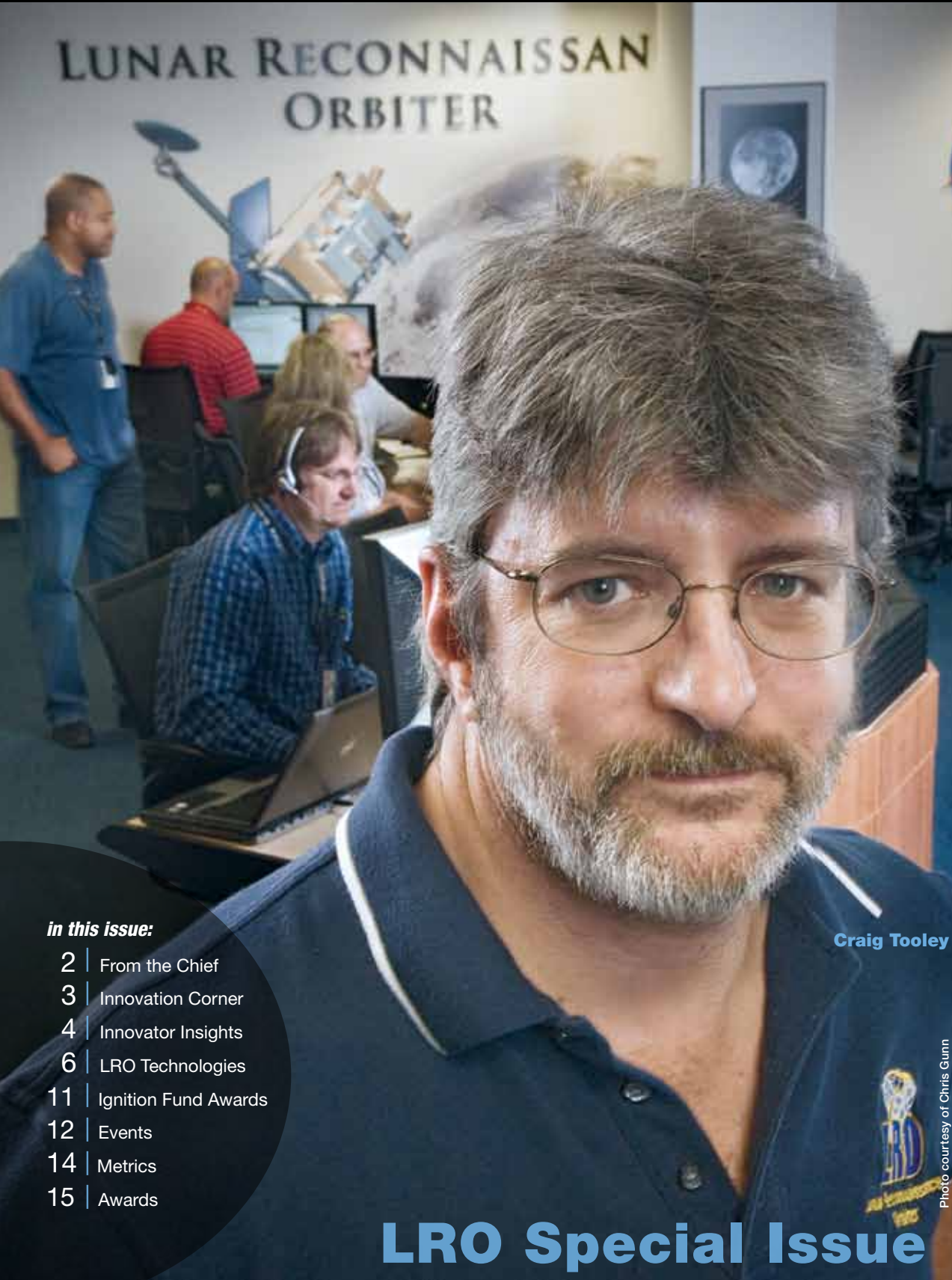




# LUNAR RECONNAISSANCE ORBITER



Craig Tooley

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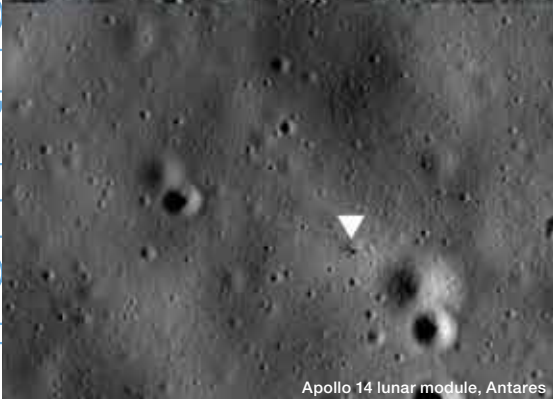
## LRO Special Issue

Photo courtesy of Chris Gunn

# tech transfer



Apollo 11 lunar module, Eagle



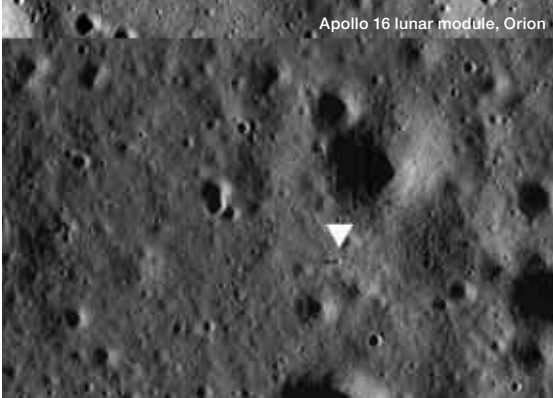
Apollo 14 lunar module, Antares



Apollo 15 lunar module, Falcon



Apollo 16 lunar module, Orion



Apollo 17 lunar module, Challenger

The Innovative Partnerships Program Office is pleased to present another special issue of Goddard Tech Transfer News. This quarter, we're featuring technologies relative to the Lunar Reconnaissance Orbiter (LRO), the first mission in NASA's Vision for Space Exploration to return to the moon and embark on future missions to Mars and beyond.



This year marks the 40th anniversary of NASA's first moon landing. On July 20, 1969, the world was captivated by images from Apollo 11's Eagle Lunar Module and the Armstrong-Aldrin moonwalk. Today, we're excited about the continuation of lunar exploration as LRO endeavors to return to the moon to address fundamental questions about the history of Earth, the solar system, and the universe. LRO will test technologies, systems, flight operations, and exploration techniques to enable future missions to Mars and beyond.

LRO has been nothing short of remarkable in its 4 1/2 year, in-house development. Its payload, now in lunar orbit, uses technologies born from previous exploration missions, demonstrating the value of innovation within NASA and the transfer of technology from one mission to another. In this issue, we explore some of the technologies and people that have made LRO possible.

We trust you will enjoy reading about LRO's incredible journey of innovation!

Nona Checks  
 Chief, Innovative Partnerships Program Office (Code 504)  
 NASA's Goddard Space Flight Center ■

*The Lunar Reconnaissance Orbiter Camera (LROC) took these images of several previous lunar landing sites*



NASA photo by Neil Armstrong

Apollo 11 Moon Landing

# LOLA Breaks New Ground with Detailed Topographic Data from the Moon

Like other instruments on the Lunar Reconnaissance Orbiter (LRO), the Lunar Orbiter Laser Altimeter (LOLA) has evolved from technology developed for previous NASA spacecraft. Thanks to several upgrades, LOLA is producing data that honors and advances the tradition of its predecessors.

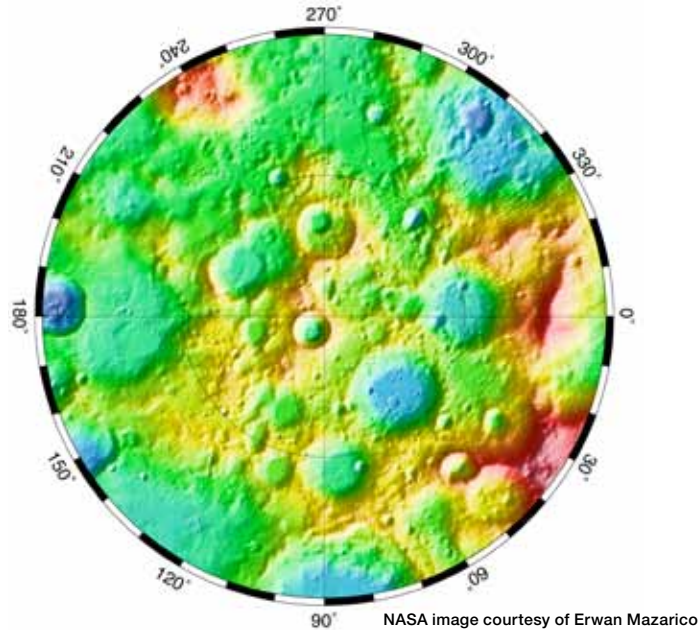
LOLA is one of seven instruments on LRO that are helping to characterize the lunar surface and provide important data, paving the way to return humans to the moon. LOLA's primary objective is to measure the lunar surface elevation and produce a geodetic topographic map of the moon for lunar science studies and future explorations. This will aid future missions by providing topographical data for safe landings and enhance exploration-driven mobility on the moon.

Conceived and built by a team of engineers and scientists at NASA's Goddard Space Flight Center, LOLA is a descendant of the Mars Orbiter Laser Altimeter (MOLA) that was flown on the Mars Global Surveyor spacecraft and the Mercury Laser Altimeter (MLA) that is currently deployed on MESSENGER (NASA's Mercury Surface, Space ENvironment, GEOchemistry, and Ranging mission). LOLA performs similar tasks to that of its predecessors, but it does so with a three to five times greater level of accuracy than MOLA and timing resolution that is significantly better than MLA.

The primary upgrade to LOLA is the use of a diffractive optical element (DOE) to split a single laser pulse into five beams, producing five independent measurements across a swath and creating a more detailed map of the local topography within a region.

"With each laser pulse, we get a more detailed understanding of the local slope and terrain, which gives us a better landing site scale topography with a single measurement," said Luis Ramos-Izquierdo, LOLA optics lead. "The upgrade from a single laser in previous laser altimeters to five on LOLA is an exciting advancement that has already generated some amazing images of the south polar region of the moon."

LOLA also is the first laser altimeter on a NASA spacecraft to carry a one-way laser ranging (LR) system that utilizes a small telescope on a high-beam antenna to optically detect and timestamp laser



LOLA is delivering valuable data and stunning images of the lunar surface, like this relief map of the the south polar region of the moon

pulses from Earth, determining LRO's precise orbit position.

"Knowing the precise location of the spacecraft helps to improve the resolution of the topographic measurement made by LOLA," said John Cavanaugh, LOLA system's engineer. "The orbit of the craft is constantly changing by meters, and determining the exact location of the satellite is essential. If you make that measurement without knowing the location of the spacecraft, you don't have an absolute reference for the topography."

These upgrades not only are helping LOLA obtain data that will assist future lunar missions, but they are also providing stunning images that will enhance the public's understanding of the moon. Members of the LOLA project team have been working to pass along the advancements from LOLA to future NASA missions—including the Geoscience Laser Altimeter System (GLAS) on the Ice, Cloud, and land Elevation Satellite-II (ICESat-II)—and they have been working closely with Goddard's Innovative Partnerships Program (IPP) Office on potential commercialization of the LOLA technology.

"The lessons learned from this mission are important for the development of the next generation of instruments," said Ramos-Izquierdo. "Future missions will be able to benefit from LOLA, just like LOLA benefited from MOLA and MLA." ■

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— Luis Ramos-Izquierdo,  
Optics Lead,  
LOLA

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It has been an honor and a real pleasure to be the project manager for this mission. I have the joy of getting to be proud of over 300 people who dedicated their lives to LRO's success over the past 4 1/2 years.

— Craig Tooley,  
Project Manager,  
Lunar  
Reconnaissance  
Orbiter project

”

*As the Lunar Reconnaissance Orbiter (LRO) project manager at NASA's Goddard Space Flight Center, Craig Tooley is responsible for the development and execution of the LRO mission. Tooley talks about this groundbreaking mission and how LRO went from inception to launch in less than 4 1/2 years.*

**Could you tell us a little bit about the projects you worked on before LRO?**

I came to Goddard in 1983 after receiving a bachelor of science in mechanical engineering from the University of Evansville in Indiana and have been here ever since, earning a master's degree in mechanical engineering at the University of Maryland along the way. I spent the first half of my career working on space shuttle-related projects, including serving as the mission manager and mechanical lead for five successful Spartan solar-science missions.

After working in the shuttle world, I moved on to be the deputy project manager for the Triana mission, an Earth-observing satellite to be placed at a sun-earth libration point that is fully developed and that NASA, together with NOAA, now plans to launch in 2012. I then joined the Hubble servicing group, where I worked as part of the EVA servicing team that developed procedures and trained astronauts for the successful Hubble Servicing Mission 3B in 2002. Immediately before being asked to start up LRO in 2004, I led the Hubble Space Telescope Instrument Development Office, overseeing the development of instruments to be installed during the fourth and final Hubble servicing mission.

**How would you describe your day-to-day responsibilities as LRO project manager?**

It has been an honor and a real pleasure to be the project manager for this mission. I have the joy of getting to be proud of over 300 people who dedicated their lives to LRO's success over the past 4 1/2 years.

The development of the LRO spacecraft was an in-house mission, so my role as the project manager prior to launch was a little different than for a mission with a prime contractor, where the spacecraft is procured. Goddard essentially served as the prime contractor, so in addition to keeping an eye on programmatic aspects of the mission such as budget and schedule, I spent much of my time directly working with the engineering and development team that designed, fabricated, and developed the spacecraft, which in many ways has been the most satisfying part of the mission.



**Craig Tooley**

Now that the spacecraft is flying, I serve as a mission director with responsibility for managing operations, making sure that all of the wheels are turning properly and everything is going as planned. The operations team does most of the post-launch work, although the systems engineers and the engineering team are engaged during the initial commissioning phase. Within the next few months, my role likely will be transitioned to the Space Science Mission Operations (SSMO) group here at GSFC.

**How did the scope of the LRO mission evolve?**

When LRO originally was envisioned in 2004, it was designed to be one in a series of unmanned missions to the moon. We were part of a stable of projects under a larger program here at GSFC. LRO evolved when NASA's Exploration Systems Mission Directorate (ESMD) decided that we didn't need to fly any additional unmanned missions to the moon, and it went from being embedded in an integrated program to being a stand-alone project here at Goddard.

**How is LRO paving the way for NASA to go back to the moon and beyond?**

The primary objective of LRO is to conduct investigations to prepare for future lunar exploration. LRO will scout for safe and compelling lunar landing sites, locate potential resources with special attention to the possibility of water ice, and characterize the effects of prolonged exposure to the lunar radiation environment. LRO's



Photo courtesy of Chris Gunn

instrument payload consists of seven scientific instruments from partner institutions around the nation and the globe, including one instrument contributed by the Institute for Space Research in Moscow. These instruments will provide lunar imagery, topography, temperatures, and more.

Returning to the moon with LRO will also enable the pursuit of scientific activities that address fundamental questions about the history of Earth, the solar system, and the universe—and about our place in them.

LRO was launched on an Atlas V 401 rocket in June and will be in a commissioning orbit until September 15, while we test and calibrate equipment. It then will move to its final orbit, a circular polar orbit approximately 50 km (31 miles) above the surface of the moon. LRO will spend a year in the NASA Exploration mission, collecting detailed information about the moon and its environment. Once the Exploration phase is completed, NASA Science will take the keys to LRO and fly it for at least 2 years as a scientific, discovery-driven project.

**How were you able to get LRO from concept to launch in less than 4 1/2 years?**

The schedule for LRO was even more aggressive than the calendar would indicate. Unlike most missions, no preliminary studies or pre-Phase A work were done for LRO; we basically started with an objective and a blank slate. So, it was a very daunting schedule from the beginning.

The most important factor in our success thus far is that we have an extraordinary team of people working on this project. We started with a core, almost turnkey team who were very familiar with each other and had experience working on projects with tight deadlines. When we assembled the initial LRO team, we were fortunate to get the individuals who we wanted to join our team as many of them sought to join the mission on their own initiative. As we brought in new people, they have assimilated into and resonated with the core team very well.

Collectively and individually, we quickly developed open and honest dialogue, which was essential because often people had been asked to do things much faster than makes them comfortable. We'd push to make quick decisions as opposed to pondering for a long time, but we also keep the lines of communication open and make adjustments, even reverse decisions, when necessary.

Other key factors are that the design of the mission as well as the hardware we used were engineered from the beginning to achieve our mission of exploring the moon and bringing back a multi-faceted atlas of information to enable the next steps for sending humans to the moon. The purpose of the mission was not to develop state-of-the-art technology—we just didn't have time for that—though we did make some exciting technology advancements. As much as possible, we adapted existing technology to meet our needs. For example, the lunar instruments on LRO are all variations of instruments that are operating around other planets in the solar system. In areas where we moved the technology forward, we often drew from technology that was already in production at Goddard. In creating the spacecraft, for instance, we tapped into state-of-the-art technology that was already being developed at Goddard, including technology that was in production for the Solar Dynamics Observatory (SDO).

**Can you give some other examples in which LRO is responsible for the creation or evolution of state-of-the-art technology?**

The state of the art for precision-pointed high-gain multi-band communication antenna systems at GSFC now resides in LRO, thanks to the work that our engineers have done to develop the LRO High-Gain Antenna System (HGAS). HGAS began under the SDO and LRO adapted the design for the harsh lunar environment. The overall LRO communication system includes a newly designed



**Craig Tooley**

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of Evansville  
MS, Mechanical  
Engineering, University  
of Maryland**

*(continued on page 10)*

## Key LRO Technologies

*The Lunar Reconnaissance Orbiter (LRO) employs many advanced innovations developed at Goddard and in collaboration with other organizations. The applications and benefits for these technologies are advantageous for many other industries as well. The following section highlights several important LRO innovations.*



*LOLA's range imaging system can optically detect laser pulses from Earth, determining LRO's precise orbit position*

Photo courtesy of Erwan Mazarico



*The Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite bound for the moon, June 18, 2009*

NASA photo by Bill Ingalls

## Space Link Extension – Return Channel Frames

### Technical Details

The Space Link Extension – Return Channel Frames (SLE-RCF) software library (GSC-15458-1) is being used by the LRO mission. It helps to monitor the health and safety of spacecraft by enabling space agency ground support and mission control centers to develop standardized and interoperable mission control applications for space telemetry data. The software library eliminates the need for missions to implement custom data communication designs to communicate with any ground station. The two main tasks accomplished via the SLE-RCF software library are processing user requests and receiving data from ground stations and ground support assets. The software library contains three layers:

- **SLE (Space Link Extension)**  
for the abstract workings of the protocol
- **DEL (Decoding and Encoding Layer)**  
to decode and encode the abstract messages used by the SLE layer
- **TML (Transport Mapping Layer)**  
to transfer the encoded messages via some underlying transport layer protocol, such as the transmission control protocol (TCP)

The library accepts configuration or SLE-RCF directives from the user and responds accordingly. Incoming data, both telemetry frames and status messages, are processed and the appropriate callback routines are triggered by the library.

### Benefits

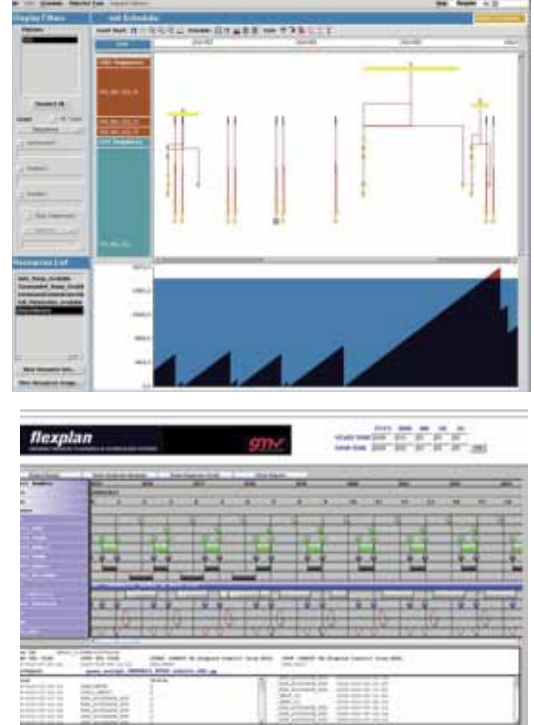
- Offers simple implementation containing less than 30 routines (whereas existing SLE-RCF libraries contain more than 1,000 routines), helping to increase reliability and easing maintenance and enhancement
- Reduces costs by significantly reducing the number of people and time needed to develop new software; for example, for LRO, what formerly would have taken five people working one year to add and modify existing software, took only one person working 3 months to develop new software
- Enables ground stations and mission user facilities across different space agencies to interoperate without the need for ad hoc and custom data communications designs

### Applications

- Worldwide mission control centers



A view of the control room at NASA's Goddard Space Flight Center in Greenbelt, Maryland, where engineers managed the LRO's arrival at the moon



NASA screen captures from the FlexPlan program

## FlexPlan Mission Planning System

### Technical Details

FlexPlan (GSC-15558-1) provides space agencies with a generic mission planning and scheduling software product that optimally organizes, schedules, and plans mission activities on the ground and onboard spacecraft—enabling ground operators to monitor the status of memory content onboard the spacecraft and the progress of planned activities throughout the mission. FlexPlan's components are divided into two categories:

- **Core components**  
modules responsible for the generation of conflict-free schedules
- **Supporting components**  
modules supporting the additional requirements of LRO and for status awareness of planned activities

Users can define flight rules and mission rules as well as events, resources (including availability profiles), tasks, and operations of the mission. Using this information, master schedules are created to define specific scenarios in the mission and break the mission up into as many scenarios as the user specifies. Additional tools detect and resolve conflicts raised by the schedule generator.

FlexPlan's modular architecture allows its components to interact via a database, enabling various components to run at different times or concurrently by multiple operators. The FlexPlan architecture allows it to be easily extended with additional modules to support specific mission requirements or needs. It has a "pluggable" architecture that uses a publicly available XML interface to adapt easily to different types of missions without the need to configure the external interface to a specific input format.

In addition, FlexPlan uses an ID system to track every output on the schedule to the input from which it was generated. This enables the system to update the status of all activities in a Web-based client. The operations team can change all the elements defined in the mission planning process during the operational lifetime of the mission.

### Benefits

- Lowers operation and maintenance costs by using Soft Algorithms, providing great flexibility that supports changes in the mission quickly and easily
- Offers a flight-proven, highly configurable design that can be efficiently configured for different missions (sometimes taking less than 1 month to incorporate new mission rules)

### Applications

- Other NASA missions including Landsat Data Continuity Mission (LDCM) and Landsat-8
- Other government agencies including the European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)
- Any mission involving spacecraft

# LRO High-Gain Antenna System

## Technical Details

Originally developed under NASA's Solar Dynamics Observatory (SDO) program, enhancements in LRO's High-Gain Antenna System (HGAS) incorporate a high data-rate Ka-band communication link as well as an S-band link for tracking, telemetry, and command of the spacecraft (GSC-15518-1).

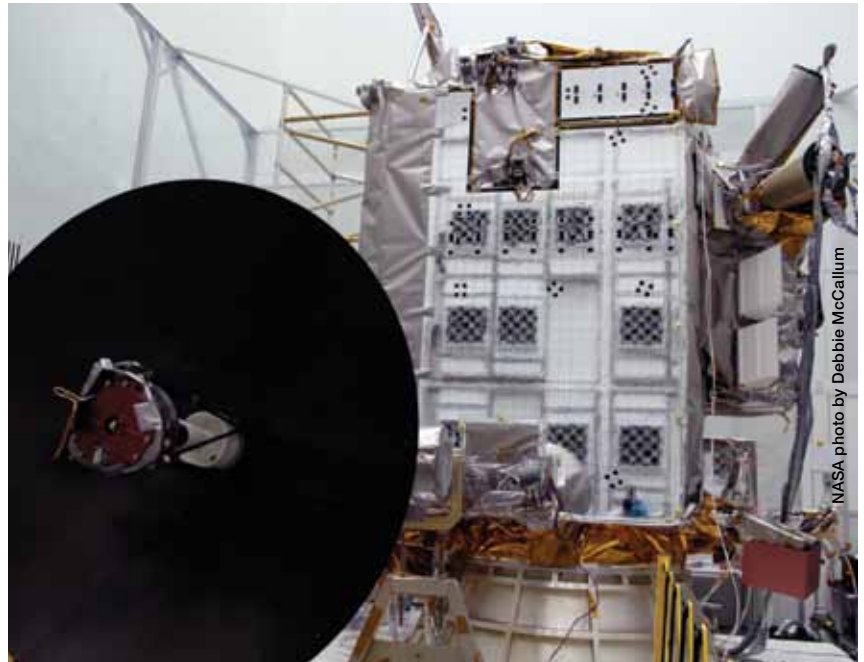
The HGAS features an axially symmetric dual reflector in a Cassegrain configuration, and a secondary reflector supported by struts over a primary reflector. This secondary reflector features an embedded Frequency Selective Surface (FSS) technology, which enables dual use of a single antenna. A Ka-band feed horn is mounted at the base of the primary reflector, and energy fed to the horn radiates to the secondary reflector, illuminating the primary reflector. The antenna's main radiation beam is formed predominantly by the energy distribution on the primary reflector. The S-band feed is housed inside the secondary reflector, at the focal point of the primary reflector. The secondary reflector is transparent to the S-band feed's radiation and reflects the Ka-band radiation from the corrugated horn feed, located at its outer focal point. Radiation from the S-band feed passes seamlessly through the secondary reflector and is reflected by the primary reflector, forming the S-band beam.

## Benefits

- Allows circular polarization at wide angles and maintains polarization purity and performance because of its novel, compact S-band feed design
- Incorporates a laser-ranging telescope that measures the distance between the Earth and the spacecraft to within 10 cm
- Employs FSS technology to enable the dual use of one antenna (Ka- and S-band), eliminating the need for two separate antennas, lowering costs, and avoiding an impractical mechanical and RF system design

## Applications

- Spacecraft that uses both Ka- and S-band communication links
- Satellite communication businesses
- Commercial antennas over a variety of bandwidths



NASA photo by Debbie McCallum

*LRO's High-Gain Antenna System stretches out toward the camera in this photo, taken in a clean room at NASA's Goddard Space Flight Center in Greenbelt, Maryland*



NASA photo by NASA/Goddard Space Flight Center

*The LRO spacecraft sits horizontally, showing its entire instrument suite*



# LRO Dynamic Model

## Technical Details

A Disturbance-Optics-Controls-Structures (DOCS) Toolbox (GSC-15385-1) is a framework for performing integrated modeling of complex systems. It allows models from different disciplines (including but not limited to structural dynamics, optics, and controls) to be coupled, enabling an end-to-end prediction of system performance in the operational environment.

For LRO, enhancement of the DOCS Toolbox allowed analysis of disturbances generated by a stepper motor mechanism. Known as the LRO Dynamic Model, this enhanced version incorporates stepper motor jitter dynamics to predict interaction between motor electro-dynamics and observatory flexible modes. The notable approach of combining the manufacturer's stepper motor model with the LRO Jitter model, developed in the DOCS framework, was chosen because it leveraged existing models, allowed access to the DOCS suite of tools, and had a significant heritage. Using the LRO Dynamic Model enabled analysis of the LRO-induced jitter for a range of actuator speeds, electrical and friction parameters, motor driver parameters, and structural parameters—enabling, under the worst-case assumptions for all parameters combined, the LRO still to be capable of meeting its optical pointing requirement. The DOCS Toolbox has been validated on the LRO Dynamic Model (comprised of finite element structural, optical, and control models).

## Benefits

- Uses existing stepper motor and discipline models to avoid an additional, costly model development effort, which can require anything from several analysts (one for each discipline) up to a large team of full time analysts (depending on model complexity)
- Employs existing models to allow risk mitigation early in the design process for identification of any potential jitter problems and reducing the cost of any required jitter management or redesign for jitter reduction

## Applications

- Other NASA missions including the James Webb Space Telescope (JWST), the Solar Dynamics Observatory (SDO), and the Terrestrial Planet Finder (TPF)
- Ground-based telescopes
- Disk and optical drive analysis
- Automotive and aircraft noise and vibration effects analysis

# Integrated Trending and Plotting System

## Technical Details

The Integrated Trending and Plotting System (ITPS) (GSC-15532-1) is a comprehensive tool for storage, extraction, and analysis of spacecraft housekeeping telemetry data. It reports information to engineers, ground controllers, and scientists regarding status and health of spacecraft and instruments. First developed for Landsat 7, ITPS was enhanced for LRO to provide a more flexible network interface supporting publish, subscribe, and messaging. This capability allows for plug-and-play and loosely coupled interfaces between the trending system and the rest of the mission operations tools. Thus, this software allows LRO to evolve as new technologies are developed or new versions are created, without affecting other components or systems in the mission management environment. ITPS can be used to monitor the spacecraft and components during pre-launch, ground-based integration and testing, and during launch and early orbit—enabling diagnostic, trending, or early issue identification.

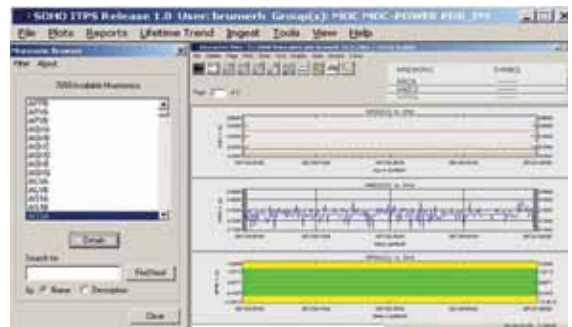
## Benefits

- Uses inexpensive personal computer, commercial off the shelf (COTS), and government off the shelf (GOTS) products to reduce mission operations and engineering costs
- Allows access to the complete full-resolution mission telemetry data archive, reducing the time to perform telemetry analysis from up to seven days to a few hours
- Increases efficiency by routine task automation and online data access
- Enables long-term trending and analyses by access to data over the life of the mission
- Improves accuracy by enabling mission management to predict or troubleshoot spacecraft issues before or after they occur, by providing timely and accurate access to all spacecraft parameters

- Decreases risk by enabling mission management to upgrade, test, or replace components without impacting other components or the existing system
- Features a modular design, enabling its use in various missions

## Applications

- Other NASA missions including SDO and Fermi Gamma-ray Space Telescope (formerly GLAST)
- Stock market analyses
- Automobile and housing industry trends and market analyses
- Any industries that need to plot data trends



NASA screen capture from the Integrated Trending and Plotting System

# Data Management System

## Technical Details

The Data Management System (DMS) (GSC-15471-1), developed for the LRO mission, manages the flow of data products between LRO's Mission Operations Center (MOC) components and between the MOC and the Science Operations Centers (SOCs). Managed data products include science products produced by the spacecraft, planning products used within the MOC and SOCs, load files to be uplinked to the spacecraft, etc. The DMS consists of a database, a web portal, and a "central agent" that run on the DMS server and "remote agent" applications that run on various computers within the MOC. The DMS is configured via an XML document that describes how the mission's products and models nominally flow. The remote agents monitor and control product flow. The central agent detects anomalies by comparing the actual flow as reported by the remote agents against the flow predicted by the model. The portal shows which products have been created and how they have flowed, allows authorized users to approve products so that they can continue their flow, and allows DMS administrators to tune the system.

## Benefits

- Reduces manpower costs associated with managing products
- Provides unified scripted procedures to flow products between computers or between folders on the same computer
- Provides unified scripted procedures to begin third party "processing" of products
- Reports and records anomalies in the product flow

- Reports and records which products have been produced and metrics on how they have flowed
- Provides an interface control description of how each type of product is expected to flow. These data flows are generated automatically from the DMS model for complete system documentation
- Provides a database containing a historical record of product flow and a web portal for querying the database
- Provides a mechanism for electronically signing/approving products and for requiring that products be approved before they can flow beyond the "wait for signature" location
- Helps manage network saturation and bandwidth by limiting how many products can be simultaneously pushed or pulled between computers

## Applications

- Other NASA missions including the Landsat Data Continuity Mission (LDCM)
- Science operations centers (SOCs)
- Science data archives
- Inventory control
- Shipping/fleet management ■

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## Craig Tooley *(continued from page 5)*

Ka-band Travelling Wave Tube Amplifier (TWTA) which was in research development at NASA's Glenn Research Center but was quickly moved forward to production for LRO. Now, the HGAS is being incorporated into the Global Precipitation Monitor (GPM) mission, and many of our engineers are moving over to GPM, continuing the Goddard tradition of sharing technology so that the next mission does not have to reinvent the wheel.

Also, the LRO flight software has been phenomenally successful. This has been one of the many highlights of the mission development. This is interesting because Project Managers often struggle with software development. When I talk with people outside of Goddard about the LRO software, they are sure that I am not telling them about the trouble, bugs, and unexpected costs we encountered while developing and implementing it. But our experience has been just the opposite. It has really been a joy to see how well the software has worked. Some of the software is new and but much of it is an evolution of what has been used here before, including the GSFC Core Flight Executive (cFE) which is at the heart of the LRO flight

software. The use of the cFE on LRO represents the first step in a much larger effort to provide an automated, platform-independent system that offers reusable software to all types of missions.

[See pages 3 and 6-10 of this magazine for more stories about LRO technologies.]

### ***How has the IPP Office and technology transfer in general been important for LRO?***

Goddard's dedication to technology development, reuse, and sharing with next-generation missions—which is fostered and encouraged by the IPP Office—is one of the reasons that Goddard got the LRO mission. NASA knew that we could complete this mission quickly and successfully, in part because of Goddard's track record for developing and promoting new technologies. I would point to HGAS and the Flight Software as specific examples. This mission has been a total team effort, and its success thus far is a significant accomplishment that should make everyone at Goddard proud. ■

## Goddard IPP Office Ignition Fund Awards

NASA's Goddard Space Flight Center has long valued and fostered the innovative spirit of its world-class scientists and engineers. This spirit has brought the world first-of-a-kind things—from pictures of the universe never previously imaged to planetary exploration capabilities beyond anything our ancestors thought possible. Goddard is renowned for having developed the most cutting-edge instruments for space and Earth exploration, inventing image analysis tools that have been recognized as Inventions of the Year, and providing state-of-the-art mission operations systems.

Goddard's Innovative Partnerships Program (IPP) Office established the Ignition Fund in 2009 to reignite the inventive spirit of our talented employees. The Ignition Fund was developed to nurture those technology ideas that are neither tested nor in a position to get NASA program or project funding. Awards of up to \$50,000 were announced in May for the following individuals and their projects. ■

Name	Organization	Technology	Description
<b>Geoff Bland</b>	SED	Advanced Techniques for Kite-Based Observations	Develop two novel techniques for kite-based observations and further adapt instrumentation for these airborne platforms
<b>William Brinckerhoff</b>	SED	Two-Step Laser Mass Spectrometry for In-Situ Organic Analysis	Begin the preliminary definition and design of a miniature two-step laser mass spectrometer (L2MS) for in-situ organic microanalysis of solid samples
<b>Jason Budinoff</b>	AETD	Assembly of a Large Modular Optical Space Telescope	Design, create, and analyze a low-cost facility within ISS to be used to demonstrate key technologies for robotic telescope assembly in space
<b>Manohar Deshpande</b>	AETD	Wideband Antenna Design and Development Concept	Develop a single wideband antenna to cover all of the frequency bands (X-, Ku-, K-, and Ka-) that are important for the Snow and Cold Land Processes (SCLP) and Surface Water Ocean Topography (SWOT) missions
<b>Kevin Fisher</b>	AETD	Rapid Prototyping for On-Board Processing of Hyperspectral Data on SpaceCube 2.0	Create a SpaceCube 2.0 simulation environment and test its ability to perform specific tasks such as the analysis of hyperspectral data to detect or rapidly analyze disasters
<b>Keith Gendreau</b>	SED	Multiplexing X-ray Fluorescence	Develop a dramatically different approach to X-ray Fluorescence (XRF) in which the detectors have simple requirements, can be made very large, and have design flexibility currently unavailable in existing XRF systems
<b>Qian Gong</b>	AETD	Point Diffraction Interferometer (PDI) for On-Orbit Wavefront Sensing	Design, fabricate, and test a simple method to measure a telescope's wavefront, independent of the sensor instrument optics, using a PDI with a star as the source
<b>John Hagopian</b>	AETD	Multiwalled Carbon Nanotubes for Stray Light Suppression	Grow longer multiwalled carbon nanotubes (MWCNT), develop a technique to adhere carbon nanotubes to a substrate, and test the adhesion to provide stray light control
<b>Sara Heap</b>	SED	Development of DMD-Based Multi-Object Spectrograph	Design, build, and test a digital micromirror device (DMD)-based, multi-object spectrograph that works at optical wavelengths
<b>William Heaps</b>	SED	Precise, Robust Sensor for Atmospheric Methane	Develop a small, simple sensor capable of measuring the total column of methane (CH <sub>4</sub> ) and water vapor from space, using reflected sunlight
<b>Mary Li</b>	AETD	Next Generation Large-Format Microshutter Arrays (NGMSA)	Design, build, and test a single microshutter array module that will be 100 times faster and 10 times smaller than state of the art
<b>Richard Lyon</b>	SED	Extremely Accurate Null Control for Exoplanets	Provide an optimal approach to null control with minimal hardware and demonstrate the approach in closed loop on an existing, upgraded null control breadboard
<b>Daniel Mandl</b>	AETD	NEREIDS—Near Real-Time Imagery for Disasters Satellites	Develop a mission concept for a constellation of three satellites to monitor disasters and emergencies with daily multispectral imaging
<b>Samuel Moseley</b>	SED	μ-Spec: A Revolutionary Compact High Performance Spectrometer	Define the requirements for and produce a preliminary design for a low-weight high-performance spectrometer, and then design, build, and test a facility that can be used to test the performance of the revolutionary spectrometer
<b>Bernard Rauscher</b>	SED	NASA Participation in Characterization of HgCdTe Avalanche Photo Diode Arrays: A Path to an Infrared Photon Counting Array	Design, build, and test electronics that will be needed for tadpole devices for quantum astronomy
<b>Ken Segal</b>	AETD	Multi-Functional Composite Structure	Design, fabricate, and test a lightweight composite thermal/mechanical structure for a sounding rocket flight opportunity
<b>Tim Stephenson</b>	AETD	A Microfluidic Device for In-Situ Genomics on Mars	Define and design a miniaturized device capable of performing in-situ environmental shotgun sequencing of microbes collected from the Martian soil and returning the sequenced genetic information to Earth
<b>Yun Zheng</b>	AETD	Exploration of a New Non-Contact Stiffness Measurement Technology	Perform a technical feasibility study using non-contact stiffness measurements to measure nanomechanical properties of a Nano E-field Sensor

AETD = Applied Engineering and Technology Directorate  
 SED = Science and Exploration Directorate

# Staff from IPP Office attended several events in summer 2009



*Goddard Celebrates 50 Years of Technology Spinoffs (L-R): Greg Moores, Black & Decker; Fred Gregory, Former NASA Deputy Administrator and veteran shuttle astronaut; Nona Cheeks, Chief of Goddard's IPP Office; Doug Comstock, Director of NASA's IPP; Greg Cole, Mainstream Engineering Corporation; and Fitz Walker, Bartron Medical Imaging*



*The IPP Office hosted an event in celebration of Goddard's 50th anniversary (L-R): Doug Comstock; Janelle Turner, IPP HQ; Sharon Moore; Darryl Mitchell; Krystal Kennedy; Dwight Norwood; Carmela Goodall; Ted Mecum; Dale Clarke; Nona Cheeks (holding a model of the Black & Decker moon drill); Enidlia Santiago-Arce; Irene Tzinis; Melissa Jackson; Laura Walker; Laura Shoppe, President of Fuentek; Rebecca Gillespie; and Fred Gregory*

## 50-Year Spinoff Art Contest (April 2009 – Greenbelt, Maryland)

Goddard's IPP Office sponsored a special art contest for students in 6th through 12th grades, encouraging them to illustrate the utilization of technology investments through technology transfer, or spinoff. The winning submission, drawn by Ja Hyun "Ashely" Lim, a student at North County High School in Glen Burnie, Maryland, depicts how the IC531 anticorrosion coating that originally was developed to protect the launch pads at Kennedy Space Center from rust and pollution now also protects the Statue of Liberty.

## Next Steps in Managing Innovation (April 2, 2009 – Baltimore, Maryland)

The IPP Office, Goddard's partner Ocean Tomo, Inc., and IPXI, Inc. hosted this unique workshop that provided information about patents, licenses, and technologies to companies interested in NASA's Small Business Innovative Research (SBIR) program. Company representatives were able to meet face-to-face with personnel from the IPP Office, Ocean Tomo, and prime contractors, to ask questions and gain insights about advancing their innovations for commercialization purposes.

## Federal Laboratory Consortium Annual Meeting (May 4-6, 2009 – Charlotte, North Carolina)

IPP personnel attended this national meeting, attending training and panel sessions. IPP Office Chief Nona Cheeks taught a "Non-CRADA Technology Transfer Mechanisms" class and took part in a panel about auctioning federal lab IP licensing rights. Technology Transfer Manager Darryl Mitchell participated in the Human Interest Panel, where he highlighted Goddard's

development of a compliant cable joint technology that was licensed to Enduro Medical Technology for use in a robotic physical therapy device called Secure Ambulation Module (SAM).

## Technical Interchange Forum (May 18, 2009 – Denver, Colorado)

This meeting brought together personnel from across NASA's IPP, the scientific and technological community, and Lockheed Martin Space Systems (LMSS) Company. IPP employees and LMSS personnel presented their respective programs and technical capabilities. Both organizations used the event as a time to explore possible partnerships to advance both NASA and LMSS missions.



*The IPP Office's Nona Cheeks (left) and Jim Chern (center) speak with Olaleye Aina, President of Epitaxial Technologies LLC (right) at the Next Steps in Managing Innovation event*

### **American Security Challenge**

(May 21, 2009 – Washington, DC)

Representatives from Goddard's IPP Office as well as other government agencies attended this event, which provides vehicles for emerging technologies to gain access to funding, contracts, or other awards to assist their vision and initiative in making the U.S. more secure. Technology Transfer Manager Ted Mecum gave a presentation about "Security Applications of Sensing and Detector Devices used for Earth and Space Science Programs" at the event.

### **Maryland's Place In Space**

(May 30, 2009 – Baltimore, Maryland)

Celebrating Goddard's 50th anniversary, Maryland's Place in Space was a public event at the Baltimore Convention Center. The IPP Office's booth at this educational event attracted hundreds of visitors, including those studying robotics at local schools. These students were able to ask questions, learn all about technology transfer, and walk away with temporary NASA tattoos and coloring books illustrating the value of technology transfer.

### **Goddard Celebrates 50 Years of Technology Spinoffs**

(June 4, 2009 – Greenbelt, Maryland)

Commemorating the 50th anniversary of NASA's Goddard Space Flight Center, the IPP Office hosted this evening event honoring the Goddard research that has developed into spin-off technologies, and highlighted significant technology transfer stories over the past five decades. The celebration included speakers from five partner organizations and IPP Office staff as well as local and regional economic development groups, technology transfer groups, innovators, and Goddard employees.



*Young attendees at Maryland's Place in Space event enjoyed the IPP Office's booth, where they could get a temporary NASA tattoo, (like the one Dwight Norwood applies to the hand of a young attendee, above) fun coloring books, and more*



*Ja Hyun "Ashely" Lim poses with her winning artwork while being presented with her certificate by Former NASA Deputy Administrator and veteran shuttle astronaut Fred Gregory*

### **Rehabilitative Engineering and Assistive Technology Society of North America**

(June 23, 2009 – New Orleans, Louisiana)

The RESNA Annual Conference is an international, interdisciplinary conference about technology and disability. Goddard's IPP Office Technology Transfer Manager Darryl Mitchell gave a presentation about the Cable Compliant Joint technology and the patent license between Enduro Medical Technology and Goddard. The license resulted in Enduro's SAM device for human and equine rehabilitation, which was made possible by the integration of the Cable Compliant Joint technology.

### **Northrop Grumman Space Technology Forum**

(June 23-25, 2009 – Redondo Beach, California)

IPP Office Chief Nona Cheeks attended this forum, which was themed "Demonstrating Advanced Capabilities for Next-Generation Systems." The event featured Northrop Grumman Aerospace Systems' leading engineers and scientists who discussed progress in developing technologies that address the hardest problems and technical challenges facing government agencies today. ■

## Patents Issued: 6

System And Method For Deriving A Process-Based Specification by James Rash (Code 585), Christopher Rouff (formerly of Code 500), and Mike Hinchey (Code 585)

Anti-Backlash Gear Bearings by John Vranish (formerly of Code 544)

Radiation Hardened Fast Acquisition/Weak Signal Tracking System And Method by Steve Sirotzky (QSS), Gregory Boegner (Code 567), Luke Winterintz (Code 596)

Conformal Gripping Device by John Vranish (formerly of Code 544)

Method And Associated Apparatus For Capturing, Servicing, And De-Orbiting Earth Satellites Using Robotics (2 patents) by Frank Cepollina (Code 442), Richard Burns (Code 444), Jill McGuire (Code 442), Nicholas Jedrich (Code 459), and James Corbo (Code 599)

## Patent Applications Filed: 1

Systems, Computer-Implemented Methods, and Tangible Computer-Readable Storage Media for Wide-Field Interferometry by Richard Lyon (Code 667), David Leisawitz (Code 605), Stephen Rinehart (Code 665), and Nargess Memarsadeghi (Code 587)

## New Technology Reports: 84

Pupil Alignment Measuring Technique & Pupil Alignment Reference to support pupil alignment measurements of instruments or optical systems by John G. Hagopian (code 551)

Space Environments Testbed (SET), Common Carrier Assembly Flight Software by David Leucht (Code 582)

James Webb Space Telescope (JWST) Integrated Ground Support System (IGSS) R5.0 by Jane Steck (Code 583)

A GIS software toolkit for converting NASA HDF-EOS data products to GIS and other geospatial formats by Brandon Moore (Aniuk Consulting, LLC)

Digital Conically Scanned L-Band Radar by Luko Krnan (Dynamic Sensing Technologies)

Core HSEG Software Package by James Tilton (Code 606)

Self-calibrating Vector Helium Magnetometer (SVHM) by Robert Slocum (Polatomic, Inc.)

Hardware for Accelerating N-Modular Redundant Systems for High-Reliability Computing by Keith Bindloss (Coherent Logix, Inc.)

Mechanical part marking for non-flight sheet metal fabrication by Francis Rondeau (Code 547)

Continuous Integration Laser Energy Monitor by Jeremy Karsh (Code 564)

DSILIU—Distributed System Integrated Lab Interface User by Tom Jackson (Code 582)

DSILCA—Distributed System Integration Lab Communications Adapter by Carlos Ugarte (Code 582)

Design, Fabrication, and Assembly of a Carbon Nanotube Field Emission Electron Gun for Ultra-Clean, Low-Contamination Applications by Stephanie Getty (Code 541)

Compiler for Fast, Accurate Mathematical Computing on Integer Processors by Gregory Donohoe (Entempo Corporation)

Octet by Andrew DeCarlo (Infocitex Corporation)

NASA TRMM Office Radar Software Library in IDL (RSL\_IN\_IDL) by Bart Kelley (Code 613)

Bioink for Organ Printing by Gabor Forgacs (University of Missouri)

Reduced-width YBCO coated conductor for adiabatic demagnetization refrigeration magnets and low heat leak current leads by William Marshall (Tai-Yang Research Co.)

Ultra-low Power (< 100mW), 64-Channel Pulse Data Collection System by Hollis Jones (Code 555)

Telemetry and Science Data Software System by Lakesha Bates (Code 568)

GPS-based attitude estimation algorithms for use with a single-aperture direction-finding antenna on spinning platforms by Kenan Ezal (Toyon Research Corporation)

Target assembly to check the boresight alignment of LIDARS, Laser Altimeters, or any other active sensor by Luis Ramos-Izquierdo (Code 551)

Adaptive Autonomy For Real-time Software by Mike Hinchey (Code 585)

Laser oscillator incorporating wedged polarization rotator & porro prism as cavity mirror by Stephen Li (Code 554)

Timeline Management Tool software by Perry Baltimore (Goldbelt Orca, LLC)

Global Precipitation Mission (GPM) Visualization Tool for Validation Network Geometrically-Matched Ground- and Space-based Radar Data by Matthew Schwaller (Code 587)

Low-Cost, Rugged, High-Vacuum System by Robert Kline-Schoder (Creare, Inc.)

Low threshold, narrow linewidth optical parametric generator by Stephen Li (Code 554)

Progressive Band Selection for Hyperspectral Images by Kevin Fisher (Code 587)

End Pumped, High Repetition rate, Ultra-thin Slab Laser by Stephen Li (Code 554)

Fabrication of Solar Array Elements for Power Collection on the Moon by Michael Van Steenberg (Code 610)

Aerodynamically Stabilized Instrument Platform for Kites and Tethered Blimps ("AeroPod") by Geoffrey Bland (Code 614)

2009 NASA Goddard Space Flight Center Mentor Request/Student Intern Program Application by Luther Lighty (Code 585)

Null Lens Assembly for X-ray Mirror Segments by David Robinson (Code 543)

A GIS Software Toolkit for Monitoring Areal Snow Cover and Producing Daily Hydrologic Forecasts using NASA Satellite Imagery by Brian Harshburger (Aniuk Consulting, LLC)

Multiplanar Feature Representation by Eric Sinzinger (Texas Tech Univ.)

Land Information System Software, Version 5.0 by Matthew Rodell (Code 614.3)

Mission Operations Planning and Scheduling System (MOPSS) by Terri Wood (Code 583)

Crystal Compositions, Trace Impurities and Properties of Nonlinear Optical Materials used for Space Systems by Galina Malovichko (Montana State University)

Modified Collins Cryocooler for Cryo-Propellant Thermal Management by John Brisson (Massachusetts Institute of Technology)

Schottky Heterodyne Receivers with Full Waveguide Bandwidth by Thomas Crowe (Code 410)

Core Flight Software System (CFS) Health & Safety Applic. Version 1 by Maureen Bartholomew (Code 582)

Software for the Automated Generation of Finite Element Models for X-Ray Mirrors by Ryan McClelland (Code 445)

Physics Mining of Multi-source Data Sets by Homa Karimabadi (SciberQuest, Inc.)

Thermally Neutral Piezoelectric Ceramic Driven Cycloidal Motor and Miniature Rotary Piezoelectric Stick-slip Motor (ELVs) by Matthew Stefanick (Dynamic Structures and Materials, LLC)

Goddard Mission Services Evolution Center (GMSEC) Trending Analysis and Plotting System (TAPS) v6.5 by Sheila Ritter (Code 583)

Wavelength Drift Corrector for Wind Lidar Receivers by J. Marcos Sirota (Sigma Space)

Computational Laws: Normalize-Transpose and Consume Simplify Produce by Daniel Cooke (Texas Tech University)

Low Cost Beamformer Phased Array Antenna for Sounding Rockets, Missiles, and Expendable Launch Vehicles by Daniel Mullinix (Code 569)

Microgravity Enhanced Stem Cell Selection by Jagan Valluri (Marshall University)

SeaDAS - SeaWiFS Data and Analysis System by Mark Ruebens (Code 614)

LIDAR Luminance Quantizer by Gerard Quilligan (Code 564)

The ISIM Photogrammetry System: A high-resolution PG system that operates at 35K by Raymond Ohl (Code 551)

Low-power Reconfigurable Data Processing Platform by Gregory Donohoe (University of Idaho)

**Multi-Mission Three Axis Stabilized Spacecraft (MTASS) Attitude Determination and Sensor Calibration System** by Richard Harman (Code 584)

**Project Task Tracking Portal** by Susan Semancik (Code 584)

**Goddard Mission Services Evolution Center (GMSEC) Environmental Diagnostic Analysis Tool (GEDAT) v1.1** by Sharon Osborne (Code 583)

**Miniaturized Airborne Imaging Central Server System** by Xuhong Sun (Flight Landata, Inc.)

**Radiation-Tolerant, Space Wire-Compatible Switching Fabric** by Vladimir Katzman (Advanced Science and Novel Technology)

**Lotus Dust Mitigation Coating** by Wanda Peters (Code 546)

**Pulsating Deionized Water Precision Cleaning System** by Michael Wilks (Code 590)

**ExPRESS Logistics Carrier Suitcase Simulator Software** by Kevin Phillips (Northrop Grumman)

**Modified Nanostructure Mirror Diffraction Spoiler Design** by Edward Wollack (Code 665)

**APS-143 radar/SureTrak Interface Software** by Ted Daisey (Code 589)

**Advanced Planetary Atmosphere-Magnetosphere Mass Spectrometer (APAMMS): ASTID Funded for Europa** by Edward Sittler (Code 673)

**Optical Coating Performance for Heat Reflectors of JWST-ISIM Electronic Component** by Robert Rashford (Genesis Engineering Solutions)

**Enhanced PBO Fiber Reinforced Balloon Envelope Materials for Titan Aerobots** by Robert Kovar (Infoscitex Corp.)

**The Corner Cathode: Making Collimated Electron Beams with a Small Number of Electrodes** by Federico Herrero (Code 553)

**Airborne CO2 Analyzer and Hygrometer Approach for Maintaining Performance Throughout Flight** by Jeffrey Pilgrim (Vista Photonics, Inc.)

**Resolution enhanced pseudo random code technique** by Stephen Li (Code 554)

**Broadband Achromatic Phase Shifter for Nulling Interferometer Using Dispersive Elements** by Matthew Bolcar (Code 551)

**High Precision Pulse Generator** by Richard Katz (Code 564)

**Advanced Spacecraft Integration & System Test Software (ASIST), Front End Data Systems/Digital History Data Store Software (FEDS/DHDS)** by Thomas Green (Code 583)

**A Quantum Well Infrared Photodetector (QWIP) Focal Plane Assembly for the Thermal Infrared Sensor (TIRS) instrument on Landsat Data Continuity Mission (LDCM)** by Murzy Jhabvala (Code 550)

**NASA TRMM Office Radar Software Library** by David Wolff (Code 613)

**Titanium Alloy Strong Back for IXO Mirror Segments** by Byron Glenn (Code 543)

**Solid-State Spectral Light Source System** by David Dana (HOBI Labs, Inc.)

**Automated Mission Planning and Scheduling System (AMPS) Version 2** by Dave Ripley (Code 583)

**Middleware Benchmarking and Performance Tool Suite for GMSEC** by Robert Antonucci (Emergent Space Technologies, Inc.)

**Dynamic Time Multiplexing Fabrication of Holographic Polymer Dispersed Liquid Crystals for Increased Wavelength Sensitivity** by Adam Fontecchio (Drexel University)

**Expedite the Processing of Experiments to the Space Station (EXPRESS) Logistics Carrier (ELC) PROM Software** by Dan Berry (Code 582)

**Integrated Modeling Environment Process Simulator** by Paul Matthew Stone (Code 592)

**Compact high energy, single mode laser and method** by Steven Li (Code 554)

**Pyxis: A New Tool for Interplanetary Mission Design** by John Downing (Code 595) ■

## NASA Inventions and Contributions Board Awards

### Tech Briefs Awards

**Objective Lens** Simultaneously optimized for Pupil ghosting, Wavefront Delivery and Pupil Imaging by Gene Olczak (ITT Space Systems)

**ZnO UV Detectors** by Henry White, Yungryel Ryu, and Tae Lee (all of MOXtronics, Inc.)

**Turbo Tech Technical Evaluation Automated System** by Dorothy Tiffany (Code 490)

**Efficient Kriging Algorithms and their Application to Image Fusion** by Nargess Memarsadeghi (Code 587)

**Enhanced surface spray cooling with Poco Foam surface enhancements** by Eric Silk (Code 552)

**Dual Channel Multi-Purpose Telescope for Astronomy** by Joseph Howard and David Content (both Code 551)

**Range Safety Algorithm Software Module for an Autonomous Flight Safety System** by James Simpson (Code 552)

**Cryogenic Chamber for Servo-Hydraulic Materials Testing** by James Tuttle and John Francis (both Code 552)

**PortOSim - A Portable Object Simulation Application for Launch Range Systems Conceptual Design, Analysis and Test** by Raymond Lanzi (Code 598)

**Range Safety Algorithm Software Module for an Autonomous Flight Safety System** by Raymond Lanzi (Code 598)

**Apparatus for Measuring Thermal Conductance Through a Thin Sample from Cryogenic Temperatures to Room Temperature** by James Tuttle (Code 552)

### Software Release Awards

**GPM Software** by Kenneth Morris (SAIC) and Matthew Schwaller (Code 581)

**DSIL Communications Adapter Set** by Eric Lidwa (SGT), Jai Song (OSC), and Jonathan Wilmot (Code 582)

**Coldfire SDN Hardware Diagnostics** by Dwaine Molock (Code 582)

**Turbo Tech Technical Evaluation Automated System** by Dorothy Tiffany (code 490)

### Space Act Awards

**Method For Implementation Of Recursive Hierarchical Segmentation On Parallel Computers** by James Tilton (Code 606)

**Passive Gas-Gap Heat Switches For Use With Adiabatic Demagnetization Refrigerators** by Peter Shirron and Michael DiPirron (both Code 552) ■

*Image by Ja Hyun "Ashely" Lim of Glen Burnie, Maryland, winner of Goddard's 50-Year Spinoff Art Contest (see details on page 12)*



# Lunar Reconnaissance Orbiter



*Smoke rolls across Launch Pad 41 at Cape Canaveral Air Force Station in Florida as the Atlas V/Centaur rocket topped with NASA's Lunar Reconnaissance Orbiter (LRO) and NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) lift off*



*LRO's first moon images taken by the Lunar Reconnaissance Orbiter Camera (LROC)*

*On Launch Complex 41 at Cape Canaveral Air Force Station in Florida, workers inside the mobile service tower prepare the LRO and LCROSS for mating inside with the Atlas V rocket*

## **Goddard Tech Transfer News** <http://ipp.gsfc.nasa.gov>

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