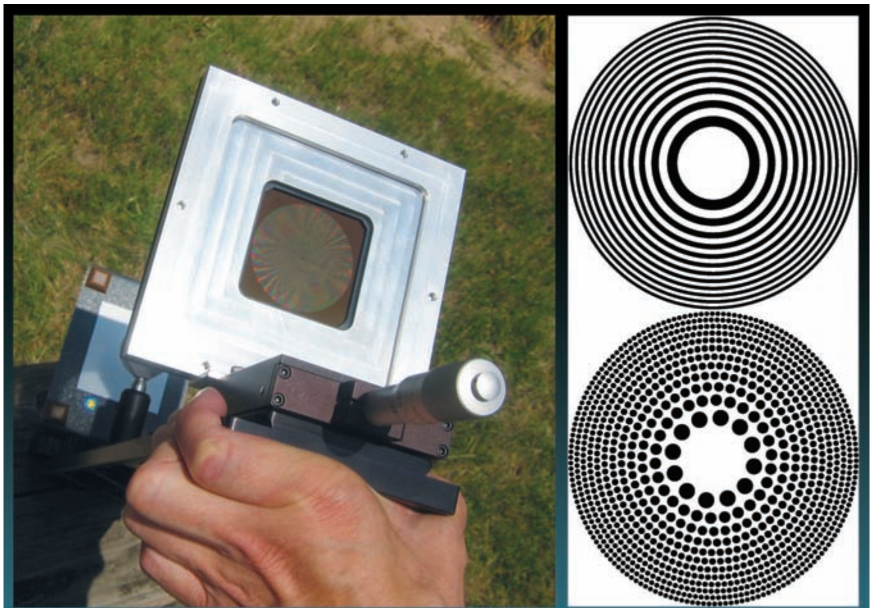

Shown here (left) is the glass photon sieve; on right are drawings of a Fresnel zone plate (top) and photon sieve (bottom).

need not be pulled to a perfect optical flatness like more traditional mirrors. In fact, surface requirements for traditional mirrors are 100 times more stringent — making the photon sieve ideal as a quick-turnaround space-based optic. This appeals to the Air Force. In the event of a catastrophic loss of its current intelligence, surveillance, and reconnaissance satellites, the military would need a simple replacement system easily deployed from a small, inexpensive satellite, like a Cubesat.

Since its invention more than a decade ago by Lutz Kipp, a professor at Kiel University in Germany, researchers at the U.S. Air Force Academy's (USAFA) Laser and Optics Research Center have experimented with different materials for making the sieve. USAFA's Geoff Andersen, Michael Dearborn, and Geoff McHarg initially experimented with chrome-coated quartz, later focusing their efforts on lightweight polyimide films or membranes. In laboratory testing, these sieves showed great promise for narrow and broadband imaging in visible wavelength bands, particularly in the H-alpha wavelength band ideal for detecting structure within the solar chromosphere.

What they lacked, however, was expertise in solar physics and some of the analytical tools needed to evaluate the sieve's deployment mechanisms. "They were looking for the best way to demonstrate their technology," Daw said. "It's easier to test imaging technologies with a really bright source, like the sun. They contacted us to see if we wanted to collaborate. Of course we did. The collaboration is proving to be of great mutual benefit to both organizations."

Goddard's Contribution to FalconSat-7

Since joining the effort, which also involves the Air Force Research Laboratory and the Air Force Institute of Technology, Goddard has contributed in two significant ways.

Goddard engineer Craig Stevens, who is a member of Daw's team, used Internal Research and Development (IRAD) and Science and Engineering Collaboration Program funding to thoroughly analyze requirements for deploying the sieve and keeping the membrane relatively flat once the Cubesat reaches its 280-mile (450-kilometer) orbit. Based on that analysis, the team is confident that a dual-hexapod deployment mechanism, equipped with lanyards and pantographs, is the best approach, Daw said.

Daw's team also used IRAD funds to design and construct a ground-based breadboard imaging system to test a glass version of the sieve. "Using this system, we took the first-ever solar images using a photon sieve," Daw said. "In fact, these are the first images of any astronomical object using a photon sieve." The next step is carrying out ground-based tests of the membrane sieve, he added.

"These two IRAD accomplishments — a ground-based demonstration of the photon-sieve technology and the analysis of the deployment system — are major advances for deployable membrane optics," Daw said.

He and his team also are investigating ways to extend the sieve's wavelength range to the extreme ultraviolet, which is most interesting to solar physicists. "The corona emits most of its light in the extreme ultraviolet," Daw said. "These developments and a successful FalconSat-7 demonstration will position us nicely for capturing a solar imaging mission in the future. This technology has lots of applications for heliophysics." ❖

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Mirror, Mirror Out in Space, How To Dust Off Your Face?

Photo Credit: Debora McCallum and Pat Izzo

Principal Investigator Fred Minetto holds the fractal Penning discharge pins he fabricated for his space-based dust buster.

One of the challenges with space telescopes and other satellite instruments is keeping their mirrors, lenses, and other surfaces free of dust and other contaminants. A Goddard researcher now has developed a way to dust these devices while the instruments are in space.

While working in his lab, Principal Investigator Fred Minetto found he could create an electric field by combining an electron gun with an item called a "fractal Penning discharge pin." The result was a proof of concept that could be used to clean space mirrors. Ultimately, he's hoping to create a device — which he calls a fractal wand — that could pass over a mirror or other sensor and simply wave off the dust.

"It's really quite dramatic," Minetto said, referring to his laboratory tests. "Our combination instrument actually blew the contamination off, in a vacuum."

Funded by Goddard's Internal Research and Development (IRAD) program and the NASA Office of the Chief Technologist's Center Innovation Fund, Minetto's work builds on the lessons NASA scientists learned when they cleaned the sensors on the Solar Terrestrial Relations Observatory (STEREO) spacecraft simply by flipping STEREO to directly face the sun. The solar wind took care of the cleaning, blowing dust and other contaminants off the spacecraft's sensors.

This method, of course, requires the instrument to stare directly into the sun, but it did give Minetto an idea.

Putting Dust in the Cross Hairs

Solar wind is actually a stream of charged particles, mostly electrons and protons, which the sun ejects from its upper atmosphere. Minetto recreated this wind by shooting dusty laboratory samples with an electron gun, a device that produces a precise beam of electrons similar to a solar wind.

Minetto combined the gun with a Penning discharge pin, developed by American scientist Hans Georg, who won the 1989 Nobel Prize in Physics for this work. The device is a small, straight metal

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pin that stores charged particles by creating both a homogeneous static magnetic field and a spatially inhomogeneous static electric field. Minetto's hybrid instrument worked well enough for him to file for and receive a patent.

"But I could only ever get movement of the dust when both the pin and the electron gun were, at most, about half-an-inch away from the contaminated surface." Beyond that distance, "I was stumped," Minetto said. For years he mulled over different ways of increasing the system's strength, and then it came to him in a dream.

"It wasn't even a mathematical thing, per se; it was visual. I saw an outline of the golden mean that I remembered from elementary-school math class," Minetto said. The golden mean, also called the golden ratio, is when the ratio of the sum of two quantities to the larger quantity is equal to the ratio of the larger to the smaller. It's a concept used in both math and art. In math, the golden mean has the unique property of saying 'a plus b' is the same to 'a' as 'a is to b.' The value of the golden ratio, expressed mathematically, is one plus the square root of five, all divided by two. The resulting number is 1.6180339887 — and on into infinity. When this is expressed in geometry, the result is an ever-curling spiral that looks like a snail's shell.

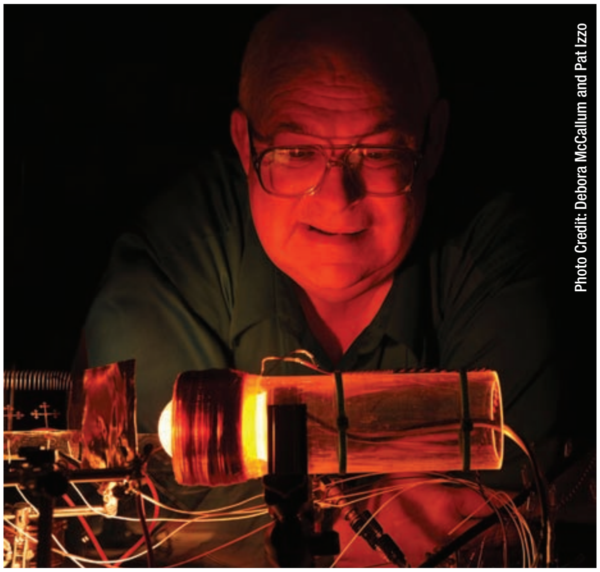
"It's interesting because it's not exactly what you'd think of as a mean, or an average," Minetto said, "and I just kept seeing it duplicated again and again and again."

Making the Call

When he woke up, Minetto looked into the math of the golden mean and found that the self-repeating pattern that he dreamt of was the same pattern used in mathematical sets known as fractals. "I dug a little more and found that this was used in antennas for our cell phones."

Cell phone antennas use fractal antennas to create a very strong signal in an exceptionally small space. These antennas look like a series of metal diamond shapes arranged first, point-to-point, and then into a second diamond shape. These shapes are arranged again into another diamond shape, over and over again.

This geometry results in the amplification of a signal. As the electricity flows from each metal diamond to another, it increases in strength. Because the pattern repeats over and over again, the signal keeps getting stronger and stronger. Minetto used IRAD funding to create hundreds of these copper metal crosses, all based on this initial fractal shape. Due to the machining process, Minetto's fractal Penning pins have a more rounded appearance. "They look like little papal crosses to me," he said.



Goddard Principal Investigator Fred Minetto is bathed in a red glow produced by an electron gun that shoots electrons at the cross-shaped, gold-colored fractal Penning discharge pins he invented.

When he combined these fractal Penning pins with the electron gun, the results were startling.

"The electron gun floods the area with negatively charged electrons. They attach themselves to the contamination, the dust, and that builds up a negative charge," Minetto said. "Then, when the fractal Penning pin comes into play, it creates this force field that blows it all off, and at the end, you've got a clean mirror."

Overall, it only took three fractal iterations to improve the strength of the electric field more than 400 percent, and, as a bonus, that meant less power was necessary to operate the electron gun. That's a big plus when it comes to adding this technology to a satellite because power supplies on satellites are very limited.

Minetto is now perfecting this process in a small glove-box chamber in his laboratory, with an eye toward finding a way to combine the electron gun and the fractal Penning pin into the same device — his so-called fractal wand. "I'm still not sure how I'm going to combine the two," he said. "I probably need to sleep on it." ❖

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Days of Launching Gizmos Return

NASA Team to Test New Vehicle-Descent Technologies

Technologists at the Jet Propulsion Laboratory (JPL) and Wallops Flight Facility will get a chance next summer to relive the good old days when NASA engineers would affix space-age gizmos to rockets just to see if the contraptions worked.

In what will be the first of four high-altitude balloon flights to begin in the summer of 2013, the team is preparing to test new deceleration devices that could replace current descent technologies for landing ever-larger payloads at higher elevations on Mars. NASA hasn't tested deceleration technologies supersonically since 1972 when it conducted four high-altitude tests of a supersonic parachute used during the Viking program. "We've been stuck with that design ever since," said Mark Adler, NASA's Low-Density Supersonic Decelerator (LDSD) program lead. NASA will use the same technology again this year when it delivers the Curiosity rover to Mars.

However, planetary landers of tomorrow will require much larger drag devices than any now in use. "What we need is new technology to slow larger, heavier landers from the supersonic speeds of atmospheric entry to subsonic ground-approach speeds," Adler said.

The LDSD program is aimed at giving NASA a new and improved capability. Funded by the NASA Office of the Chief Technologist, the JPL-led team plans to conduct full-scale, stratospheric tests of three potentially breakthrough technologies. The aim is to raise their technology-readiness levels to about six, which means they could be used in a flight project, perhaps as early as 2018.

The first two are supersonic inflatable decelerators, large pressure vessels that inflate around an entry vehicle and slow it from Mach 3.5 or faster to about Mach 2. One of these inflatable devices measures nearly 20 feet in diameter (six meters), the other nearly 26 feet (eight meters). The third technology is a 110-foot (33.5-meter) parachute to further slow the entry vehicle from Mach 2 to subsonic speeds needed for a safe landing. All three would be the largest devices of their kind ever flown at speeds several times greater than the speed of sound.

The design calls for the team to attach a test vehicle equipped with the decelerator and parachute to a Wallops-provided high-altitude balloon. Once the balloon reaches an altitude of about 22 miles (36 kilometers) above Earth's surface, the rocket would fire its engines and carry the test vehicle to Martian atmospheric densities at an altitude of 31 miles (50 kilometers) at Mach 4. There, the test vehicle would deploy the supersonic decelerator, followed by the parachute.

NASA is conducting a series of rocket sled tests at the U.S. Naval Air Weapons Station at China Lake, Calif., in preparation for full-up tests of the Low-Density Supersonic Decelerator.

Perfect Marriage of Capabilities

The project leverages the strengths of both organizations, said Scott Schaire, Wallops LDSD acting project manager. While JPL and its contractors are developing the test vehicle, decelerators, and parachute, Wallops is responsible for balloon operations, balloon instrumentation, and other operations associated with balloon launches.

One significant Wallops-provided technology is an entirely new balloon launch system — an effort Schaire's team undertook specifically for the supersonic tests. With this new system, the test vehicle will be suspended from a vertical, 80-foot tower. Its job is preventing the test vehicle from hitting the ground as the balloon begins to lift off. A modified apparatus that resembles a farm-irrigation system will help technicians lay out the balloon and a new spool vehicle will hold the balloon until launch.

In the first test as early as August 2013, the team plans to evaluate the performance of both the decelerator and parachute. "Launching small rockets from large balloons," Schaire said. "What could be a better project for Wallops?" ❖

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Spacecraft Cleanroom Goes Green

When it launches in 2014, NASA's new Magnetospheric Multiscale (MMS) mission is expected to give scientists unprecedented insights into a little-understood physical process that sparks solar flares, coronal mass ejections, and other phenomena that can imperil Earth-orbiting spacecraft and even power grids on terra firma.

But the technological advances that will make MMS possible aren't restricted to the mission's four identically equipped spacecraft.

Some technological advances are found inside a 4,200-square-foot facility where Goddard engineers and scientists are assembling and integrating the four spacecraft, which will study the mysterious process that occurs when magnetic fields cross and reconnect, releasing magnetic energy in the form of heat and charged-particle kinetic energy. This phenomenon causes flares and coronal mass ejections in the sun and geomagnetic storms in Earth's atmosphere. These storms can wreak havoc on spacecraft orbiting in low-Earth orbit and cause surges that take down power grids.

"Everyone can get very excited about the science MMS will gather. That's the cool part," said Goddard Facilities Project Manager Dave Richardson, who managed the facility's development. "But what people may not appreciate is that a lot of state-of-the-art technology went into enabling this mission."

Warehouse Transformed

The new facility sits within a former warehouse that a Goddard team transformed into a "smart cleanroom." The air inside the new facility is relatively free of dust, aerosol particles, and chemical vapors — contaminants that can damage highly sensitive science instruments. To give perspective, outdoor air in a typical urban area contains 1 million particles per cubic foot. But the MMS cleanroom will have no more than 10,000 particles per cubic foot. These particles are small, too, measuring about half the width of a human hair.

Although cleanrooms are ubiquitous, the MMS facility stands out because it features state-of-the-art technology that not only filters air but also performs this job consuming 30 percent less energy under low-load conditions.

The energy savings are due in large part to a computer-controlled sensing system that switches off lights when no one is using the facility and

Goddard's new cleanroom, created from former warehouse space, is equipped with the latest energy-saving technologies.

orders the facility's 153 high-efficiency particulate air fans to slow down if the particle monitors sense the cleanroom has reached the required cleanliness levels. Should someone enter the facility, the system turns on the lights. When the particulate count reaches higher levels, it commands the fans to operate at higher speeds, filtering and distributing the air inside the voluminous space.

Another efficient design choice is treating 10 percent of the air to maintain the proper air conditions, said Project Manager Bill Bond, of QinetiQ North America, a contractor that operates cleanroom facilities for Goddard. The other 90 percent represents already-filtered, recycled air.

Engineering Feat

While MMS needed a relatively large space, other missions in the future may not. Therein lies another advantage of the new cleanroom, designed and built by CleanAir Solutions of Fairfield, Calif.

"It's versatile," said company President Kathie Kalafatis. Unlike fans in traditional cleanrooms that run at full throttle at all times, this cleanroom senses particulates and modulates the fan speed up and down depending on the particle readings. This allows technicians to partition off parts of the room to accommodate different missions. "I always call it the room-in-a-room concept," she said.

"This really is a creative design, and I really appreciate what the design team came up with. They looked at many, many ways we could maximize the cleanroom size, make it versatile, and meet performance and energy-reduction goals," Richardson added. "This is a darn interesting engineering feat." ❖

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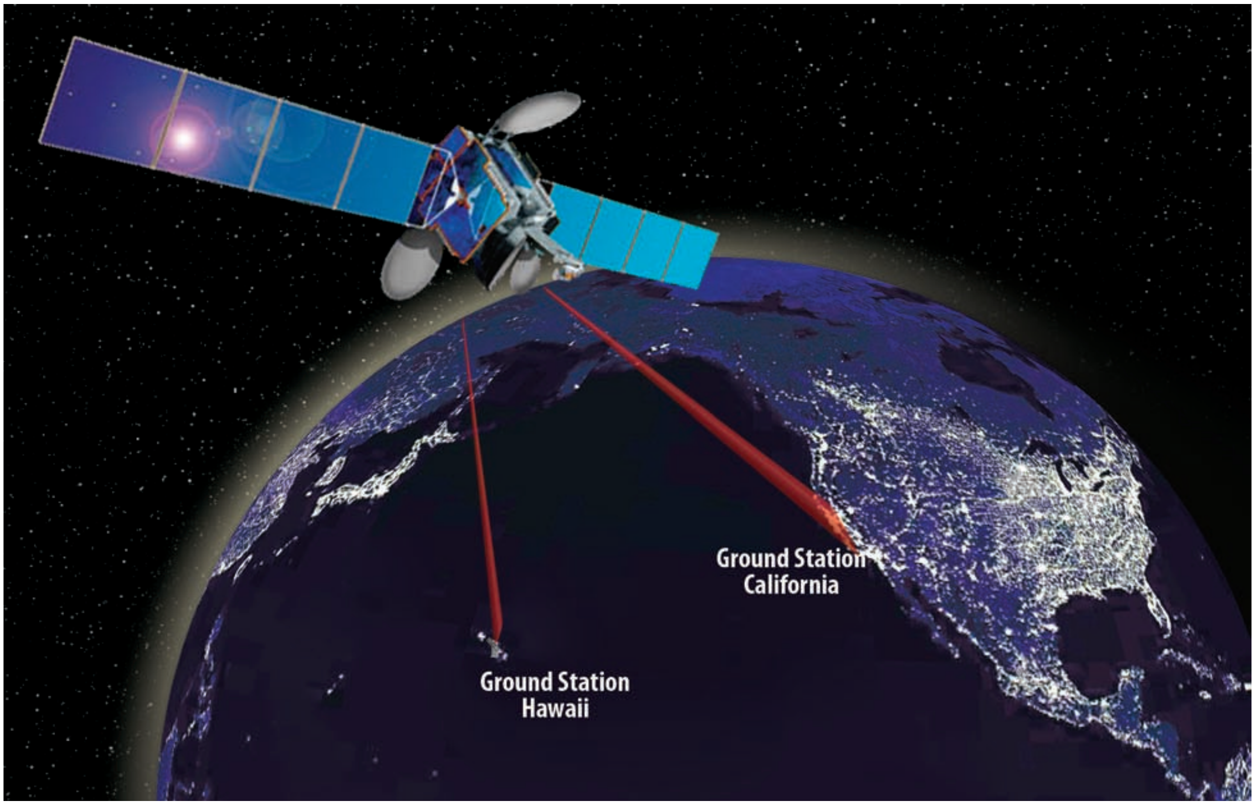
Mason Peck, *continued from page 3*



The Goddard-led Laser Communications Relay Demonstration project is one of the NASA-funded technology-demonstration missions that shows great promise, says NASA Chief Technologist Mason Peck.

You've been the Chief Technologist for only a few months. But in your relatively short time at NASA, which technology developments here at NASA exemplify the best in R&D, at least from your perspective?

There's probably no single one. I'll tell you that I'm particularly excited about the lasercom demo. The prospect of using the same amount of power to pack 10 times as much information into a data stream than we currently can, that is — not to overuse the word — a game changer. That will increase by an order of magnitude the data we can get for science. As you know right now, 10 to 20 percent of the images we take on Mars stay on Mars. It also complements human space activities. Again, it's one of those cross-cutting, broadly applicable activities. But it's only one.

Going all the way to the other end of the scale to early-stage innovations, I want to highlight NIAC, the NASA Innovative Advanced Concepts program. Fascinating work is being done there. Not to pick on one in particular, I'll give you the example of the project looking at Cubesats for interplanetary exploration. Cubesats, of course, are small spacecraft, the size of a small loaf of bread. They're typically seen as informal projects that can be conducted within universities. And the fact that small companies are now building components and creating viable commercial enterprises around these small satellites means that for years to come we'll be able to leverage what is commercially available. Although it may be 10 years before we see planetary science missions, the fact is they remain on the horizon.

Coming from academia, you may have a better perspective on how NASA could work with the universities. What is your advice to academics interested in collaborating with the Agency? How important do you think collaboration is in R&D?

One really important message is that we're experiencing a renaissance in technology at NASA and the Space Technology Program is open for business. We're able to support universities now in a way that we haven't been able to previously. Specifically, we now have several programs that universities can directly benefit from. One is the Space Technology Research Fellowships Program that supports graduate students. I'm also pleased

Continued on page 15

to say that we now have the Space Technology Research Grants Program, which supports faculty interested in engaging in NASA-relevant space technology. But let's not forget the broader scope of this. It's absolutely essential that we get the best ideas from wherever they arise. We really are casting a very wide net for ideas at every stage of innovation.

Technologists recognize program managers' reluctance to incorporate new technologies into their missions. How do you view risk? What is the best way to manage risk?

"The fact is, we are returning NASA to its technology roots. And that return is welcome."

— Mason Peck, NASA Chief Technologist

If we're talking about an $8-billion mission, it makes perfect sense for a program manager to manage risk as vigorously as he or she can. But when we undertake smaller-scale activities, which we are doing — particularly those that encourage new technology exploration with small satellites — our risk posture needs to be scaled accordingly. Applying the same level of rigor that we apply to a large space telescope or a Mars rover, for example, to a $1-million technology activity is inappropriate. We waste our effort and we miss out on opportunities to realize the benefits of technology.

You outlined a few areas where technologists could get involved in this program. What is your advice to technologists, who are not currently involved in the program, but would like to be?

It is very much a new day at NASA in terms of technology development. The Space Technology Program is a young one. And for that reason, I don't think a lot folks are yet familiar with the opportunities it represents. Because we are casting this wide net, because we're trying to encourage broad community engagement, all comers are welcome. We're looking for academics, small and large businesses, private individuals, and partnerships with other government agencies to bring good ideas to bear. One way to find out what NASA is interested in is taking a look at our technology roadmaps and NRC's assessment. It's not the final story, but for now, it's the best information we have to help folks understand what areas matter to NASA. Soon enough we'll have that strategic technology investment plan. It will fuse all that information together. Once we publish it, the plan will provide the clearest information for understanding what we're interested in.

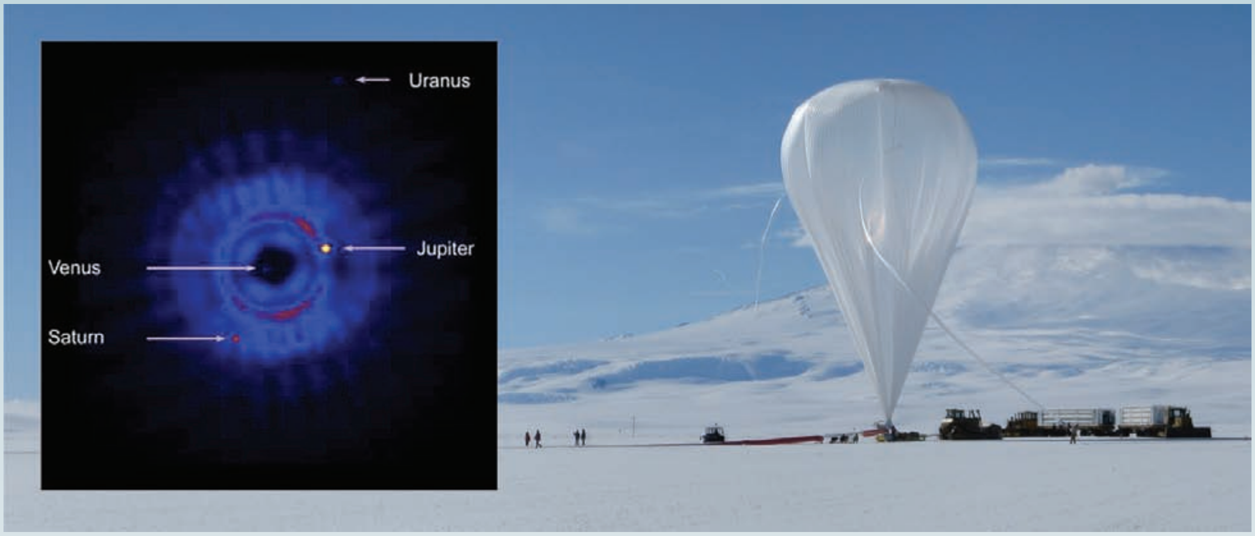
What challenges to you see on the horizon?

One thing I will say is that we already know there are more technology opportunities than we possibly can afford to invest in. Without going into specific examples, I can tell you there are going to be some conflicts, some areas where we want to invest and need to invest, but can't afford to invest. So, we're going to balance those needs. But in doing so, we're going to reach out to other government agencies to make sure we can leverage their capabilities and maybe their resources where it makes sense, and vice versa. So that's the challenge. We have more to do than we can afford to do.

Are there any comments you would like to add?

Yes, one quick reminder. It's a point we make a lot, but I'll mention it again. When we invest in technology, we do further NASA's interests. But we don't spend that money in space; we spend that money here on Earth. That investment in small and large businesses and the people at NASA centers ripples out to the rest of the economy. We are doing much more than exploring space. We also are enabling our country to be competitive, thanks to technology investment. So I want to leave folks with a reminder that we do technology because it means something important for the rest of the country. It's not just about NASA. ❖

BigBENI, *continued from page 5*



Principal Investigator Rick Lyon wants to fly the Visible Nulling Coronagraph (VNC) technology on a balloon-borne instrument called BigBENI. The artist's rendition on the left shows what the VNC would see if it were searching for planets around our sun.

unlikely in the near future" and that he "really had to use what was available" to satisfy the scientific community's long-held goal of searching for life beyond our solar system by imaging and characterizing planets in other solar systems. The team switched gears and focused their efforts instead on modifying the instrument to fly in near space aboard a long-duration balloon.

Since then, the team has used both Goddard and NASA technology-development funds to steadily advance the VNC and its associated technologies, including two that could potentially revolutionize wavefront sensing and control. One of these technologies is a tiny deformable mirror currently made up of 169 individual segments.

Ultimately, BigBENI's deformable mirror will contain 313 segments. Each segment pistons, tips, and tilts to cancel starlight, creating a coronagraph that blocks light from a star so that nearby objects can be seen. No other coronagraph has been made of segmented mirrors, Lyon said. Given the team's progress and laboratory tests confirming the instrument's ability to detect and image likely targets, Lyon believes the technology is mature enough to compete for an Explorer-type mission, with operations to begin as early as 2016.

Compelling Science

The science that BigBENI could perform is compelling, Lyon added. At 135,000 feet — the altitude at which many NASA balloons fly — Lyon estimates he could detect and image at least eight science targets in less than five hours and an additional six in about 20 hours. "This represents a significant first result and would help us better define realistic science goals if NASA pursues a dedicated spacecraft mission in the future," Lyon said.

Another advantage, he added, is that he could fly BigBENI multiple times and at six-month intervals. "With balloons, you're allowed to make mistakes," Lyon said. "You can bring the payload down, make corrections, and fly it again," he said. "BigBENI offers a nearer-term way to image planets and analyze their light for specific chemicals, like oxygen, methane, water, carbon dioxide, and ozone that might indicate the presence of life." ❖

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Cutting edge Goddard's Emerging Technologies

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