National Aeronautics and Space Administration

# 2012 annual report

## Earth Science Technology Office

# Executive Summary

*As reported in the pages that follow, fiscal year 2012 (FY12) has been a productive year that saw numerous successes in the advancement and infusion of technologies for NASA Earth science.*

*Activities within the Earth Science Technology Office (ESTO) continue to center on guidance provided by the first Earth Science Decadal Survey – "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" by the National Research Council (NRC) of the National Academies – and by the NASA plan for climate-centric observations: "Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations from Space." Of note, this year saw significant technology demonstrations and infusions on a variety of airborne platforms. We have highlighted these flights on pages 7-8.*

*Eighteen new investments were added to the ESTO portfolio in FY12 through solicitations under the Advanced Information Systems Technology program. In addition to ESTO's existing programs, a new pilot program, In-Space Validation of Earth Science Technologies, or InVEST, was created during FY12 to provide validation opportunities for space-based emerging technologies. The first InVEST solicitation was released in September of 2012.*

*ESTO also continues to build upon a strong history of technology development and infusion. In FY12 40% of active ESTO technology projects advanced at least one Technology Readiness Level (TRL). Of the nearly 600 completed projects in the ESTO portfolio, 37% have already been infused while an additional 43% have a path identified for future infusion in Earth observing missions or commercial applications.*

*These successes demonstrate the hard work of our principal investigators and their collaborators. Their contributions to technology development ensure a bright future for Earth science innovations. We welcome another year of continued technology advancement in FY13.*

**George J. Komar, *Program Director*** **Robert A. Bauer, *Deputy Program Director***

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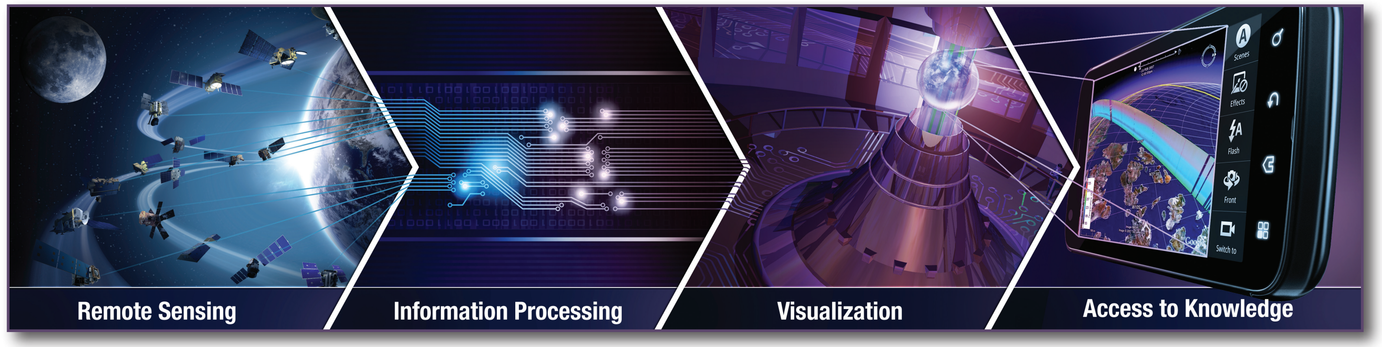
# About ESTO




*ESTO's technology portfolio enables end-to-end science measurements, from the instruments that make observations to the data systems and information products that make observations useful.*

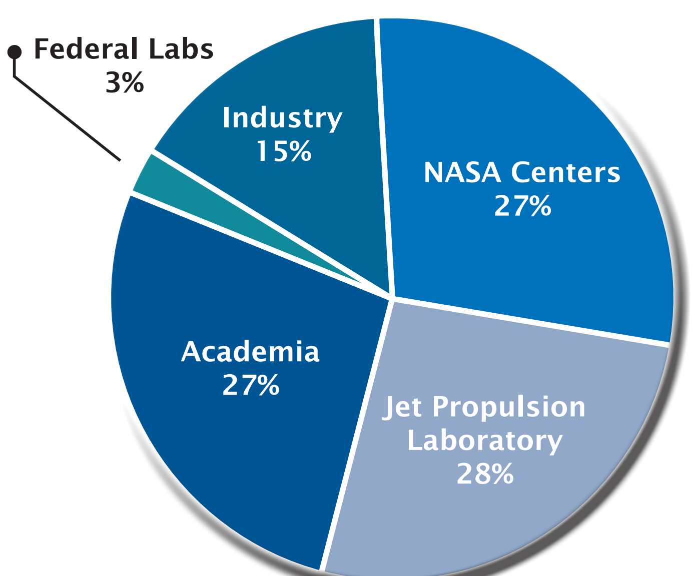
As the technology function within NASA's Earth Science Division, the Earth Science Technology Office (ESTO) performs strategic technology planning and manages the development of a range of advanced technologies for future science measurements and operational requirements.

ESTO employs an open, flexible, science-driven strategy that relies on competition and peer-review to produce the best, cutting-edge technologies for Earth science endeavors.

ESTO also applies a rigorous approach to technology development:

- Planning investments by careful analyses of science requirements
- Selecting and funding technologies through competitive solicitations and partnership opportunities
- Actively managing the progress of funded projects
- Facilitating the infusion of mature technologies into science measurements

The results speak for themselves: a broad portfolio of nearly 700 emerging technologies – 138 of which were active at some point during Fiscal Year 2012 (FY12) – ready to enable or enhance science measurement capabilities as well as an ever-growing number of technology infusion successes.




*The 138 active projects during FY12 included the combined efforts of more than 509 principal investigators (PIs), co-investigators (Co-Is), and partners from a variety of institutions. The graph at left gives the distribution of these participating institutions.*

## Student Participation

Student participation in ESTO projects has always been substantial. Since 1998, at least 430 students have been involved in ESTO-funded work and as many as 120 graduate-level degrees have been awarded. In 2012 alone, 118 students were actively involved with ESTO projects. Roughly half are pursuing doctorates while the remainder are working toward master or undergraduate degrees.

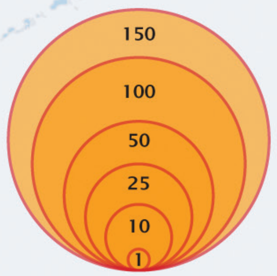
*University of Pittsburgh graduate student Kevin Reath stands among the mud volcanoes (gryphons) at the geothermally active Salton Sea in southern California. Reath conducted in situ measurements of the thermal signatures and mineralogy, which were later used for calibration of the ESTO-funded MAGI (Mineral and Gas Identifier) airborne sensor as well as satellite measurements. ESTO funding allowed Reath to earn his Masters degree in Geology and Planetary Science. (image: University of Pittsburgh)*

*Several University of Arizona students were involved in the development of the Ground-based Multiangle SpectroPolarimetric Imager (GroundMSPI) instrument. Pictured with the GroundMSPI from left to right: Nirantha Balagopal (undergrad), Stacey Sueoka (PhD), Christine Bradley (PhD), Jacob Krause (BS, completed in 2012), Russell Chipman (Professor / Co-Investigator), and Anna-Britt Mahler (PhD, completed in 2010). (image: D. Diner)*

# 2012 Metrics

**With nearly 600 completed technology investments and an active portfolio during fiscal year 2012 (FY12) of 138 projects, ESTO is driving innovation, enabling future Earth science measurements, and strengthening NASA's reputation for developing and advancing leading-edge technologies.**

**To clarify ESTO's FY12 achivements, what follows are the year's results tied to NASA's performance metrics for ESTO:**



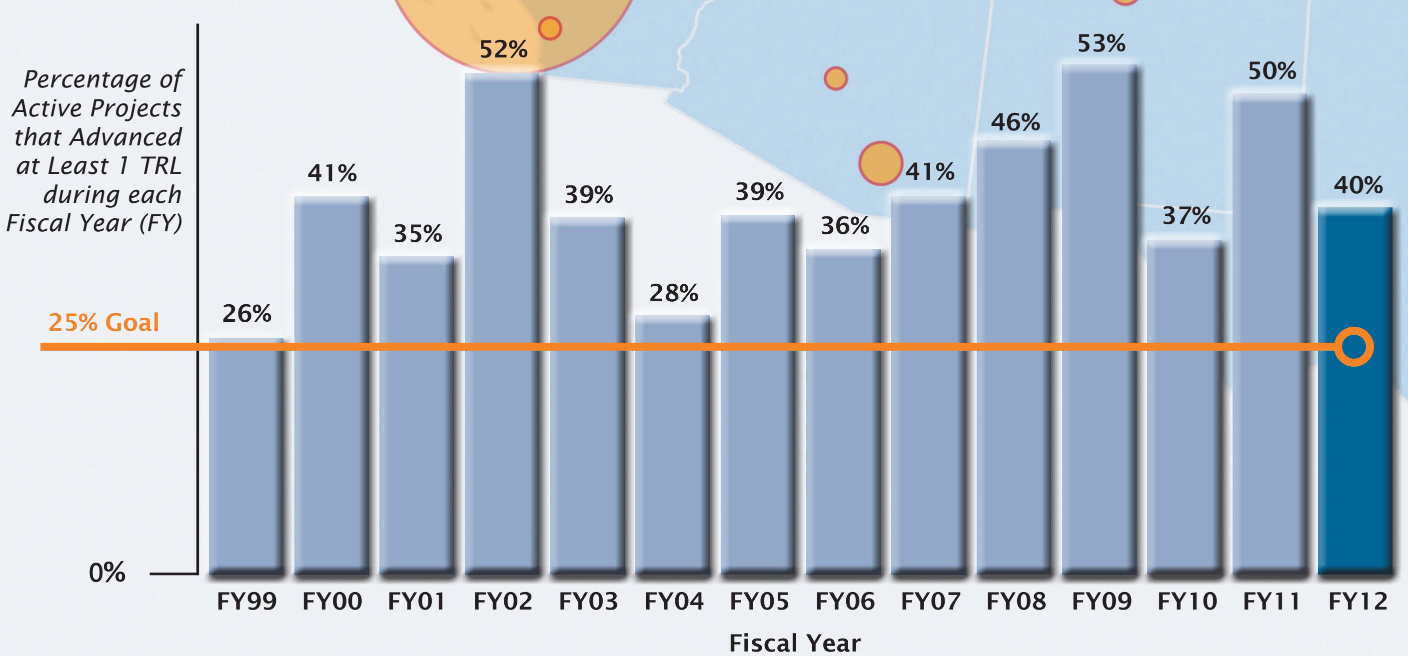

*Map provides geographical distribution of principal investigators for the nearly 700 projects (active and completed) in the ESTO portfolio.*

## GOAL #1:

Annually advance 25% of currently funded technology projects at least one Technology Readiness Level (TRL).

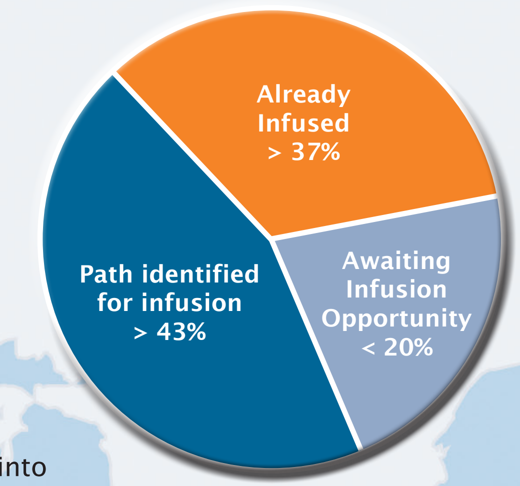
## FY12 RESULT:

40% of ESTO technology projects funded during FY12 advanced one or more TRLs over the course of the fiscal year. Nearly half of these (17% of the FY12 projects) advanced more than one TRL. See the graph below for yearly comparisons. [Note: because of the variable periodicity of solicitations and reporting, multi-year trends are not meaningful.]




## GOAL #2:

Mature two to three technologies to the point where they can be demonstrated in space or in a relevant operational environment.




*ESTO's infusion success - drawn from over 600 completed projects through the end of FY12*

## FY12 RESULT:

At least six ESTO projects achieved infusion into space missions or airborne campaigns in FY12. Notable examples include:

- The **Airborne Scanning Microwave Limb Sounder (A-SMLS)**, a prototype next-generation MLS for measuring trace species in the upper troposphere, completed its first test flights on July 3 and 5, 2012. Flying on the NASA WB-57 aircraft near the coast of Houston, TX, A-SMLS successfully acquired ozone measurements and can be configured for a variety of other trace species. *(PI: Paul Stek, JPL, 2007 Instrument Incubator Program (IIP-07) award)*

The Hyperspectral Infrared Imager (HyspIRI) mission concept proposes to study the world's ecosystems and provide information on natural disasters such as volcanoes, wildfires and drought. Two ESTO-funded projects have developed and demonstrated airborne precursor instruments for HyspIRI-like measurements:

- The **Hyperspectral Thermal Emission Spectrometer (HyTES)** – which aims to provide high spatial and spectral resolution thermal land imaging data – was integrated and test flown on a Twin Otter over Cuprite, Nevada, in July 2012. As an airborne instrument, HyTES can be used to study Earth's ecosystems, natural disasters, and changes in land surface as well as test and refine requirements for a future spaceborne thermal infrared imager. *(PI: Simon Hook, JPL, IIP-07)*

- Another thermal infrared imager prototype – an imaging spectrometer for **Mineral and Gas Identification (MAGI)** – has also been designed as an airborne demonstrator of the planned HyspIRI imager. MAGI, which can collect 32 spectral channels of image data between 7 and 12.7 microns while weighing only 1 pound and measuring 4.6 inches long, conducted test flights on a Twin Otter aircraft in October of 2011. *(PI: Jeffrey Hall, Aerospace Corporation, IIP-07)*

# 2012 Metrics (continued)

## GOAL #3:

Enable a new science measurement or significantly improve the performance of an existing technique.

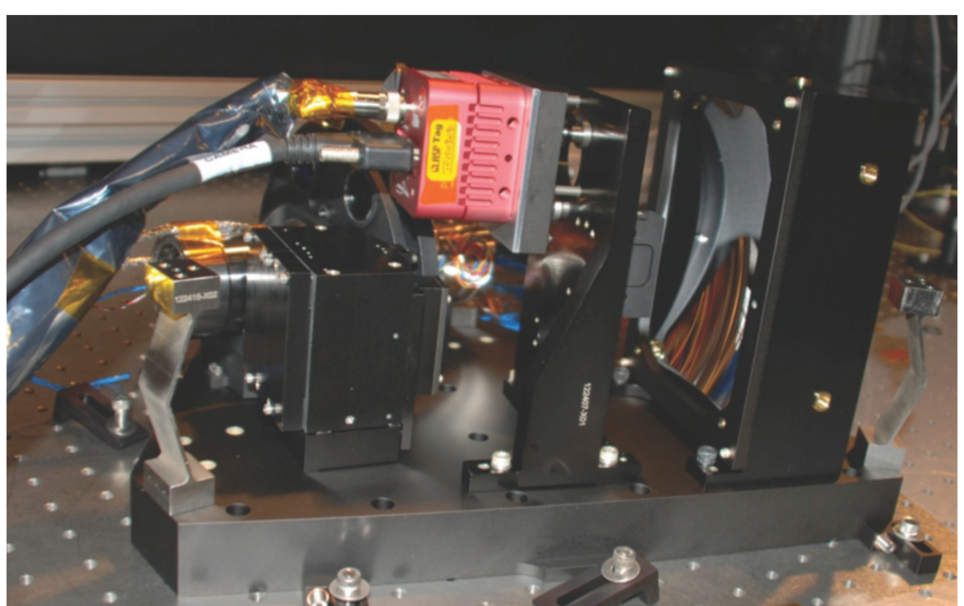
## FY12 RESULT:

A notable example:

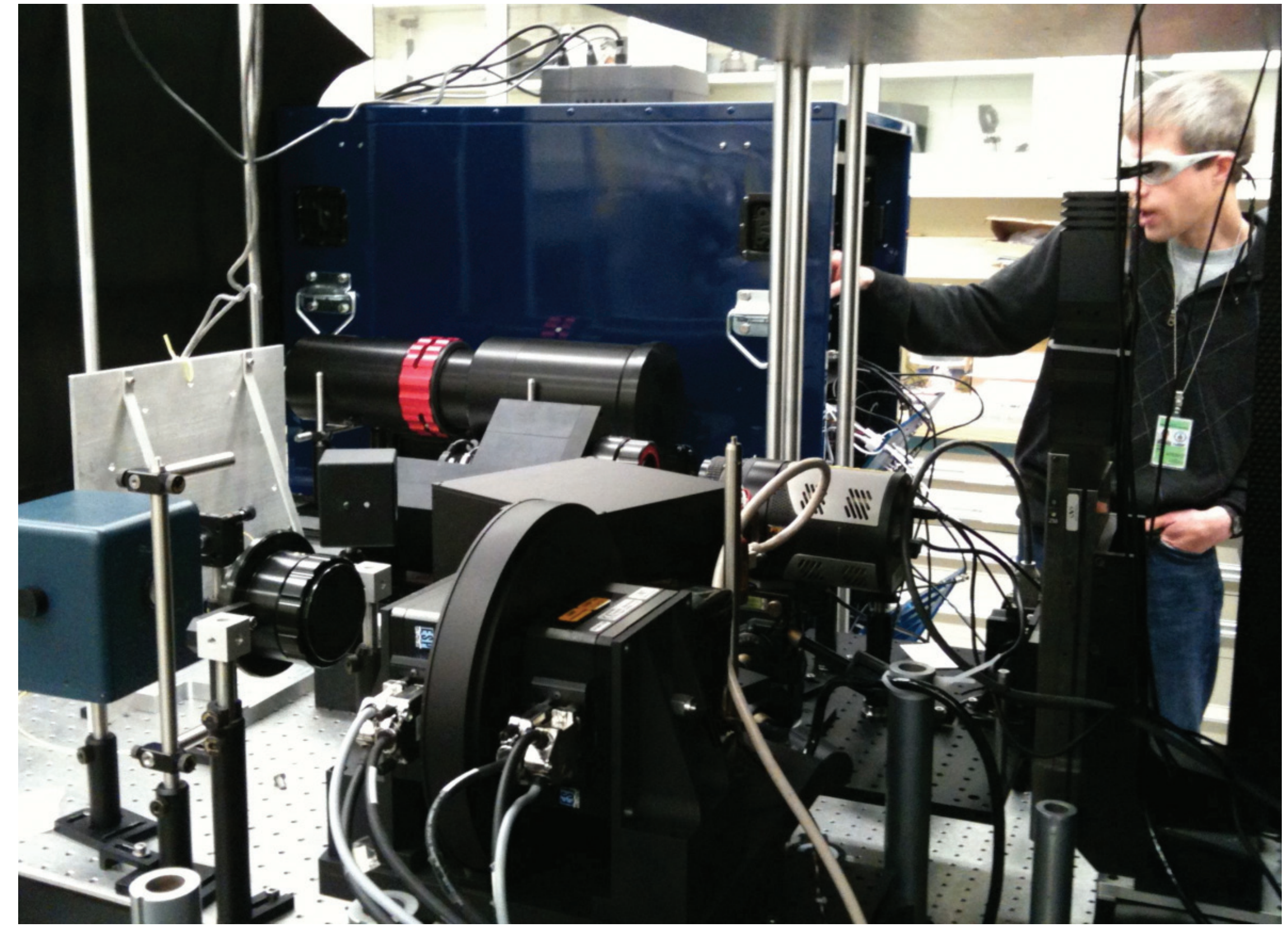
- An accurate accounting of the amount of energy entering and leaving the Earth's atmosphere – the planet's radiation budget – is key to improving climate prediction and establishing a reliable benchmark for Earth's current climate. Climate is affected by the long-term balance between the solar irradiance absorbed by Earth's land, atmosphere, and oceans and that which is reflected back into space. To acquire the necessary measurements, future NASA missions, such as the proposed Climate Absolute Radiance and Refractivity Observatory (CLARREO), will require shortwave radiometric accuracies that are nearly ten times better than current on-orbit capabilities.

Initiated in 2008, an ESTO project titled "Hyperspectral Imager to Meet CLARREO Goals of High Absolute Accuracy and On-Orbit SI Traceability" has prototyped, characterized, and demonstrated a hyperspectral imager containing a new, novel solar cross-calibration system to meet the accuracy goals. Essentially, the imager will compare the relative irradiances from the Sun and the Earth with high accuracy. The project additionally designed and built an engineering model using flight-like mechanisms and optics that underwent vibration, thermal/vacuum, and lifetime tests to demonstrate the ruggedness and viability of the system as a deployable instrument.

*(PI: Greg Kopp, University of Colorado, Laboratory for Atmospheric and Space Physics)*



*A prototype hyperspectral imager to demonstrate a novel new solar cross-calibration method for improving on-orbit radiometric accuracies (image: G. Kopp)*



*Testing the hyperspectral imager at the National Institute of Standards and Technology (image: G. Kopp)*

## WEB FEATURE: Over 10 Years of Investments Shaping Future Radiation Budget Measurements

For more than a decade, numerous ESTO projects have built and validated early versions of the instruments and components needed for Earth radiation budget measurements. In many ways, these early investments enabled the designation of CLARREO as a mission concept. Learn more at:

**esto.nasa.gov/news/CLARREO.html**

# Going Airborne

## Technologies Take Flight in FY2012

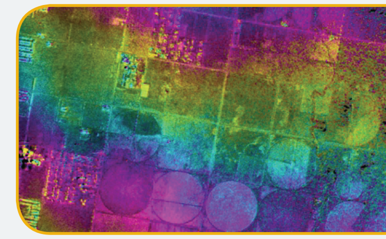
**Airborne platforms are often essential to the calibration and validation of emerging technologies. They provide a stepping-stone to reduce risk prior to committing new technologies to space missions. They also enable mature instruments and systems to be rapidly put into service on airborne field campaigns, collecting science data and validating the observations of satellites.**

**Airborne testing often occurs during, and within the scope of, technology development and funding. In other cases, ESTO has partnered with platform providers – in particular, NASA's Airborne Science Program – to provide follow-on opportunities and manage technology progress from integration to validation.**

**Since 1998, more than 70 ESTO technologies have been demonstrated onboard airplanes, UAVs (Uninhabited Aerial Vehicles) or high-altitude balloons, logging hundreds of flight hours in aggregate. As illustrated in the timeline below, FY12 was a banner year for airborne technologies.**

**At least 17 current projects – ESTO projects as well as partnerships with NASA's Airborne Science and Earth Science Research and Analysis programs – were demonstrated on airborne platforms or flew as part of airborne science campaigns. Nine of these projects flew for the first time in FY12.**

OAWL, an airborne prototype instrument in support of the proposed 3D-Winds decadal survey mission concept, measures aerosol and molecular winds with a single 355 nm laser. OAWL completed five test flights on the NASA WB-57 and measured winds with 2-6 m/s precision, corroborated by ground-based radar wind profiler data. *(image: D. Hanselman)*



The Airborne Glacier and Land Ice Surface Topography Interferometer (GLISTIN-A) is a new, modified version of a swath-mapping airborne sensor originally developed to collect data for high-resolution ice-surface topography maps. GLISTIN-A features higher peak transmit power and its antenna can transmit and receive to improve the vertical accuracy of data. At left is first-look, uncalibrated elevation data over the Rosamond Lake, CA, from the August engineering flights. *(image: D. Moller)*

Oct-11 | Nov-11 | Dec-11 | Jan-12 | Feb-12 | Mar-12 | Apr-12 | May-12 | Jun-12 | Jul-12 | Aug-12 | Sep-12

### First Flights

**Optical Autocovariance Wind Lidar (OAWL)**
10/26-11/8; Aircraft: WB-57; PI: S. Tucker, Ball Aerospace

**Portable Remote Imaging Spectrometer (PRISM)**
5/7; Aircraft: Twin Otter; PI: P. Mouroulis, JPL

**Glacier & Land Ice Surface Topography Interferometer**
8/8 & 8/13; Aircraft: WB-57; PI: D. Moller, Remote Sensing Solutions

**Next Generation Airborne Visible InfraRed Imaging Spectrometer (AVIRISng)**
4/22; Aircraft: Twin Otter; PI: R. Green, JPL

**Hyperspectral Thermal Emission Spectrometer (HyTES)**
7/18-19; Aircraft: Twin Otter; PI: S. Hook, JPL

**Mineral and Gas Identification (MAGI, Thermal Infrared Imaging Spectrometer)**
10/18; Aircraft: Twin Otter; PI: J. Hall, Aerospace Corporation

**Cloud-Aerosol Transport System (CATS)**
2/21 & 6/18-22; Aircraft: ER-2; PI: M. McGill, NASA GSFC

**Airborne Scanning Microwave Limb Sounder (A-SMLS)**
7/3, 7/5 & 8/7; Aircraft: WB-57; PI: P. Stek, JPL

**Enhanced MODIS Airborne Simulator (e-MAS)**
8/22-30; Aircraft: ER-2; PI: S. Hipskind, NASA ARC

**Airborne UV-SWIR Multiangle Spectropolarimetric Imager (AirMSPI)**
1/6 & 8/28; Aircraft: ER-2; PI: D. Diner, JPL

**Electronically Steerable Flash Lidar (ESFL)**
Oct - Dec; Aircraft: Twin Otter; PI: C. Weimer, Ball Aerospace

**On-Board Processing to Optimize MSPI**
1/6; Aircraft: ER-2; PI: P. Pingree, JPL

**Integration of HSRL Into Ozone DIAL System**
5/15-6/30; Aircraft: DC-8; PI: J. Hair, NASA LaRC

**Efficient Swath Mapping Laser Altimetry Demonstration**
8/16-28; Aircraft: P-3; PI: A. Yu, NASA GSFC

**Radar On-board Processing and Auonomous Data Collection**
1/5; Aircraft: G-III; PI: Y. Lou, JPL

**Real Time Mission Monitor (RTMM)**
1/17-2/29 & 6/25-29/6 & 8/13-18; Aircraft: various; PI: M. Goodman, NASA MSFC

**High Spectral Resolution Lidar-2 (HSRL-2)**
6/20-22; Aircraft: B-200 King Air; PI: C. Hostetler, NASA LaRC

RTMM is a science decision-making tool for monitoring and managing NASA airborne field campaigns and ground validation exercises. RTMM was used on several campaigns in 2012, including: the NASA GPM Cold-season Precipitation Experiment (DC-8, Jan/Feb) and the DARPA-funded Nimbus flight experiment focused on lightning initiation processes (Spear UAV, Jun & Aug). RTMM utilizes sensor-web-enabled data access and services via a web portal. *(image: NASA)*

The HSRL-2 project, which is funded by the NASA Airborne Instrument Technology Transition (AITT) program and managed by ESTO, is also supporting the Two-Column Aerosol Project (TCAP), a 12-month Department of Energy research campaign. TCAP is studying aerosols to learn how they scatter and absorb sunlight and how they affect cloud formation. HSRL-2 measures aerosol backscatter and depolarization to provide the vertical distribution of aerosols within the atmosphere. *(image: NASA)*

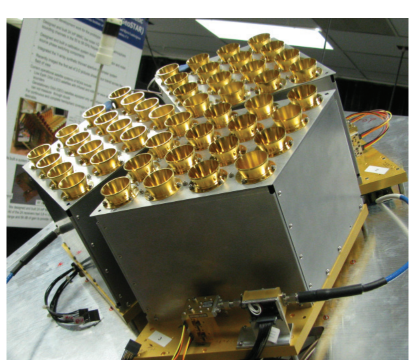
ESTO Projects | Partnerships & ESTO Heritage

# 2012 in Review: **Instruments**

The Instrument Incubator Program (IIP) provides funding for new instrument and observation techniques, from concept development through breadboard and flight demonstrations. Instrument technology development of this scale outside a flight project consistently leads to smaller, less resource-intensive flight instruments. Furthermore, developing and validating these technologies before mission development improves their acceptance and infusion by mission planners and significantly reduces costs and schedule uncertainties.

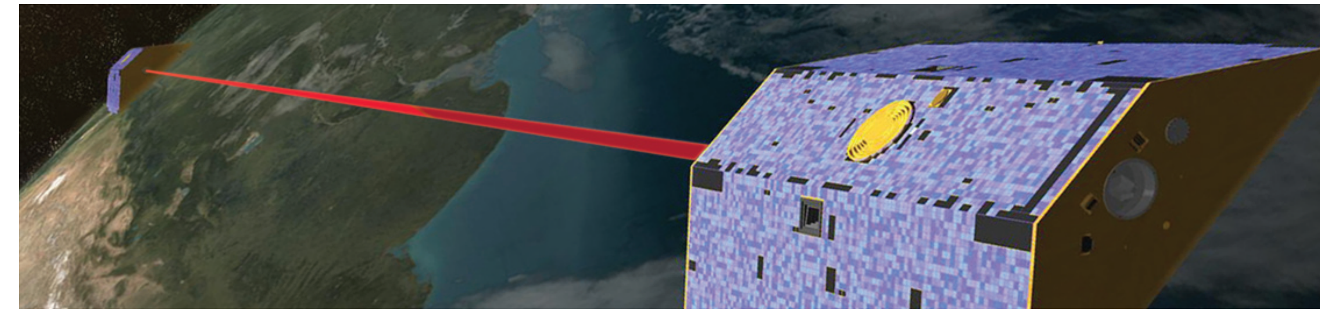
The IIP included 35 active projects in FY12, 16 of which were added in December 2010 through a competitive solicitation that sought instrument technologies to enable and achieve the mission concepts outlined in the NRC Decadal Survey as well as innovative instrument approaches that support other compelling Earth Science measurements. The next IIP solicitation is expected to be released in 2013. 14 projects were completed over the past year, 12 of which advanced at least one Technology Readiness Level (TRL) during the period of funding. The FY12 graduates are as follows:

- ***HyTES: A Hyperspectral Thermal Emission Spectrometer for HyspIRI-TIR Science,*** **S. Hook, JPL**
- ***Development of Lightweight, 3-D Integrated X-Band Radar Antenna Using SiGe Chips and RF MEMS Circuits For Snow Accumulation Measurements,*** **I. Papapolymerou, Georgia Institute of Technology**
- ***Calibrated Observations of Radiance Spectra from the Atmosphere in the far-InfraRed - CORSAIR,*** **M. Mlynczak, NASA LaRC**
- ***Novel Laser Approach for Precision CO2 Column Measurement,*** **W. Heaps, NASA GSFC**
- ***GeoSTAR Technology Development and Risk Reduction for PATH,*** **B. Lambrigtsen, JPL**
- ***SWIR Aerosol/Cloud Polarimetric Imager, D. Diner,*** **JPL**
- ***Development of an Ocean Radiometer for Carbon Assessment (ORCA) Prototype,*** **C. McClain, NASA GSFC**
- ***A Hyperspectral Imager to Meet CLARREO Goals of High Absolute Accuracy and On-Orbit SI Traceability,*** **G. Kopp, University of Colorado / Laboratory for Atmospheric and Space Physics** *(see p. 5 for more on this project)*
- ***Ka-band SAR Interferometry Studies for the SWOT mission,*** **L. Fu, JPL**
- ***Panchromatic Fourier Transform Spectrometer (PanFTS) Instrument for the Geostationary Coastal and Air Pollution Events (GEO-CAPE) Mission,*** **S. Sander, JPL**
- ***Infrared Correlation Radiometer Fabrication and Characterization as Applied to the GEO-CAPE Decadal Survey Mission,*** **D. Neil, NASA LaRC**
- ***Laser Ranging Frequency Stabilization Subsystem for GRACE II,*** **W. Folkner, JPL**
- ***Development and Demonstration of an Optical Autocovariance Direct Detection Wind Lidar (OAWL),*** **S. Tucker, Ball Aerospace & Technologies Corporation**
- ***A Scanning Microwave Limb Sounder for Studying Fast Processes in the Troposphere,*** **P. Stek, JPL**



*At Left: Three sub-array modules, each with 16 antenna elements and 16 miniaturized receiver modules, built to test and demonstrate a microwave sounder antenna/receiver array concept. The project sought to reduce the risk of microwave antenna and receiver technologies that will be critical to the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR), an instrument proposed as part of the Precipitation and All-weather Temperature and Humidity (PATH) mission concept. If successful, GeoSTAR will be the first microwave sounder to operate from Geostationary Earth orbit. (image: B. Lambrigtsen)*

## SPOTLIGHT: Laser System on GRACE Follow-On to Measure Gravity More Accurately



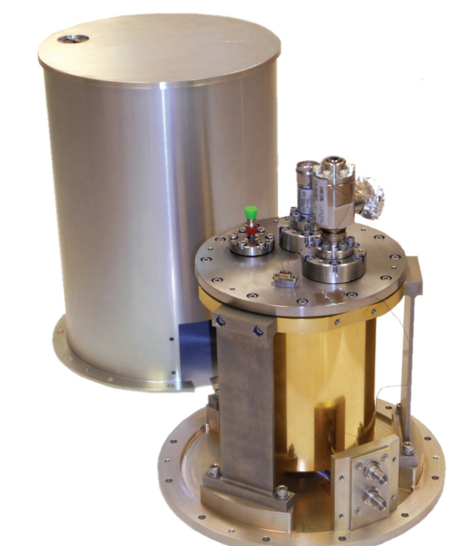
*The twin satellites of NASA's Gravity Recovery and Climate Experiment (GRACE) mission, developed in partnership with Germany and launched in 2002, have provided a dramatic view of Earth's variable gravity and mass distribution and spurred new insights in a variety of scientific fields. From hydrology and geophysics to ice mass estimates and global sea levels, GRACE has produced discoveries with far-reaching impacts on society.*

*The planned GRACE Follow-On mission, with a launch as early as 2017, aims to demonstrate an advanced laser instrument that could improve the accuracy of inter-spacecraft ranging by tenfold or more and lead to enhanced gravity measurements. The instrument technology was developed at the Jet Propulsion Laboratory, in collaboration with Ball Aerospace, with IIP funding.*

*As the existing GRACE satellites orbit Earth, they encounter subtle changes in gravitational pull. These variations produce slight movements in the spacecraft orbits that can be detected by careful range measurements between the satellites. GRACE uses a microwave ranging instrument, referenced to a stable quartz clock and coupled with precise GPS tracking, to measure these minute changes to a few microns over the approximately 220 km distance separating the satellites.*

*GRACE Follow-On will use the same overall technique – carefully measuring the variations between two spacecraft – but the laser approach will be much more accurate. The advantage is due largely to the shorter wavelength of the laser, compared to the microwave wavelength, referenced to a thermally isolated optical cavity, which is more stable than the quartz clock.*

*The laser demonstration on GRACE Follow-On will be a partnership between NASA, which will provide the laser, cavity assembly, and ranging processor, and the German Space Program, which will provide the measurement optics and steering mirror assembly along with instrument integration and testing.*



*Top : Artist's depiction of the GRACE Follow-On twin spacecraft.*

*Above: Prototype assembly and thermal enclosure (approximately 10" tall) for the advanced laser cavity. The cavity itself is made using glass with a low coefficient of thermal expansion in order to maintain a constant distance between end mirrors. (image: W. Folkner)*

# 2012 in Review: **Information Systems**

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Advanced information systems play a critical role in the collection, handling, and management of large amounts of Earth science data, in space and on the ground. Advanced computing and transmission concepts that permit the dissemination and management of terabytes of data are essential to NASA's vision of a unified observational network. ESTO's Advanced Information Systems Technology (AIST) program employs an end-to-end approach to evolve these critical technologies – from the space segment, where the information pipeline begins, to the end user, where knowledge is advanced.

The AIST program included 47 active investments in FY12, one-third of which have already advanced one or more Technology Readiness Levels (TRL) to date. 18 of the 47 investments were awarded in February 2012, through an AIST solicitation released in 2011. The new projects are as follows:

- ***Plume Tracer: Interactive Mapping of Atmospheric Plumes,*** A. Berk, Spectral Sciences
- ***High-Speed On-Board Data Processing for Science Instruments (HOPS),*** J. Beyon, NASA LaRC
- ***Next-Generation Real-Time Geodetic Station Sensor Web for Natural Hazards Research and Applications,*** Y. Bock, Scripps Institution of Oceanography, UCSD
- ***Multivariate Data Fusion and Uncertainty Quantification for Remote Sensing,*** A. Braverman, JPL
- ***Automated Event Service: Efficient and Flexible Searching for Earth Science Phenomena,*** T. Clune, NASA GSFC
- ***An Advanced Learning Framework for High Dimensional Multi-Sensor Data,*** M. Crawford, Purdue
- ***QuakeSim: Multi-Source Synergistic Data Intensive Computing for Earth Science,*** A Donnellan, JPL
- ***Fusion of Murricane Models and Observations: Technology to Improve Forecasts,*** S. Hristova-Veleva, JPL
- ***Advanced Rapid Imaging and Analysis for Monitoring Hazards (ARIA-MH),*** H. Hua, JPL
- ***EPOS for Coordination of Asynchronous Sensor Webs,*** S. Kolitz, Draper Laboratory
- ***A High Performance, Onboard Multicore Intelligent Payload Module for Orbital and Suborbital Remote Sensing Missions,*** D. Mandl, NASA GSFC
- ***Land Information System for SMAP Tier-1 and AirMOSS Earth Venture-1 Decadal Survey Missions: Integration of SoilSCAPE, Remote Sensing, and Modeling,*** M. Moghaddam, USC
- ***Semi-Automatic Science Workflow Synthesis for Computing on the NASA Earth Exchange,*** R. Nemani, NASA ARC
- ***A Mission Simulation and Evaluation Platform for Terrestrial Hydrology Using the NASA Land Information System (LIS),*** C. Peters-Lidard, NASA GSFC
- ***On-Board Processing (OBP) to Advance the PanFTS Imaging System for GEO-CAPE,*** P. Pingree, JPL
- ***Integration of the NASA CAMVis and Multiscale Analysis Package (CAMVis-MAP) For Tropical Cyclone Climate Study,*** B. Shen, University of Maryland
- ***Unified Simulator for Earth Remote Sensing (USERS),*** S. Tanelli, JPL
- ***Empowering Cloud Resolving Models Through GPU and Asynchronous IO,*** W. Tao, NASA GSFC

22 projects graduated from AIST funding in FY12, all of which advanced at least one TRL during the course of funding. The FY12 graduates are:

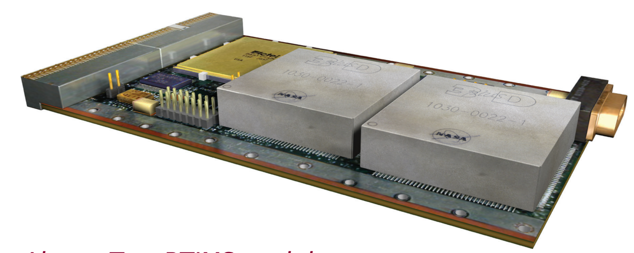
- *Real-Time and Store-and-Forward Delivery of UAV Sensor Data, W. Ivancic, NASA GRC*
- *Geostatistical Data Fusion for Remote Sensing Applications, A. Braverman, JPL*
- *Instrument Simulator Suite for Atmospheric Remote Sensing, S. Tanelli, JPL*
- *QuakeSim: Increasing Accessibility and Utility of Earthquake Fault Data, A. Donnellan, JPL*
- *Network Design and Operation for Near Real-Time Validation of Space-Borne Soil Moisture Measurements, M. Moghaddam, University of Michigan*
- *OSCAR: Online Services for Correcting Atmosphere in Radar, P. von Allmen, JPL*
- *InSAR Computing Environment, P. Rosen, JPL*
- *On-Board Processing to Optimize the MSPI Imaging System for ACE, P. Pingree, JPL*
- *Coupling NASA Advanced Multi-scale Modeling and Concurrent Visualization Systems for Improving Predictions of Tropical High-impact Weather, B. Shen, University of Maryland*
- *Anomaly Detection and Analysis Framework for Terrestrial Observation and Prediction System (TOPS), R. Nemani, NASA ARC*
- *Sensor Web 3G to Provide Cost-Effective Customized Data Products, D. Mandl, NASA GSFC*

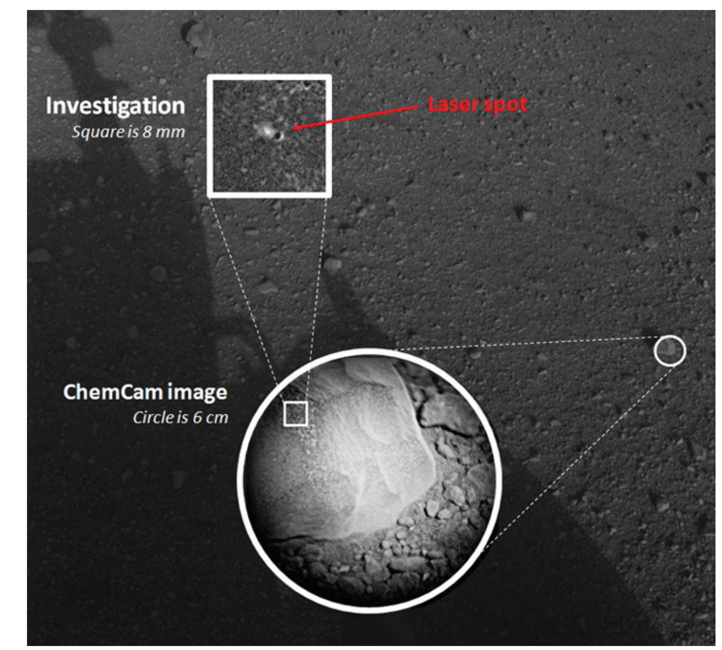
*...FY12 Graduates continue on page 12*

## SPOTLIGHT: Memory Module Enables Research on Mars

*On August 19th, the Chemistry and Camera instrument – or ChemCam – on NASA's Curiosity rover used its powerful laser for the first time to study a small Martian rock named Coronation. ChemCam was able to perform this task and return the data to Earth, in part, through the ESTO-funded Radiation Tolerant Intelligent Memory Stack (RTIMS) – a memory module that controlled the firing of the laser, data acquisition, data buffering, and communication with the Rover Computer Element.*

*Jeffrey Herath of NASA Langley Research Center developed RTIMS under a 2002 AIST award for Earth-observing missions at geostationary and low-Earth orbit. Now it is being used as part of ChemCam, an instrument on Curiosity's mast that uses a laser to vaporize materials up to 9 meters away to determine their elemental composition. RTIMS is helping safeguard ChemCam observations with novel radiation shielding and mitigation technologies. RTIMS also provides a significantly smaller and lighter memory array than was previously available, saving as much as 80% in volume and footprint.*






*Above: Two RTIMS modules on a demonstration board (image: J. Herath)*
*Right: A composite image, with magnified insets, depicts the first laser test by ChemCam (image: NASA/JPL)*

**Web Feature:**
Watch a video about RTIMS at ESTO's YouTube channel: youtube.com/user/NASAESTO

- *Multi-Sensor Data Synergy Advisor (MDSA), C. Lynnes, NASA GSFC*
- *Technology Infusion for the Real Time Mission Monitor, M. Goodman, NASA MSFC*
- *Integration of Data Assimilation, Stochastic Optimization and Uncertainty Modeling within Land Information System (LIS), C. Peters-Lidard, NASA GSFC*
- *Real-Time In Situ Measurements for Earthquake Early Warning and Spaceborne Deformation Measurement Mission Support, Y. Bock, Scripps Institution of Oceanography, UCSD*
- *End-to-End Design and Objective Evaluation of Sensor Web Modeling and Data Assimilation System Architectures: Phase II, S. Talabac, NASA GSFC*
- *Autonomous On-Board Processing for Sensor Systems (A-OPSS) Technology Transition for HyspIRI, M. French, USC Information Sciences Institute*
- *Automated Tracking of Earth Science Phenomena for Ingest into Moving Object Database to Enable Systematic Studies, T. Clune, NASA GSFC*
- *High-End Computing On-demand Model Execution Environment, R. Nemani, NASA ARC*
- *Secure, Autonomous, Intelligent Controller for Integrating Distributed Emergency Response Satellite Operations, W. Ivancic, NASA GRC*
- *Increasing Utility of UAVSAR and Model Applications, A. Donnellan, JPL*

# 2012 in Review: **Components**

The Advanced Component Technology (ACT) program leads research, development, testing, and demonstration of component- and subsystem-level technologies for use in state-of-the-art Earth science instruments and information systems. ACT program funding is primarily geared toward producing technologies that reduce the risk, cost, size, mass, and development time of future space-borne and airborne missions.

The ACT program often brings component technologies to a maturity level that allows their integration into other technology projects, such as those selected by the Instrument Incubator Program, or for further development by other programs. In other cases, the ACT produces component technologies of sufficient readiness that they can be directly infused into mission development or science campaign activities.

In FY12, the ACT program portfolio held a total of 28 investments. 15 of these were added in FY11 through a competitive solicitation that received 96 proposals.

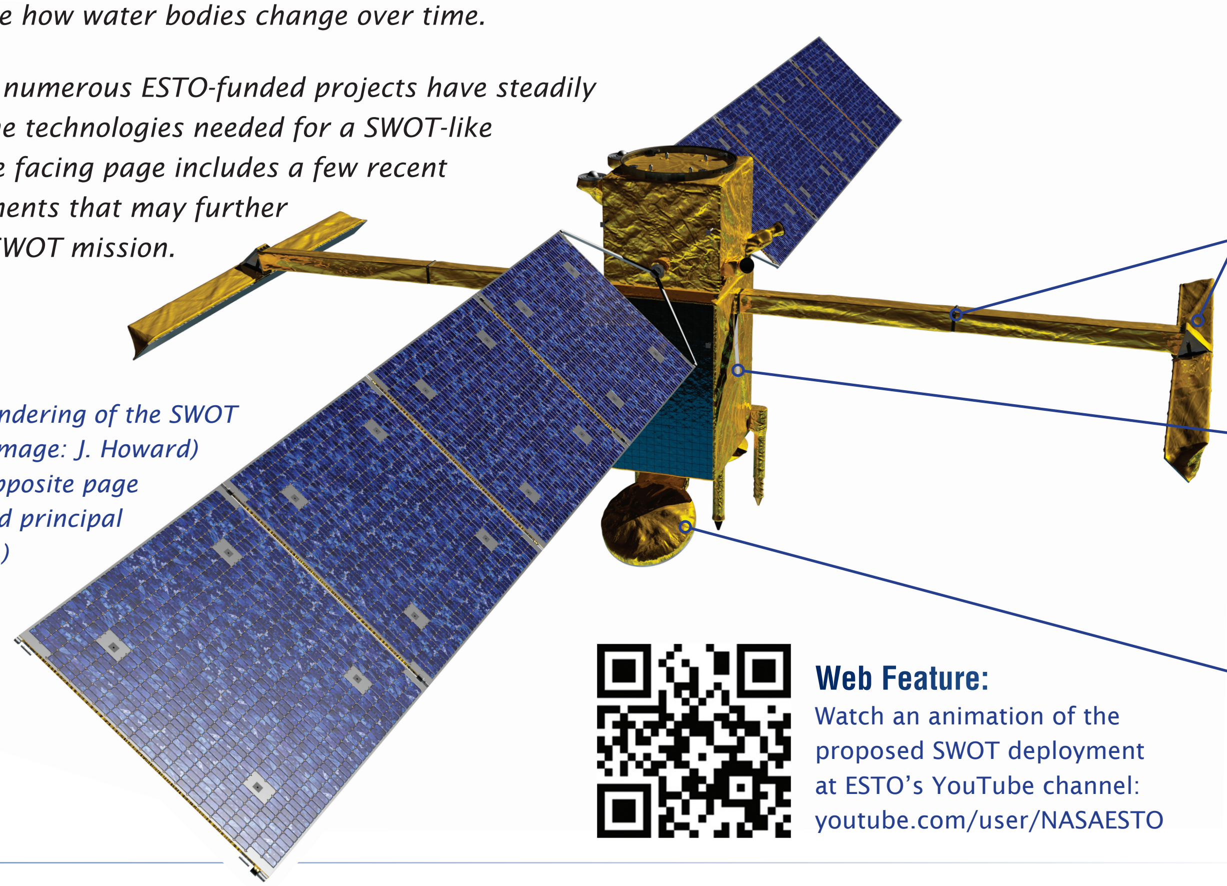
12 projects graduated from the ACT program during the past year, 10 of which advanced at least one Technology Readiness Level (TRL). The FY12 graduates are:

- ***Far-Infrared Extended Blocked Impurity Band (FIREBIB) Detectors Optimized for Earth Radiance Measurements,*** **M. Mlynczak, NASA LaRC**
- ***CLASS Instrument Technology Maturation for ASCENDS,*** **M. Phillips, Lockheed Martin Coherent Technologies**
- ***Hybrid Doppler Wind Lidar Transceiver,*** **C. Marx, NASA GSFC**
- ***A Large High-Precision Deployable Reflector for Ka- and W-band Earth Remote Sensing,*** **M. Lane, JPL**
- ***A Low Power, High Bandwidth Receiver for Ka-band Interferometry,*** **P. Siqueira, University of Massachusetts**
- ***Ultra-sensitive Near-Infrared Optical Receiver Using Avalanche Photodiodes,*** **M. Krainak, NASA GSFC**
- ***Advanced Thermal Packaging Technologies for RF Hybrids,*** **J. Hoffman, JPL**
- ***Advanced Component Development to Enable Low-Mass, Low-Power High-Frequency Radiometers for Coastal Wet-Tropospheric Correction on SWOT,*** **S. Reising, Colorado State University**
- ***Large Deployable Ka-Band Reflectarray for the SWOT Mission,*** **M. Thomson, JPL**
- ***In-Pixel Digitization Readout Integrated Circuit (ROIC) for the Geostationary Coastal and Air Pollution Events (GEO-CAPE) Mission,*** **D. Rider, JPL**
- ***Large Aperture, Solid Surface Deployable Reflector,*** **R. Taylor, Composite Technology Development**
- ***A GNSS RF ASIC for Digital Beamforming Applications,*** **T. Meehan, JPL**

## SPOTLIGHT: Several Component Technologies to Enable SWOT Decadal Survey Mission

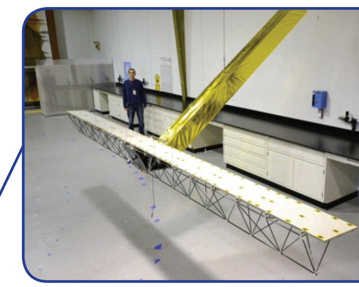
*The Surface Water Ocean Topography (SWOT) mission concept is intended to produce a better understanding of the world's oceans and terrestrial surface waters at a much higher spatial resolution than is currently available. Using wide-swath radar altimetry measurements, SWOT could make the first global survey of Earth's surface water, observe the fine details of the ocean's surface topography, and measure how water bodies change over time.*

*Since 1998, numerous ESTO-funded projects have steadily advanced the technologies needed for a SWOT-like mission. The facing page includes a few recent ACT investments that may further enable the SWOT mission.*

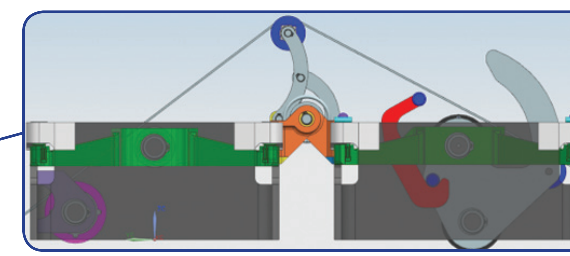


*An artist's rendering of the SWOT spacecraft. (image: J. Howard) (images on opposite page courtesy listed principal investigators.)*

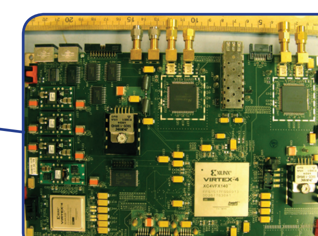
**Web Feature:**
Watch an animation of the proposed SWOT deployment at ESTO's YouTube channel: youtube.com/user/NASAESTO



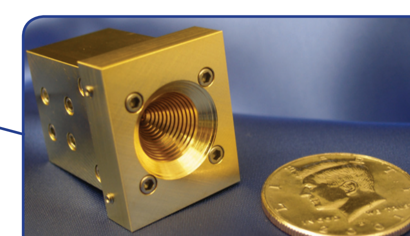
The design for SWOT includes two deployable, 5 meter, Ka-band reflectarray antennas – part of the Ka-band Radar Interferometer (KaRIn) proposed for SWOT – that will be separated by 10 meters and need to be structurally flat and thermally stable to meet demanding pointing and interferometric phase stability requirements. This project built and tested a full-scale deployable reflectarray prototype (left) that has become the current baseline for the SWOT mission. *(M. Thompson, JPL, ACT-08)*



A second project is working to design and prototype a precision deployable mast for the two KaRIn antennas, including the hinges and latches needed for precise space deployment and an accurate pointing adjustment mechanism. Shown here is the mechanical drawing for a 180 degree hinge and latch at the mid-span of the boom. *(G. Agnes, JPL, ACT-10)*



A key challenge for the SWOT mission will be a low-power, high bandwidth Ka-band receiver that is capable of making precision measurements over a wide bandwidth. This project has completed design, development, and implementation of a single-stage Dual Down Converter (or DDC, shown here) that meets SWOT mission requirements. *(P. Siqueira, University of Massachusetts, ACT-08)*



A three-frequency microwave radiometer has also been proposed for the SWOT mission to improve accuracy in estimating wet tropospheric path delay in coastal zones and over land. This ACT project designed, developed and built the multi-frequency antenna horn shown here and integrated it into the radiometer system. The completed prototype underwent testing and met SWOT requirements. *(S. Reising, Colorado State University, ACT-08)*

# Toward In-Space Validation

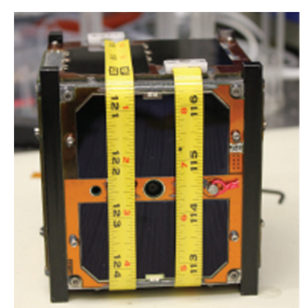
The space environment imposes harsh conditions on satellite components and systems. In some cases, there is a need to validate certain new technologies in space prior to use in a mission– particularly those that cannot be adequately and completely tested on the ground or in airborne systems. The In-Space Validation of Earth Science Technologies (InVEST) program was established as a pilot program in 2012 to provide a new validation option for these types of emerging technologies.

Recent advancements in small, standardized satellites and increasing, low-cost, access to space are rapidly transforming the way technologies can be demonstrated and validated. CubeSats – 10 cm cube platforms launched as secondary payloads to a larger satellite – are leading the way as a standardized platform. They can be inexpensive, as little as $1-2M including launch and basic operations when leveraging prior payload development, and can be built and launched quickly, generally within 18 to 24 months from concept formulation to deployment. CubeSats can be combined to form 2- or 3-unit configurations for a variety of applications. Although precise numbers are unavailable, there have been approximately 100 CubeSats launched as of 2012.

The first InVEST solicitation was released in September 2012, with proposals due in late November. The solicitation focused on small instruments and instrument systems that can: comply with the CubeSat standard, launch within two years of funding, and provide significant reductions in technology risk.

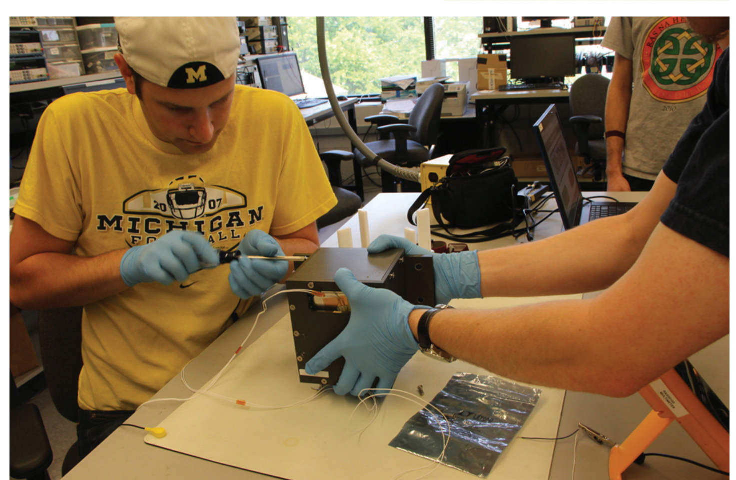
*Future missions will generate very high data volumes. For example, the Multi-angle Spectropolarimetric Imager (MSPI - Instrument Incubator Program, Diner/JPL), a candidate for the ACE mission concept, will produce 95 Megabytes per second per camera. MSPI will house a total of nine cameras. There is currently no way to get that amount of raw data from space to the ground.*

*One solution is to move the first stage of ground processing to the satellite in a new radiation-hard-by-design FPGA. This would reduce downlink requirements by two orders of magnitude.*



*In 2011, the MSPI algorithm – developed under an ESTO Advanced Information Systems Technology (AIST) project (AIST-07, Pingree, JPL) – and a new FPGA developed by the Xilinx Corporation were launched on a CubeSat (top right), built by the University of Michigan's Student Space Systems Fabrication Lab (S3FL, shown at right).*

*The CubeSat was a secondary payload to the NASA Suomi NPP mission. Access to space was enabled by the NASA CubeSat Launch Initiative. (images: University of Michigan)*



# Additional Resources

ESTO launched a new website for 2012 that contains several online resources as well as additional information on ESTO's approach to technology development, programs, validation activities, and strategic planning:

*General Information on current and past programs, studies, solicitations, TRL definitions, events, and more.*

*Timely features on ESTO technology projects, progress, achievements, and infusions*

*A fully-searchable database of ESTO investments*

*Social media and news listserv options to stay connected:*

*> Twitter: @NASAESTO*

*> YouTube: NASAESTO*


*An active, regularly updated section for news items and announcements*

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