National Aeronautics and Space Administration

Goddard's Emerging Technologies:

On the Cutting Edge

A Report from the Goddard Office of the Chief Technologist

Goddard Space Flight Center

Greenbelt, MD

2011

R&D Achievements

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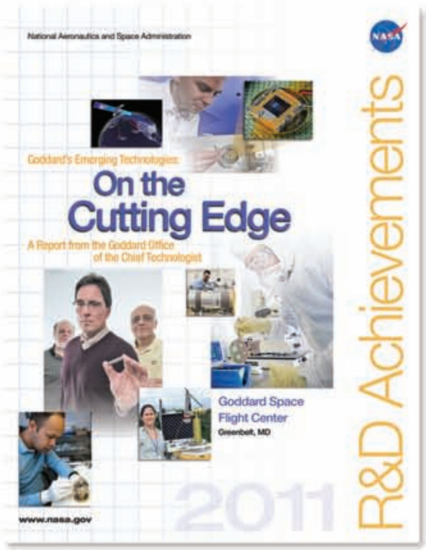

About the Cover

The cover photos depict technological developments in each of the center's core lines of business: astrophysics; communications and navigation; crosscutting technologies; heliophysics, earth science, planetary and lunar science, and suborbital platforms and launch services.

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Peter Hughes
Chief Technologist

Chapter One

Message from the Chief Technologist:

Goddard's Emerging Technologies: On the Cutting Edge

Our technology-development program has consistently generated measurable and increased returns on investment over the past six years. Yet we're not satisfied with the status quo. We're continuing to push harder. We're thinking bolder.

Though we still tie our investments to Goddard's strategic lines of business (LOBs) (see list on page 3), we're dedicating a larger share of our resources to developing potentially revolutionary technologies that simply don't advance capabilities in increments, but potentially leapfrog existing approaches — in essence the definition of cutting edge. The aim is to do bigger science and enable whole new missions, while reducing mission risks and costs. The aim is to be at the cutting edge.

We remain steadfast in that goal. Since FY07, we've increased our investment in early-stage, emerging technologies by 300 percent.

In addition to our own IRAD investments, early-stage innovation received a big assist in FY11 with the official rollout of NASA's Office of the Chief Technologist's (OCT) Space Technology Program, which consists of a variety of funding initiatives. In addition, Goddard technologists received funding under OCT's Center Innovation Fund, which provides funding to each center to invest in even higher-risk, crosscutting technologies.

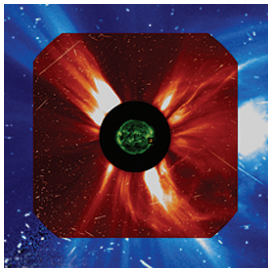
We're thrilled with the positive results, both in our own IRAD program and the OCT-sponsored efforts, and believe the decision to invest more resources into cutting-edge technology is bearing significant results. Tied to our core lines of business and OCT's own strategic direction, our investments are resulting in mission wins, follow-on funding, concept validations, and collaborations that ultimately could keep Goddard and the Agency at the cutting edge of exploration and science. Our relatively modest investment in R&D is translating into millions of dollars in new awards — a key metric in determining the success of our program.

This report chronicles some of the successes on Goddard's technology front as we work to keep our investments competitive and forward reaching.

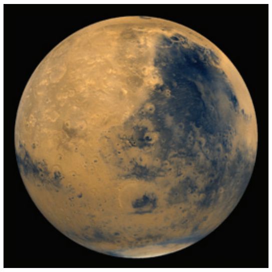
Peter M. Hughes
Chief Technologist

Astrophysics

Earth Science



Heliophysics



Planetary and Lunar Science

Suborbital Platforms and Launch Services

Chapter Two

Staying Strategic:

Goddard's Line of Business

The secret to our R&D success is our methodology — the focus and discipline we employ to identify investment priorities, unmet needs, and target opportunities. Also critical are our LOB management teams, which play a key role in identifying and selecting promising new technologies and encouraging our technologists to compete for IRAD resources, technology funding now available through NASA's Office of the Chief Technologist, and more traditional Directorate funding sources.

Our LOBs include:

Astrophysics

Focuses on missions and technologies enabling the study of galaxies, stars, and planetary systems beyond our own solar system.

Communications and Navigation

Supports systems and technologies needed for responsive communications and navigation.

Crosscutting Technologies

Addresses capabilities that touch on two or more strategic LOBs, everything from nanomaterials, electronics and detectors, to system architectures.

Earth Science

Supports technologies and advanced science instruments needed to observe and understand changes in Earth's climate system.

Heliophysics

Focuses on capabilities essential for understanding solar structure and magnetic activity, solar wind, solar disturbances, and their effects on Earth's upper atmosphere.

Planetary and Lunar Science

Supports technologies to explore the solar system, particularly instruments for landers and orbiting spacecraft.

Suborbital Platforms and Launch Services

Supports mechanisms typically used to place payloads into suborbital attitude, including sounding rockets, balloons, manned and unmanned aircraft, and Cubesats. Range services include assets for conducting, launching, and managing missions.

Chapter Three

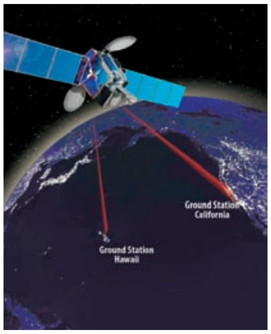
A Year in Review:

A Snapshot of the Year's Notable Achievements

It often takes years for new technologies to mature; therefore we use a variety of metrics to gauge our effectiveness. The ultimate and most tangible measure is whether Goddard-developed technologies are chosen for inclusion in new mission or instrument opportunities. Another is whether the technology receives follow-on funding from external sources to continue its maturation. Other metrics include successful flight demonstrations of emerging technologies, the delivery of hardware for upcoming missions, and the development of enhanced capabilities that bring about discovery. We detail these accomplishments in this chapter.

New Missions, Explorer Phase-A Studies, and Flight Opportunities

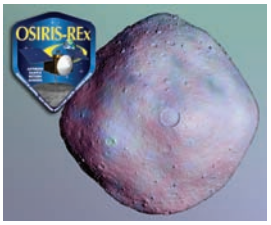
The crowning achievement of any technology program is an investment that leads to the award of a new spaceflight mission or instrument opportunity. In FY11, principal investigators won new missions and demonstrated new technologies on NASA high-altitude aircraft, sounding rockets, Cubesats, and scientific balloons.



This artist's rendition shows the mission concept of the Laser Communications Relay Demonstration project selected by NASA's Office of the Chief Technologist.

Laser Communications Relay Demonstration

One of three projects selected under NASA's Office of the Chief Technologist's new Technology Demonstrations Missions program is the Laser Communications Relay Demonstration (LCRD) project. LCRD will demonstrate an operational optical communications system featuring both ground and space assets. The effort, valued at more than $200 million, involves a hosted payload on a commercial communications satellite and two specially equipped ground stations in California and Hawaii. The demonstration, led by Principal Investigators Dave Israel and Bernie Edwards, is expected to launch in 2016 and operate for two to three years. *(LOB: Communications and Navigation)*



The OSIRIS-REx mission will collect a sample from an asteroid and return it to Earth for analysis. A previous IRAD helped the principal investigator retire a mission risk.

OSIRIS-REx

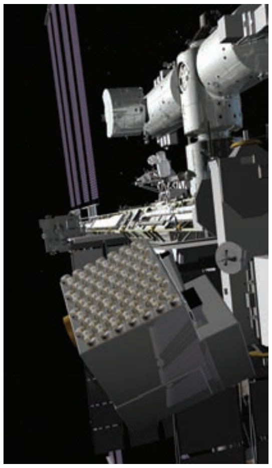
When NASA selected Goddard's OSIRIS-REx mission in FY11, few realized the role that IRAD played in the mission's development. Jason Dworkin used his FY06 IRAD to determine whether hydrazine contamination from the spacecraft would destroy organic compounds, particularly amino acids. In short, Dworkin was able to test a plausible hypothesis, finding, in the end, a negative result. His discovery allowed the OSIRIS-REx team to propose a greatly simplified mission design and retire a potential risk early in the mission's formulation phase. *(LOB: Planetary and Lunar Science)*

Low-Density Supersonic Decelerators

A second Technology Demonstration Mission the NASA Office of the Chief Technologist selected is the Low-Density Supersonic Decelerators initiative, which will develop supersonic inflatable decelerator and parachute technologies. These capabilities will allow scientists to send larger payloads and with greater precision to higher elevations on Mars. Though led by the Jet Propulsion Laboratory, the Wallops Flight Facility is responsible for balloon operations, instrumentation, flight and ground safety, ordnance handling, range coordination and recovery, among other tasks. The team will begin conducting full-scale stratospheric tests of these breakthrough technologies in 2013. *(LOB: Crosscutting Technologies)*

Atmosphere-Space Transition Region Explorer

Principal Investigator Robert Pfaff won $1 million to carry out an 11-month Phase-A study detailing his proposed Atmosphere-Space Transition Region Explorer (ASTRE). The mission would study the interaction between Earth's atmosphere and ionized gases in space. By flying excursions deep into Earth's upper atmosphere, ASTRE measurements would improve satellite drag models and show how space-induced currents in electric grids originate and evolve with time. Should NASA choose ASTRE as one of its Explorer missions, Pfaff said the mission would benefit from technology developed for the IRAD-funded Plasma Impedance Spectrum Analyzer instrument. *(LOB: Heliophysics)*



This artist's rendition shows the NICER instrument payload and its position on the International Space Station. The instrument also demonstrates X-ray communications and a novel navigational approach where pulsars are used as a time and navigation standard, much like atomic clocks on GPS satellites.

NICER

Principal Investigators Keith Gendreau and Zaven Arzoumanian won $250,000 to develop a Phase-A study for the proposed Neutron Star Interior Composition Explorer (NICER), expected to fly on the International Space Station. The experiment would consist of 56 compact X-ray telescopes, advanced detectors, and other technologies to explore the exotic states of matter within neutron stars and reveal their interior and surface compositions. Implementation of the NICER science experiment also advances technology. Gendreau and Arzoumanian hope to demonstrate pulsar-based navigation and the world's first X-ray communication system in space from the same platform. This three-in-one instrument concept earned the NICER team recognition as Goddard's FY11 "IRAD Innovators of the Year" (see page 17). *(LOBs: Astrophysics and Communications and Navigation)*

Cats on Space Station

Scientist Matt McGill won $12 million to adapt the Cloud-Aerosol-Transport System (CATS) as one of the first U.S.-provided "hitchhiker" instruments to be installed on the International Space Station's Japanese Experiment Module. Slated for completion in two years, CATS will provide long-term observations of clouds and aerosols to study their influence on atmospheric circulation and precipitation. The payload is inspired by a similarly named instrument that McGill developed with IRAD funds for flights on ER-2 aircraft. "Airplane CATS" was successfully tested for the first time in April 2011. *(LOB: Earth Science)*

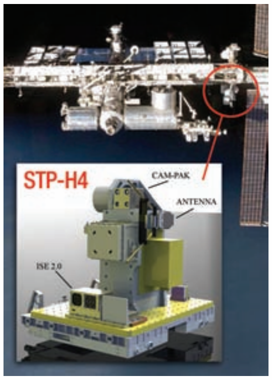
A new CO2 Sounder Lidar, developed in part with IRAD funds, again proved its effectiveness during a field campaign in 2011. The CO2 Sounder Lidar team is show here inside a DC-8. From top left (clockwise): Haris Riris, Jim Abshire, Bill Hasselbrack, and Mike Rodriguez.

CO2 Sounder Lidar

The IRAD-funded CO2 Sounder Lidar proved again in aircraft demonstrations that it can meet the measurement criteria of a next-generation carbon-measuring mission, the Active Sensing of CO2 Emissions over Nights, Days, and Seasons. The field campaign, carried out on a DC-8 over several Western and Midwestern states in July, was supported with $4.5 million in Earth Science Technology Office funding awarded earlier in FY11. Unlike current carbon-measuring instruments, the CO2 Sounder Lidar carries its own light source and can measure through thin clouds and particles, which prove troublesome for passive instruments. *(LOB: Earth Science)*

Follow-On Funding and Demonstrations to Advance Technology-Readiness Levels

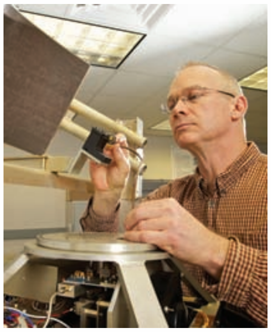
The IRAD program is not meant to provide cradle-to-grave support. Therefore, a key success metric is whether principal investigators succeed in securing follow-on funding to further advance their technologies. In FY11, these funding sources came from NASA's Office of the Chief Technologist (OCT), the Earth Science Technology Office's Instrument Incubator Program (ESTO-IIP) and Advanced Component Technology (ACT) programs, the Astronomy and Physics Research and Analysis (APRA) program, and the Strategic Astrophysics Technology (SAT) program, among others.



This composite shows STP-H4, a military-sponsored experiment pallet, and its location on the International Space Station.

Four Technologists Secure Berth on STP-H4

In FY11, four Goddard technologists secured berths on the Air Force Space Test Program's (STP) experiment pallet to demonstrate multiple advanced technologies. To deploy on the International Space Station in 2013, the pallet will include SpaceCube 2.0, a next-generation onboard processor that is 25 times more robust than traditional flight processors (see page 14); a miniaturized electrohydrodynamic thermal-control technology, which uses electric fields to pump coolant through tiny ducts inside a thermal cold plate (see page 10); a miniaturized heliophysics instrument, Firestation, that uses spare parts from a similar experiment to fly on a Cubesat mission also slated to fly in 2013; and the Winds-Ion-Neutral Composition Suite, which will study the ever-changing dynamics of Earth's upper atmosphere (see page 16). *(LOBs: Crosscutting Technologies and Heliophysics)*



Technologist Paul Racette is working with Northrop Grumman Electronic Systems on advanced antenna technologies that could enable the proposed Aerosol-Clouds-Ecosystem mission.

Antenna Technologies for 3-D Imaging

Bolstering Goddard's growing radar capabilities, Principal Investigator Paul Racette received $4.5 million in ESTO-IIP funding to advance antenna technologies for a novel dual-frequency Doppler radar that provides fixed-beam operation at W-band and wide-swath imaging at Ka-band from a common aperture. By combining the antenna systems, the team can develop a smaller, lighter, and lower-cost instrument to measure

Ocean Radiometer for Carbon Assessment

Principal Investigator Chuck McClain received $4.3 million in ESTO-IIP funding to develop a flight-like prototype of the Ocean Radiometer for Carbon Assessment, also known as ORCA. ORCA is a next-generation instrument that would measure marine photosynthesis. The instrument is a frontrunner for the proposed Aerosol-Cloud-Ecosystems mission recommended by the National Research Council. *(LOB: Earth Science)*

This artist's rendition shows the data-gathering technique EcoSAR will employ to measure biomass.

EcoSAR

The ESTO-IIP program awarded Principal Investigators Lola Fatoyinbo and Rafael Rincon $4.3 million in FY11 to mature key components of a new instrument called EcoSAR, which will help close the gaps in scientists' understanding of the carbon cycle. Significant progress was made. The team also tested the technologies in a three-week P-3 aircraft campaign in August-September 2011, traveling as far north as Quebec and as far as Florida. EcoSAR traces its heritage to Rincon's L-Band Digital Beamforming Synthetic Aperture (DBSAR), initially developed with Goddard R&D funding (see item below). *(LOB: Earth Science)*

Advanced Antenna for Digital Beamforming Synthetic Aperture Radar

Also in FY11, Principal Investigator Rafael Rincon won a $499,000 in ESTO-ACT funding to develop a wideband L-band phased-array antenna, which Rincon plans to eventually fly on a second-generation DBSAR. The design is compact and lightweight, allowing scientists to easily install the DBSAR on a range of aircraft, thereby providing more opportunities to capture measurements for carbon-cycle research. *(LOB: Earth Science)*

Harvey Moseley holds the detector that Goddard technologists developed for a revolutionary, far-infrared spectrometer called MicroSpec.

HgCdTe Infrared Avalanche Photodiode Single Photon Detector Arrays

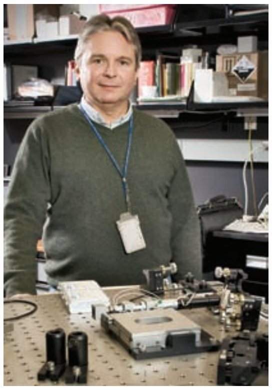
Principal Investigator Xiaoli Sun won nearly $2 million in ESTO-ACT funding to advance a highly sensitive array detector for a swath-mapping lidar for the recommended Lidar Surface Topography Survey mission. The lidar is electrically efficient and uses 1,000 parallel laser beams to simultaneously profile the elevation of Earth's solid surface and its overlying covers of vegetation, water, snow, and ice. *(LOB: Earth Science)*

MicroSpec

A new miniaturized far-infrared spectrometer that is expected to be 10,000 times more sensitive than competing instruments received a boost in FY11 from NASA's APRA program. MicroSpec Principal Investigator Harvey Moseley and his team received $1.5 million in funding to further advance MicroSpec whose components would fit onto a silicon chip measuring just four inches in diameter. The instrument would probe a wide range of environments, including distant galaxies in the early universe and stars forming in our Milky Way. *(LOB: Astrophysics)*

Principal Investigator Will Zhang has won APRA funding to advance a new fabrication technique for making X-ray mirrors.

Engineer Dan Kelly mounts a next-generation microshutter array in a vacuum chamber for testing.



Scientist Rick Lyon is pictured in the lab where he and other team members currently are developing new technologies that would allow scientists to image Jovian-size planets beyond our solar system.

Compact Remote Sensing Lidar

To further bolster the capabilities of the CO2 Sounder Lidar (see page 6), Principal Investigator Haris Riris won nearly $1 million in ESTO-ACT funding to develop a lidar operating in the near infrared that could measure methane, carbon dioxide, and other greenhouse gases. *(LOB: Earth Science)*

Magnetically Coupled Microcalorimeter Arrays

In his FY11 IRAD, Principal Investigator Thomas Stevenson sought to develop a magnetic penetration depth thermometer — an enabling detector technology for a revolutionary X-ray camera for imaging spectroscopy. Based in part on the results of that IRAD effort, Stevenson and his University of Maryland partner, Simon Bandler, received $844,000 in APRA funding to further advance the detector. Of that amount, Goddard will receive about $576,000, which Stevenson said should help improve his team's competitive posture in X-ray microcalorimeters. *(LOB: Astrophysics)*

Lightweight X-ray Mirror Using Mono-Crystalline Silicon

Three factors affect X-ray optics: angular resolution, effective area per unit mass, and production cost. In general, these three factors conflict with one another. Principal Investigator Will Zhang won $800,000 in APRA funding to advance a new fabrication technique that would allow scientists to build X-ray mirror segments that provide high-angular resolution, yet are less massive and expensive to produce. The method uses an industrial material and commercial polishing technique. *(LOB: Astrophysics)*

Next-Generation Microshutter Array

The Goddard-developed microshutter array is considered among the most innovative technologies flying on the James Webb Space Telescope. With $744,000 in APRA funding, Principal Investigators Harvey Moseley, Mary Li, and Alexander Kutyrev are continuing their efforts to advance a new approach that promises to potentially revolutionize an already groundbreaking observing technology. The team is now creating an array whose tiny shutters are opened through electrostatic actuation, rather than mechanically by a magnet that sweeps over the array. The shutters allow only light from targeted objects to enter a spectrograph. *(LOB: Astrophysics)*

Compact Achromatic Visible Nulling Coronograph

NASA's Strategic Astrophysics Technologies program awarded scientist Rick Lyon nearly $650,000 to advance an important planet-imaging technology — the Visible Nulling Chronograph (VNC). This hybrid interferometer could be coupled to a single telescope to suppress starlight and increase the contrast of the circumstellar region surrounding a Jovian-size planet. The idea is to retire technology risks early so that Lyon and his team can compete for a planet-finding mission when NASA releases an Announcement of Opportunity in the future. Should NASA seek such a mission, Lyon's technology would be competing with other techniques for imaging planets. *(LOB: Astrophysics)*

Balloon-borne Experiment with Superconducting Spectrometer

With $264,000 in APRA funding, Principal Investigator John Mitchell will finish analyzing data from the Balloon-borne Experiment with Superconducting Spectrometer (BESS) experiment and prepare for another BESS mission possibly in Spring 2013. The sophisticated high-energy particle detector is capable of completely identifying and characterizing incident cosmic-ray nuclei and elementary particles by measuring their charge, charge-sign, mass, and momentum (energy). BESS has been the premier, balloon-borne instrument for measuring cosmic-ray antiprotons, which are interesting in their own right, as well as providing important tests of candidate explanations for dark matter. *(LOB: Astrophysics)*

Technologist Marvin Noreiga is shown here with a next-generation oven that is being developed for the proposed VAPoR instrument.

Volatile Analysis by Pyrolysis of Regolith

A new instrument that borrows heavily from Goddard's Sample Analysis at Mars instrument suite received nearly $144,000 from the Moon and Mars Analog Missions Activities program in FY11. Principal Investigator Danny Glavin used the support to continue field tests of the new suitcase-size instrument, Volatile Analysis by Pyrolysis of Regolith (VAPoR). VAPoR features an improved oven and eventually a miniaturized time-of-flight mass spectrometer ideally suited for lunar and planetary studies, including those of asteroids. *(LOB: Planetary and Lunar Science)*

Sensor for Aerosol and Trace Gas Retrieval

Principal Investigator Scott Janz received $144,000 in ESTO-IIP funding to develop a prototype sensor for retrieving aerosol and trace-gas data. The instrument is being developed to fly on aircraft and validate data gathered by the proposed Geostationary Coastal and Air Pollution Events mission. *(LOB: Earth Science)*

Enhanced Aluminum Mirror for Far-Ultraviolet Astronomy

The SAT program awarded $98,000 to a team led by Principal Investigator Manuel Quijada to increase the reflectivity of optical surfaces in the far ultraviolet. Current coating technology does not provide good reflectivity much below 120 nanometers, preventing scientists from carrying out important science that can be done only at shorter wavelengths. The team is investigating the viability of depositing aluminum-magnesium-fluorine coatings onto a hot substrate, as opposed to the normal process of depositing the coating onto substrates at room temperature. Used on small optics, the technique now will be tested on larger optics under the SAT funding. *(LOB: Astrophysics)*

Critical Support Capabilities

Some technologies are not meant to provide scientific data; their sole purpose is to provide technologists and others with capabilities that assist them in their quest to develop advanced instruments or to interpret data needed by the public. These capabilities include everything from specialized laboratories to instrument subsystems.

This is a breadboard device to prove the concept of using electrohydrodynamic-based thermal-control techniques for microscale applications.

Electrohydrodynamic Thermal-Control Systems

Principal Investigator Jeff Didion received funding from the Air Force Office of Strategic Research to further advance an emerging IRAD-funded thermal-control technology — the electrohydrodynamic (EHD) pump. Didion, who has demonstrated EHD on sounding rocket flights, also will get a chance to demonstrate the technology on the International Space Station in 2013 (see page 6). The miniaturized technology promises to make it easier and more efficient to remove heat from small spaces, vastly expanding the capabilities of advanced instruments and microprocessors. The technology offers widespread applications to commercial products. *(LOB: Crosscutting Technologies)*

Ground Truthing Lunar Data

Principal John Keller and his partner, the Oak Ridge National Laboratory, received Lunar Advanced Science and Exploration Research support to develop a laboratory that will ground truth interpretations of data gathered by current and future lunar spacecraft, particularly as they relate to the formation of water on the Moon. The laboratory will examine the relative importance of impacts by highly charged ions and micrometeorites on the lunar regolith. *(LOB: Planetary and Lunar Science)*

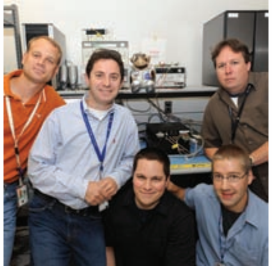
Jennifer Sichler, Karin Blank (not pictured), and Semion Kizhner have developed a next-generation data-processing system based on the world-renowned Hilbert-Huang Transform Method.

HHT-Based Data-Processing Tool

An engineering tool that implemented a set of algorithms made famous by former Goddard scientist Norden Huang for analyzing data and images from nonlinear and nonstationary sources — everything from ocean currents and earthquakes, to traffic moving over bridges — is about to become more capable. Principal Investigator Semion Kizhner is completing a next-generation data-processing system based on the world-renowned Hilbert-Huang Transform (HHT) Method. Called HHT2, the technology takes data analysis to the next level of sophistication. It enables the characterization of spatial connections between pixels, such as water near forests, roads near buildings, or to differentiate a relatively smooth area from a textured one. *(LOB: Crosscutting Technologies)*

High-Energy Lab Astrophysics

Twenty-five years ago, scientists began developing and operating advanced X-ray spectrometers to analyze plasmas created at the Lawrence Livermore National Laboratory. The measurements are used to validate and improve the models scientists use to interpret spectra from astrophysical X-ray sources. With $800,000 in follow-on APRA funding, Principal Investigator Scott Porter is continuing that work. He will use the funding to operate the third-generation cryogenic X-ray spectrometer, which is similar to what NASA will fly on Astro-H in 2014, and begin building the fourth-generation spectrometer based on technology destined for an International X-ray Observatory-like mission. *(LOB: Astrophysics)*



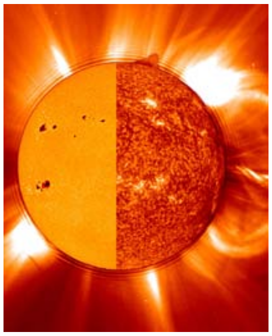
The Navigator team shown here advances its Navigator technology to receive GPS signals even at lunar distances.

Next-Generation Navigator GPS Receiver

The Goddard-developed Navigator GPS receiver, which quickly acquires and tracks weak GPS signals above and below the GPS constellation, already has been slated to fly on NASA's Magnetospheric Multiscale mission. With IRAD funds, the technology's developers are now further advancing the technology. In FY11, the team, led by Principal Investigator Luke Winternitz, completed the design and assembly of an advanced digitally steered antenna array and successfully demonstrated the tracking of live GPS signals. The team also enhanced the MATLAB array signal simulator used to successfully test beamforming and weight-design algorithms. The simulator was key to the successful demonstration. *(LOB: Communications and Navigation)*

Spaceborne Computing

Future space missions will require significant increases in onboard processing to handle the expected increases in data rates. Multicore processors have become common in commercial electronics, and with the development of the radiation-hardened Maestro processor, they are becoming viable for spaceflight applications. Using $542,000 in funding from NASA's Exploration Technology Development and Demonstration program, Goddard Principal Investigator Wes Powell and his team began investigating ways to advance multicore technology for use in space. In related work, Principal Investigator Daniel Mandl used an FY11 IRAD to gain experience using Maestro multicore processors for hyperspectral applications. *(LOBs: Crosscutting Technologies and Earth Science)*



Goddard's Space Weather Center keeps tabs on the Sun and alerts its customers to potentially harmful solar storms, such as the coronal mass ejection captured here in this image.

Space Weather Center

The Space Weather Center received NASA support for two full-time employees to help implement "ensemble" forecasting at Goddard's Space Weather Center, the organization responsible for keeping tabs on the sun and alerting NASA, the Air Force, and others if the sun does something that could be potentially harmful to astronauts and spacecraft. Ensemble forecasting allows scientists to run multiple conditions at a time — a technique that weather forecasters use to create computer models that help track, for example, storm paths. The enhanced capability will improve the center's forecasts, particularly timely since the Sun has entered its period of maximum activity. *(LOB: Heliophysics)*

Spherical Primary Optical Telescope Testbed

In FY11, Principal Investigator John Hagopian continued the development of a Spherical Primary Optical Telescope (SPOT) testbed, which consists of three, one-meter-class segments. SPOT will help demonstrate advanced wavefront sensing and control technologies. The testbed, which Hagopian plans to complete in FY12, will demonstrate the advantages of near-real-time wavefront sensing and control that technologists can then apply to other segmented telescopes. *(LOB: Astrophysics)*

Chapter Four

Technologies to Watch

Research and development is a high-risk endeavor. In some cases, the research doesn't yield the expected outcome or result. In others, the principal investigator achieves precisely what he or she set out to accomplish. Here we spotlight just a few IRAD-funded efforts that are early-stage, often higher-risk technologies that could one day result in Goddard creating new opportunities and helping NASA carry out its science and exploration missions.

Astrophysics

Atom Interferometry

Principal Investigator Babak Saif, who is teaming with Stanford University and the California-based AOSense, Inc., is exploring atom interferometry for use as phase sensors to detect gravity waves, gravity gradiometers in geodesy measurements, and as precise navigational devices. Atom optics is an emerging technology that exploits the wave character of atoms.

ExoPlanetSat

ExoPlanetSat (EPS) is a Cubesat that Principal Investigator Stephen Rinehart is designing and building in collaboration with the Massachusetts Institute of Technology and Draper Laboratory. Chosen for launch between 2012 and 2014, EPS is being designed to look for transiting exoplanets in the habitable zones of their parent stars. Rinehart created a first cut of the spacecraft's thermal model and bolstered the team's understanding of what will be needed for spacecraft testing.

Lobster Transient X-Ray Detector and Application to the International Space Station

The scientific goal of the Lobster Transient X-ray Detector team, led by Jordan Camp, is the development of a detector useful for time-domain X-ray astronomy. The detector is needed to measure compact binary mergers, gamma-ray bursts, and supernova shock breakouts. The technology, however, can be used for detecting ammonia leaks — a capability that could be used on the International Space Station.

Communications and Navigation

Precision Navigation Strategies for Sample-Return Missions

Sample-return missions to primitive solar system bodies, including asteroids and comets, can provide a wealth of scientific information about the composition and origin of the solar system. Principal Investigator Kenneth Getzandanner and his team are developing a baseline navigation strategy and bolstering in-house simulation and navigation analytical tools needed to navigate to and return samples from these primitive bodies. The team's work is especially important now that Goddard has won the OSIRIS-REx mission (see page 4) in 2011.

Crosscutting Technologies

Cleaning Telescope Mirrors with Electron Beams

A challenge with space telescopes is preventing dust and other particulates from contaminating their surfaces. Technologists already have demonstrated the effectiveness of using electron beams to remove massive amounts of dust from contaminated surfaces; however, the electron gun that produces the electron beams must be positioned only three inches from the telescope's surface. Principal Investigator Fred Minetto discovered that the approach is just as effective when the electron gun is positioned as far away as three feet. The increased distance allows technicians to cover a larger surface, making it a more efficient method for cleaning mirror surfaces.

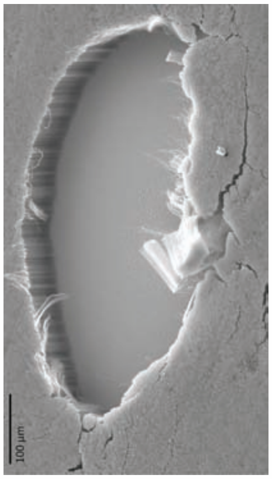
Technologist Mahmooda Sultana examines graphene film under an optical microscope.

Graphene

The rush is on worldwide to perfect a "miracle" material believed to be the strongest, most conductive material ever developed. Technologists, led by Mary Li and Mahmooda Sultana, have accepted the challenge and in FY11 set up fabrication facilities to produce graphene for use as a transparent conductive electrode. In testing, the team proved that its sample performed better than the current state of the art.

Controlled-Expansion Alloys

NASA has always had a need for alloys that are immune from shrinkage or expansion due to extreme changes in temperature. These materials, suitable for mounting optics and detectors in spacecraft, provide the stability needed to capture the stunning images and data the public has come to expect from NASA observatories. Principal Investigator Tim Stephenson and his team are developing a process for designing alloys that perform to a specific coefficient of thermal expansion (CTE) — in particular, the lower CTE range where silicon and many glasses used in optics are required to perform. By the end of 2011, Stephenson expected to complete four different alloys and begin testing in 2012.



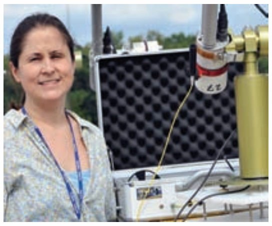
This close-up view shows the internal structure of a carbon-nanotube coating that absorbs about 99 percent of the ultraviolet, visible, infrared, and far-infrared light that strikes it. A section of the coating, which was grown on smooth silicon, was purposely removed to show the tubes' vertical alignment.

Super Black Carbon-Nanotube Coating

Principal Investigator John Hagopian and his team last year received the FY10 "IRAD Innovator of the Year" award for their work advancing a highly absorbent carbon-nanotube coating. Under their FY11 IRAD, they showed in testing that the material absorbs on average more than 99 percent of the ultraviolet, visible, infrared, and far-infrared light that hits it. No one else has achieved this milestone yet. For NASA, the results are highly promising. These tests show that the material is especially useful for spaceflight applications, where observing in multiple wavelength bands is important to scientific discovery.

SpaceCube 1.0 is now being tested on the MISSE-7 experiment pallet. Technologists are expanding "radiation-tolerance-by-design" technology for a next-generation processor, SpaceCube 2.0, which will fly on another military-sponsored experiment pallet to be deployed on the International Space Station in 2013.

Goddard technologists are studying three different techniques for corralling particles and transporting them via laser light to instruments on rovers and orbiting spacecraft.



Principal Investigator Emily Wilson Steel successfully packaged and tested an inexpensive laser heterodyne radiometer for measuring three important carbon-cycle gases — carbon dioxide, methane, and carbon monoxide — all from a small suitcase.

Radiation-Tolerance By Design Technology

Principal Investigator Daniel Espinosa is expanding "radiation-tolerance-by-design" technology for Xilinx field programmable gate arrays used in a next-generation processor, SpaceCube. SpaceCube 1.0 is now being tested on the MISSE-7 experiment pallet flying on the International Space Station. The team expects to apply advances to SpaceCube 2.0, which is slated to fly on another military-sponsored experiment pallet to be deployed on the orbiting outpost in 2013 (see page 6).

Tractor Beams for Sample Collection

Principal Investigator Paul Stysley won $100,000 from the NASA Innovative Advanced Concepts program — created exclusively to spur the development of "revolutionary" space technologies — to study three experimental methods for corralling particles and transporting them via laser light to an instrument on a rover or orbiting spacecraft for analysis. With the Phase-1 funding, Stysley's team will study the state of the technology and determine which is appropriate for sample collection, with the ultimate goals of formulating a possible system and advancing the technology to the next level.

Earth Science

AERONET

In FY11, Principal Investigator Emily Wilson Steel successfully packaged and tested an inexpensive laser heterodyne radiometer for measuring three important carbon-cycle gases — carbon dioxide, methane, and carbon monoxide — all from a small suitcase. The instrument, composed of commercially available telecommunications components, is competitive as a ground-validation instrument. Currently, the only ground-based network that measures atmospheric carbon dioxide and methane is the Total Carbon Column Observing Network; however, only two of its 16 sites are in the U.S. Steel's goal is to deploy her mobile instrument at a Goddard-run network, NASA's AERONET, which runs more than 450 aerosol-monitoring instruments worldwide.

In a related effort, Principal Investigator Si-Chee Tsay established a network of thermal-dome-effect corrected pyranometers in collaboration with the AERONET project. This capability will generate datasets of surface downward solar and terrestrial irradiance with unprecedented precision and accuracy — information needed in climate-related research. In addition to incorporating the instrument into AERONET, Tsay is working with a South African research group to fly the instrument on the group's aircraft.

James Tilton is applying the Hierarchical Segmentation method he developed for fusing lidar with synthetic-aperture radar data.

In FY11, Goddard composite experts designed and are building the first-ever composite telescope that could house the TWiLiTE experiment.

Data Fusion Approach

More than two decades ago, Principal Investigator James Tilton created a new approach — Hierarchical Segmentation (HSeg) — for analyzing digital images, which are made up of thousands of pixels. Like a single piece of a jigsaw puzzle, a pixel often does not provide enough information about where it fits into the overall scene. HSeg, however, organizes and groups images at different levels of detail. He has applied this technique for fusing lidar with synthetic-aperture radar data. Tilton originally hoped to have his technique adopted by the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission. Since DESDynI's cancellation, Tilton is now focusing on having the data-fusion technique applied to ICESat-2 and the Carbon Monitoring System for mapping continental biomass at fine-spatial resolutions.

First-Ever Unibody Composite Telescope

Goddard composite experts designed and manufactured the first-ever unibody composite telescope. The structure may be used for Goddard's Tropospheric Wind Lidar Technology Experiment (TWiLiTE), which will operate autonomously on high-altitude aircraft as part of NASA's four-year Hurricane and Severe Storm Sentinel in 2013. The new telescope housing accommodates four telescopes — rather than just one, which is typical of most lidar systems — and would enable scientists to profile three-dimensional winds. The composite housing is ideal for this application because it is stiffer and immune to distortions caused by changes in temperature — conditions encountered when flying on high-altitude aircraft. A decision on whether to use the telescope is pending.

PACS Imaging Polarimeter

The role of aerosols in climate forcing and air quality is a research priority in Earth science. The future lies in polarimetry for measuring aerosols. To maintain Goddard's leading role in aerosol and cloud remote sensing, Principal Investigator Leroy Sparr is developing a multi-angle imaging polarimeter — the PACS imaging polarimeter — sensitive to a wide range of wavelengths, from the ultraviolet to the infrared. A demonstration is scheduled for the spring.

Heliophysics

EASCO Mission Study

The Earth Observing Solar Causes Observatory (EASCO) is envisioned as a single observatory that would study large-scale solar disturbances, especially those affecting Earth. Principal Investigator Natchimuthuk Gopalswamy carried out a Mission Design Lab study in FY11 to evaluate the feasibility of such a mission. The key accomplishment was the realization that electric propulsion makes it possible to place the large payload in the desired L5 orbit, which opens the way for proposing EASCO or a reduced version to one or more upcoming mission opportunities.

The WINCS development team includes (from left to right): Patrick Roman, Rusty Jones, and Fred Herrero. The team now is further reducing the instrument's size, increase its reliability, and improve data quality.

iWINCS

Principal Investigator Fred Herrero is now building eight units of the Winds-Ion-Neutral Composition Suite (WINCS) for upcoming Cubesat missions and a stint on the International Space Station (see page 6). While this instrument is now in big demand among scientists interested in gathering information about the ionosphere-thermosphere system, Herrero would like to further reduce the instrument's size, increase its reliability, and improve data quality. In FY11, Herrero laid the foundation for a new generation, called iWINCS. The goal is to simplify data analysis and enable onboard processing with current Cubesat computing power.

Prototype Low-Energy Energetic Particle Detector

A team led by Principal Investigator Eric Christian is developing a bench-top prototype of a hockey puck-sized low-energy charged particle instrument. The prototype allows Goddard to test improved instrument designs, which should make the center more competitive in the 30 keV to a few MeV energy range. In addition, the team now plans to fly the prototype on an upcoming Cubesat mission, which will add credibility for future mission programs, such as the Europa-Jupiter System Mission.

Scientist Eric Christian developed ultrathin silicon-nitride windows for preventing ultraviolet light and dust from contaminating sensitive solid-state detectors to be used in the ambitious Solar Probe Plus mission.

Ultrathin Windows for Silicon Solid-State Detectors

Continuing work begun last year, Principal Investigator Eric Christian manufactured and tested a flight-sized ultrathin silicon-nitride window for preventing ultraviolet light and dust from contaminating sensitive solid-state silicon detectors to be used in the Energetic Particle-High instrument flying on the ambitious Solar Probe Plus mission. Due to IRAD support, Christian believes the window technology will achieve a technology-readiness level of six by the mission's Preliminary Design Review in January 2014.

Suborbital Platforms and Range Services

Water Recovery Systems

Currently, no standard water-recovery system exists for sounding-rocket missions due to increases in typical payload mass, low reliability of heritage systems, and loss of vendor expertise. With increased emphasis on launching more missions from the Wallops Test Range, the development of a system has become increasingly more important. Principal Investigator Christopher Shreves created a prototype inflation system based primarily on commercial-off-the-shelf components adapted for sounding-rocket flights.

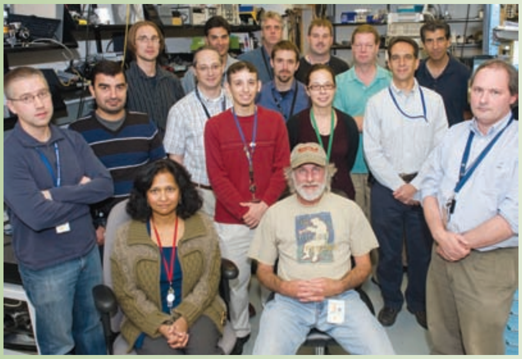
Currently, no standard water-recovery system exists for sounding-rocket missions. Principal Investigator Christopher Shreves used IRAD funds to create a prototype inflation system that could one day be used for recovery purposes.

Chapter Five

Recognizing Goddard's Top Performers

Goddard technologists Keith Gendreau, Zaven Arzoumanian, and their team were named FY11's "IRAD Innovators of the Year." We bestow the award annually on technologists who exemplify the best in R&D. The selection committee chose the team because of its sustained effort developing innovative solutions for navigating in deep space using pulsars, transmitting data via X-rays, and gathering first-of-a-kind measurements to better understand the interior composition of neutron stars.

The team's technology-development effort has reaped rewards. The NASA Science Mission Directorate recently awarded the group $250,000 to further advance the Neutron Star Interior Composition Explorer (NICER) concept, which would place an X-ray timing instrument on the International Space Station to explore the exotic states of matter within neutron stars and reveal their interior and surface compositions.



This year's winners of the "IRAD Innovator of the Year" award include (left to right): Luke Winternitz, Monther Hasouneh, John Gaebler, Jason Mitchell, Sridhar Manthripragada, Patrick Jordan, David Fickau, Michael Blau, Zaven Arzoumanian, Lalit Jalota, and Keith Gendrea. Center (left to right): Steven Kenyon, Michael Moreau, and Alissa Mitchell. Front (left to right): Clara Hollenhorst and Nicholas Spartana.

NICER Also Advances Technology

Principal Investigator Keith Gendreau holds a sample X-ray mirror assembly, the type that will be used in his proposed NICER instrument.

The same mission concept, however, also advances technology. With the NICER instrument, equipped with 56 state-of-the-art X-ray telescopes, Gendreau and Arzoumanian hope to demonstrate two potentially groundbreaking navigation and communications technologies. In particular, this year's Innovators of the Year hope to demonstrate pulsar-based navigation and the world's first X-ray communication system in space, which has the potential to provide high data rates at low power over vast distances. The NICER three-in-one instrument truly exemplifies crosscutting capabilities so important to NASA.

In addition to Gendreau and Arzoumanian, team members include Michael Blau, David Fickau, John Gaebler, Monther Hasouneh, Clara Hollenhorst, Lalit Jalota, Patrick Jordan, Steven Kenyon, Sridhar Manthripragada, Alissa Mitchell, Jason Mitchell, Michael Moreau, Nicholas Spartana, and Luke Winternitz.

Chapter Six

The Final Event:

Scenes from the FY11 IRAD Poster Session

The IRAD year culminated with the annual "IRAD Poster Session," which showcased the work of nearly 90 principal investigators and attracted hundreds of visitors who praised the event's high-caliber content. This chapter tells the story in photos.

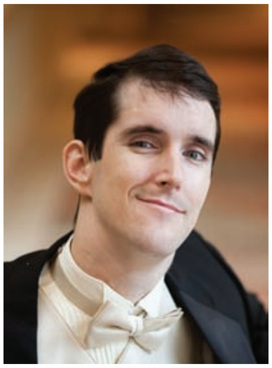
1. The annual "IRAD Poster Session" celebrating the successes of Goddard's premier R&D program attracted hundreds of visitors to the Building 8 auditorium on Dec. 1.

2. Goddard Chief Technologist Peter Hughes (left) awarded his FY11 "IRAD Innovator of the Year" award to technologists Zaven Arzoumanian and Keith Gendreau. Goddard Deputy Director for Science and Technology Christyl Johnson was on hand for the awards ceremony.

3. Co-Principal Investigators Claef Hakun (standing), Corina Koca, and Tom Capon demonstrated electro-optic components for improving the performance of infrared spectrometers.

4. Jennifer Valdez and Monther Hasouheh, two of 10 team members enhancing capabilities of the Goddard-developed Navigator GPS system, exhibited hardware created for Navigator's digitally steered antenna array.

5. Nithin Abraham and Sharon Straka displayed a novel molecular adsorber technology — for which Abraham has filed a patent — to protect sensitive surfaces from outgassed molecular contaminants.



Chapter Seven

In Memoriam:

Dan Powell (1975-2011)

In everything that he tackled, Goddard technologist Dan Powell demonstrated the rare ability to inspire, persevere, and overcome what his colleagues thought impossible. As his colleague, Ted Swanson, recalled: Powell "truly inspired me. He never gave up. He just wouldn't take no for an answer."

On Sept. 5, Powell lost his battle to complications caused by pneumonia and died at Johns Hopkins University Hospital in Baltimore, surrounded by his family and friends.

Powell, who began his career at Goddard in 2002 as a structural analyst in the Mechanical Systems Analysis and Structures Branch, championed the use of applied nanotechnology for spaceflight applications. He served as the principal investigator for a flight experiment involving carbon nanotube (CNT)-enhanced polymers and radiation-hardened memory. The memory board successfully flew aboard the Hubble Space Telescope Servicing mission in May 2009 — a groundbreaking demonstration of a CNT-based device in space.

In addition, he cofounded the Greater Washington Nanotechnology Alliance and served as the chairman of the Inter-Organization Nanotechnology Council. An expert in the development of metallic and organic-matrix composite structures, Powell received multiple patents for his work.

The news of his death stunned his Goddard colleagues, who remembered his seemingly unquenchable zest for life and unstoppable drive to make the impossible, possible. During his 36 years — 20 of them spent confined to a wheelchair because of a paralyzing injury he suffered during a flag football game at a Boy Scout camp — he accomplished so much, his colleagues said. "Despite his physical disability, Dan was bound and determined to move forward. He took a positive spin on everything," Swanson said.

Indeed, during an interview with the Office of the Chief Technologist's quarterly magazine, ***CuttingEdge***, the California native talked about the accident that changed his life. He explained that had it not been for his injury, he probably would have never focused on developing his mind and applying his vast intelligence to developing technologies that would make life better for everyone. In fact, he always continued learning, whether it was pursuing graduate studies in mechanical engineering or collaborating with colleagues from across government and industry on new nanotechnology applications.