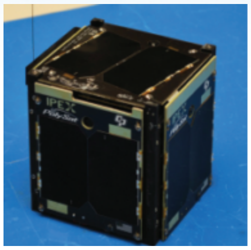
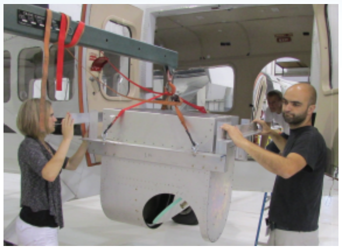
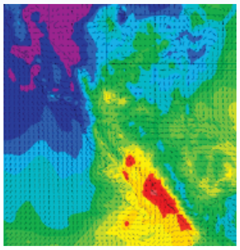
National Aeronautics and Space Administration

2014 Annual Report







NASA Earth Science Technology Office

On the Cover

Cover images, from left to right:

- Balloon launch of the HyperSpectral Imager for Climate Science (HySICS) instrument in August 2014 (see page 7; Credit: G. Kopp, University of Colorado, LASP)
- The EcoSAR field measurement team collecting forest structure and biomass measurements in a tropical mangrove forest of Costa Rica in March 2014 (see page 6; Credit: T. Fatoyinbo, NASA)
- The Intelligent Payload Experiment (IPEX) CubeSat (see page 14; Credit: Cal Poly / JPL)
- Colorado State University graduate student Torie Hadel and postdoctoral scholar Xavier Bosch-Lluis install the High-frequency Airborne Microwave and Millimeter-wave Radiometer (HAMMR) instrument into the Twin Otter aircraft for test flights (see page 5; Credit: S. Reising, Colorado State)
- Model data of monsoonal moisture from the Gulf of California, made possible in part by the Next-Generation Real-Time Geodetic Station Sensor Web for Natural Hazards Research and Applications project (see page 9; Credit: NOAA)

Illustrations throughout by Jennifer Mottar, NASA

Executive Summary

As reported in the pages that follow, fiscal year 2014 (FY14) was a full and productive year for technology development, a year that saw numerous successes in the selection of new projects and the advancement and infusion of technologies for NASA Earth science.

Activities within the Earth Science Technology Office (ESTO) continue to proceed around guidance provided 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," as well as the 2007 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.

Of particular note, during this fiscal year ESTO funded 11 new Advanced Component Technology (ACT) projects and solicited new Advanced Information Systems Technology (AIST) proposals, both through the NASA Research Announcement Research Opportunities in Space and Earth Sciences (ROSES) omnibus announcements. News on the new ACT awards can be found on page 13. The AIST awards will be announced in FY15. Additionally, the In-Space Validation of Earth Science Technologies (InVEST) program expects to release its next solicitation in FY15.

ESTO continues to build upon a strong history of technology development and infusion. In FY14 54% of active ESTO technology projects advanced at least one Technology Readiness Level (TRL). Of the 644 completed projects in the ESTO portfolio, 35% have already been infused while an additional 46% have a path identified for future infusion in Earth observing missions or commercial applications. See pages 3-6 for more on ESTO programmatic metrics.

These successes demonstrate the hard work of our past and present principal investigators and their collaborators. We welcome the new group of ACT investigators as they begin their selected projects and we look forward to their contributions that, along with our existing projects, will ensure a bright future for Earth science discovery.

George J. Komar
Program Director

Robert A. Bauer
Deputy Program Director

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.

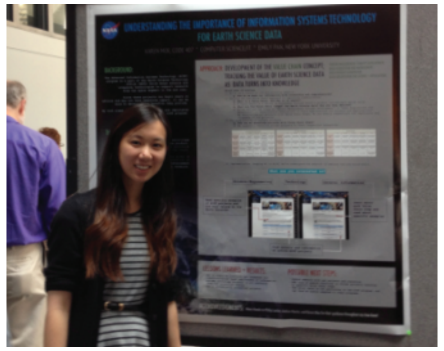
As the technology function within NASA's Earth Science Division, the Earth Science Technology Office (ESTO) performs strategic technology planning and manages the development of a range of advanced technologies for future science measurements and operational requirements.

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:

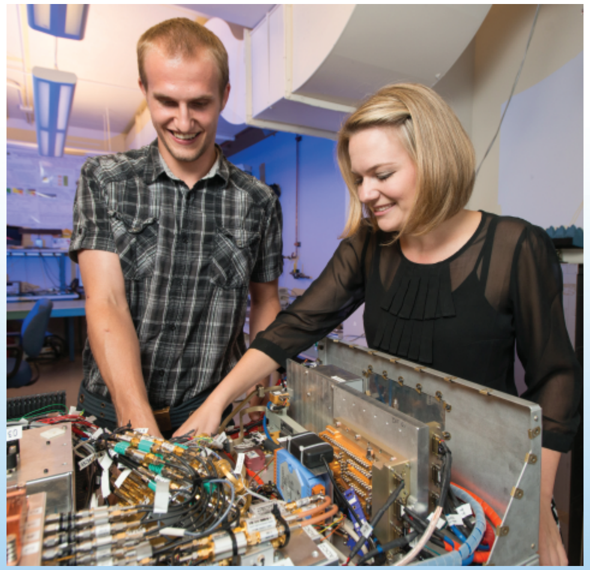
- Planning investments by careful analyses of science requirements
- Selecting and funding technologies through competitive solicitations and partnership opportunities
- Actively managing the progress of funded projects
- Facilitating the infusion of mature technologies into science measurements

The results speak for themselves: a broad portfolio of 757 emerging technologies – 118 of which were active at some point during Fiscal Year 2014 (FY14) – ready to enable or enhance science measurement capabilities as well as an ever-growing number of technology infusion successes.



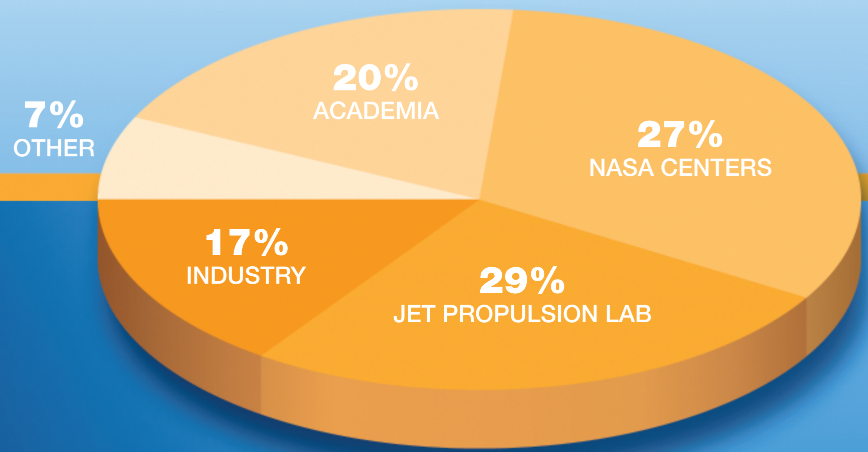
Student Participation

Student participation in ESTO projects has always been substantial. Since 1998, at least 570 students from over 110 institutions have been involved in ESTO-funded work and as many as 120 graduate-level degrees have been awarded. In 2014 alone, at least 117 students were actively involved with ESTO projects. Roughly half are pursuing doctorates while the remainder are working toward master or undergraduate degrees.

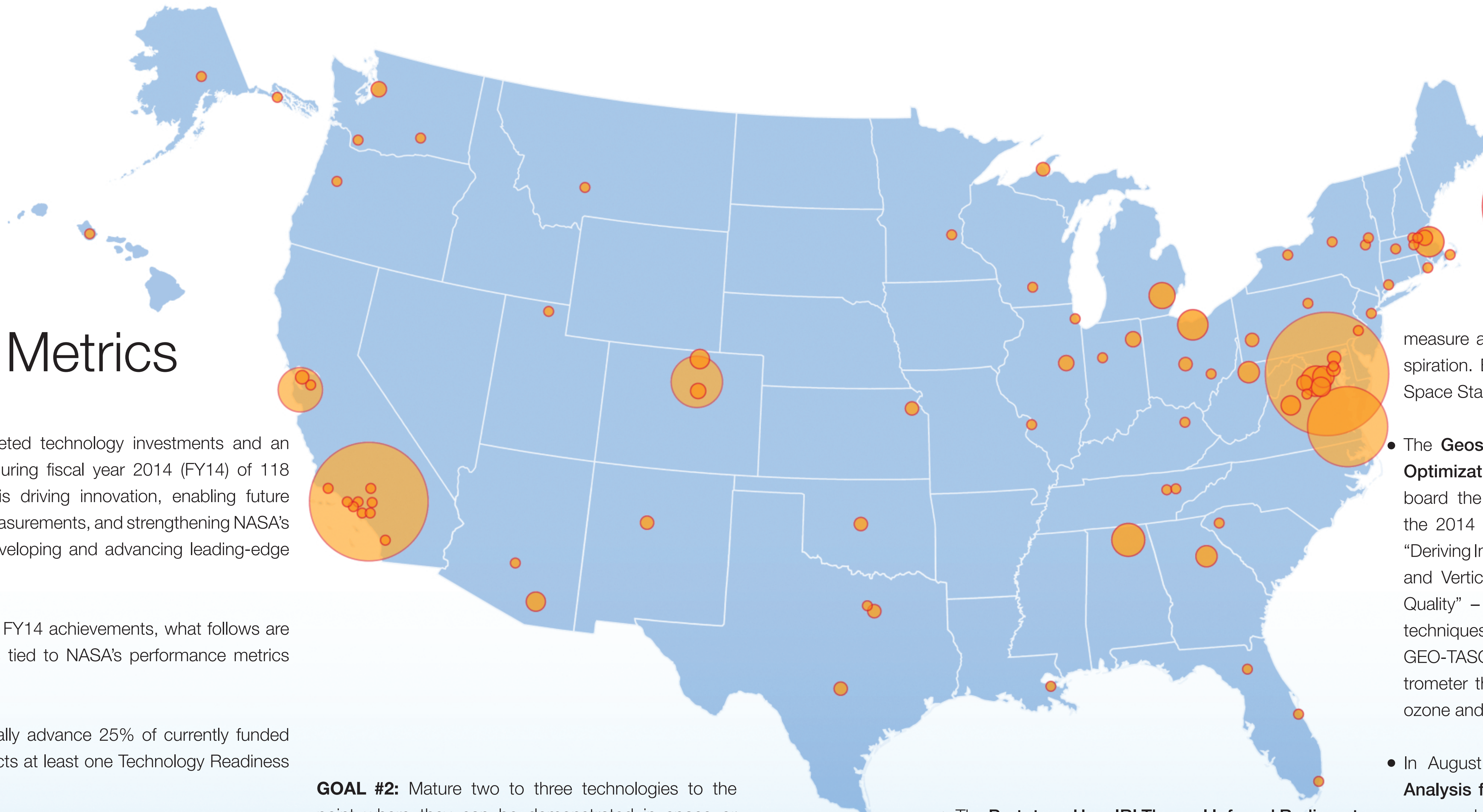


Top: Emily Pan, a senior at New York University majoring in mathematics, interned with ESTO over the summer of 2014. Emliy is shown here next to her poster: "Understanding the Importance of Information Systems Technology for Earth Science Data - Development of the Value Chain Concept." (Credit: P. Larkin)

Left: Graduate students Thaddeus Johnson and Torie Hadel work on the HAMMR (High-frequency Airborne Microwave and Millimeter-wave Radiometer) instrument at Colorado State University in Fort Collins, Colorado. Both also helped to prepare and integrate the instrument for its first engineering flights in July 2014 - see page 5. (Credit: S. Reising)



The 118 active projects during FY14 included the combined efforts of more than 385 principal investigators (PIs), co-investigators (Co-Is), and partners from a variety of institutions. The graph at right gives the distribution of these participating institutions



2014 Metrics

With 644 completed technology investments and an active portfolio during fiscal year 2014 (FY14) of 118 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 FY14 achievements, what follows are the year's results tied to NASA's performance metrics for ESTO:

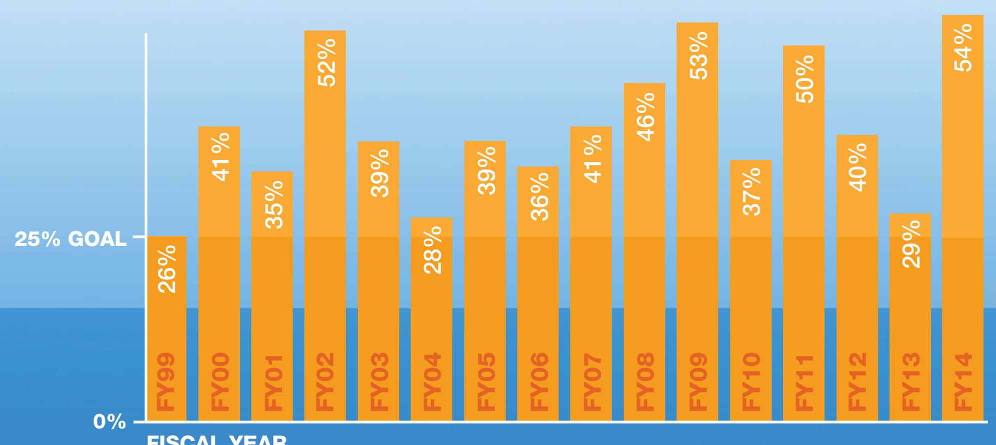
GOAL #1: Annually advance 25% of currently funded technology projects at least one Technology Readiness Level (TRL).

FY14 RESULT: 54% of ESTO technology projects funded during FY14 advanced one or more TRLs over the course of the fiscal year. Five of these projects advanced more than one TRL. See the graph below for yearly comparisons. [Note: because of the periodicity of solicitations and reporting, interannual comparisons are not relevant.]

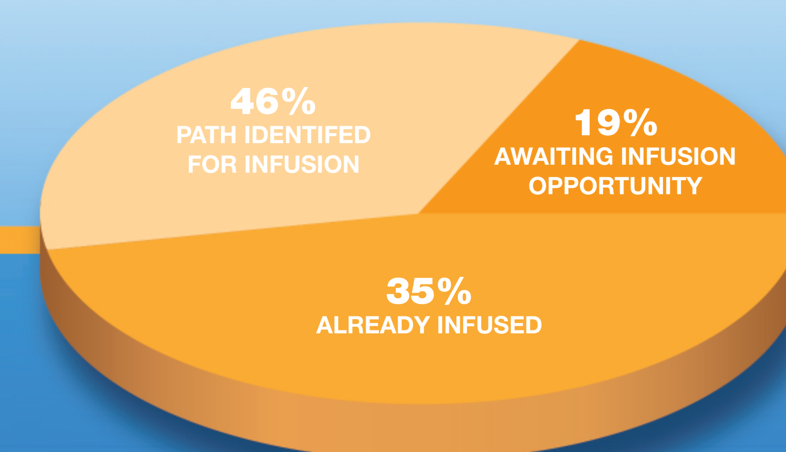
GOAL #2: Mature two to three technologies to the point where they can be demonstrated in space or in a relevant operational environment.

FY14 RESULT: At least nine ESTO projects achieved infusion into science measurements, airborne campaigns, data systems, or follow-on development activities in FY14. Examples include:

- The **Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)** instrument, which was completed in FY14, has been selected by a new NASA Earth Venture-Instrument mission: the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS). The ECOSTRESS mission will use a high-resolution thermal infrared radiometer derived directly from PhyTIR to measure and monitor plant-water dynamics and transpiration. ECOSTRESS will launch to the International Space Station between 2017 and 2019.
- The **Geostationary Trace gas and Aerosol Sensor Optimization (GEO-TASO)** instrument, which flies on board the NASA HU-25C Falcon aircraft, supported the 2014 DISCOVER-AQ flights. DISCOVER-AQ – or "Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality" – is a four-year airborne campaign studying techniques to measure pollution near the Earth's surface. GEO-TASO, a nadir-viewing ultraviolet-visible spectrometer that measures aerosols and trace gases like ozone and formaldehyde, had its first flights in 2013.
- In August 2014, the **Advanced Rapid Imaging & Analysis for Monitoring Hazards (ARIA-MH)** project was used to provide rapid turn-around of Italian Space Agency Cosmo-SkyMed radar data to the Napa, CA, earthquake response team. The rapid ingest, cataloging and processing of the data by ARIA-MH allowed the team to compare July 26 and Aug 27 data, revealing the surface deformation and aiding in initial damage assessments with more current data than previously possible.



Percentage of Active Projects that Advanced at Least 1 TRL during each Fiscal Year (FY).



ESTO's infusion success—drawn from the 644 completed projects through the end of FY14

2014 Metrics (continued)

GOAL #3: Enable a new science measurement or significantly improve the performance of an existing technique.

FY14 RESULT: Two notable examples:

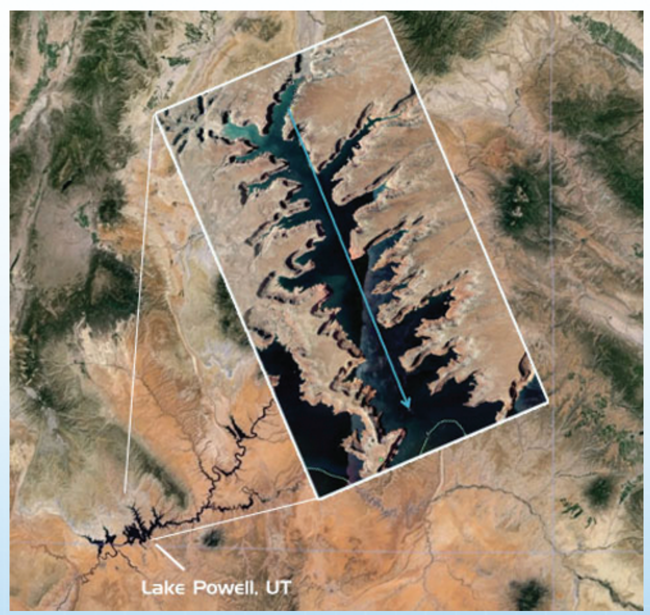
HAMMR, the High-frequency Airborne Microwave and Millimeter-wave Radiometer, completed its first engineering flights in early July 2014. The internally-calibrated, wide-band microwave instrument was developed by PI Steven Reising of Colorado State University, in collaboration with JPL and UCLA, to demonstrate wet-path delay measurements with much higher spatial resolution than current measurement capabilities allow.

Current sea surface height altimeter measurements utilize microwave radiometers operating at cm wavelengths to correct for errors due to changes in humidity between the satellite and the surface. If humidity in the atmosphere is not accurately characterized, it skews the data enough to make sea surface height measurements inaccurate, an error known as wet-path delay.

Radiometers have been used successfully to measure this wet-path delay on radar altimeter missions for more than two decades, but the currently-used cm-wavelength radiometers can only provide valid measurements over large water bodies, such as oceans. Errors are prevelant within 25 to 50 km from coasts and over inland bodies of water, such as lakes and rivers.

HAMMR successfully completed its first engineering flight on July 9, 2014 onboard a Twin Otter aircraft. The instrument incorporates the currently-used cm-wavelength microwave channels (18.7, 23.8 and 34.0 GHz) and provides enhanced capability by adding higher frequency millimeter (mm)-wavelength channels at 90, 130 and 166 GHz. Operating at mm-wavelengths, as HAMMR does, could enable 5 to 10 km or better resolution from space, greatly improving the performance of radar altimetry.

HAMMR will fly to California for a series of coastal flights in early FY2015. There, the team will coordinate with the National Center for Atmospheric Research for ground-truth humidity measurements to further calibrate and validate the instrument's capabilities. HAMMR could eventually be used to perform regular regional high-resolution wet-path delay measurements along coasts and over small rivers and lakes, which would provide scientists with a better understanding of water surface height and sea level changes.



Above: On July 10th and 11th, HAMMR made several engineering flights totaling ~12 hours) over Lake Powell in Utah. Lake Powell was chosen as a large inland body of water with a number of clear land-to-water transitions. The inset map shows one of the flight lines over Lake Powell. (Image credit: Google Earth)

In March 2014, an airborne polarimeteric and interferometric P-band radar instrument named EcoSAR – the first P-band radar of its kind in the U.S. – made its inaugural flights on a NOAA P-3 aircraft out of MacDill Air Force Base, FL. The first flight was over Andros Island in the Bahamas. Later in the month, EcoSAR flew from MacDill over Mexico, Belize, Honduras, Guatemala, Costa Rica and El Salvador to collect measurements of carbon-dense forests.

EcoSAR uses two antennas mounted 25 meters apart on either wing of the aircraft. By spacing the antennas, EcoSAR is able to achieve interferometry with a single pass instead of flying repeat passes over the same area.

After the successful science flights, EcoSAR returned to Goddard Space Flight Center in Maryland where the team, led by principal investigator Temilola Fatoyinbo, is processing and analyzing the over 6 Terabytes of raw data that were collected.

With the longer P-band wavelength, EcoSAR can penetrate more deeply into forest canopy to measure the forest volume and woody density, the biomass, than the more commonly used L-, C- or X- band wavelengths. EcoSAR demonstrated its ability to measure canopy height of tall forests to within 1-meter accuracy and above-ground woody biomass with an 20% accuracy.

EcoSAR's measurements can tell researchers much about the extent of terrestrial forests and the changes to which these environments are prone, from flooding, wildfires and deforestation. Understanding these high-biomass ecosystems and the changes they are undergoing will give climate researchers new insights about how much carbon these environments store and how much carbon can be released as the ecosystem faces natural and human-caused changes.

In the future, the EcoSAR team plans to fly over different ecosystems from those already sampled to test the instrument's capability for permafrost, ice and snow depth measurements. It is estimated that twice the amount of carbon that is stored in the atmosphere can be found locked away in permafrost. Once fully demonstrated, EcoSAR may prove to be a valuable tool that provides highly-accurate data for use in studying climate, ecosystem changes, and atmospheric science.

Top: The NOAA P3, with EcoSAR onboard, is prepared for the flights at the MacDill Air Force Base hangar. One of the EcoSAR antennas is visible on the right, mounted underneath the aircraft's left wing. (Image Credit: Fatoyinbo, NASA)

2014 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 that reduce costs and risk.

The IIP included 35 active projects in FY14, 17 of which were added in January 2014 through a competitive solicitation seeking new instrument technologies to enable new types of Earth observations and improve temporal and spatial resolution capabilities for Earth science measurements. These new awards are:

- *High Accuracy Vector Helium Magnetometer (HAVHM)* - Andy Brown, Polatomic Incorporated
- *Enhancement, Demonstration, and Validation of the Wideband Instrument for Snow Measurements (WISM)* - Tim Durham, Harris Corporation
- *Signals of Opportunity Airborne Demonstrator (SoOp-AD)* - James Garrison, Purdue University
- *Multi-Wavelength Ocean Profiling and Atmospheric Lidar* - Chris Hostetler, NASA LaRC
- *UWBRAD: Ultra Wideband Software Defined Microwave Radiometer for Ice Sheet Subsurface Temperature Sensing* - Joel Johnson, Ohio State University
- *Wide-Swath Shared Aperture Cloud Radar (WiSCR)* - Lihua Li, NASA GSFC
- *A Compact Adaptable Microwave Limb Sounder for Atmospheric Composition* - Nathaniel Livesey, JPL
- *MISTiC Winds* - Kevin Maschhoff, BAE Systems
- *Snow and Water: Imaging Spectroscopy for Coasts and Snow Cover (SWIS)* - Pantazis Mouroulis, JPL
- *Ka-band Doppler Scatterometer for Measurements of Ocean Vector Winds and Surface Currents (DopplerScatt)* - Dragana Perkovic-Martin, JPL
- *Wide-band Millimeter and Sub-Millimeter Wave Radiometer Instrument to Measure Tropospheric Water and Cloud ICE (TWICE)* - Steven Reising, Colorado State University
- *Development of a Compact Solar Spectral Irradiance Monitor with High Radiometric Accuracy and Stability* - Erik Richard, University of Colorado, Boulder
- *Three Band Cloud and Precipitation Radar (3CPR)* - Gregory Sadowy, JPL
- *Cold Atom Gravity Gradiometer for Geodesy* - Babak Saif, NASA GSFC
- *Triple-Pulsed 2-Micron Direct Detection Airborne Lidar for Simultaneous and Independent CO_2 and H_2O Column Measurement Novel Lidar Technologies and Techniques with Path to Space* - Upendra Singh, NASA LaRC
- *HSRL for Aerosols, Winds, and Clouds Using Optical Autocovariance Wind Lidar (HAWC-OAWL)* - Sara Tucker, Ball Aerospace & Technologies Corp.
- *TIRCIS: A Thermal Infrared, Compact Imaging Spectrometer for Small Satellite Applications* - Robert Wright, University of Hawaii

Seven IIP projects were completed over the past year, six of which advanced at least one TRL during the period of funding. The FY14 graduates are as follows:

- *A Multi-parameter Atmospheric Profiling Radar for ACE (ACERAD)* - Stephen Durden, JPL
- *Multi-Slit Offner Spectrometer (MOS)* - Timothy Valle, Ball Aerospace & Technologies Corp.
- *Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) for Earth Science* - Simon Hook, JPL
- *A Flight-like Prototype of the Ocean Radiometer for Carbon Assessment (ORCA)* - Gerhard Meister, NASA GSFC
- *An 8-40 GHz Wideband Instrument for Snow Measurements (WISM)* - Tim Durham, Harris Corporation
- *Prototype Sensor Development for Geostationary Trace gas and Aerosol Sensor Optimization (GEO-TASO)* - James Leitch, Ball Aerospace & Technologies Corp.
- *Panchromatic Fourier Transform Spectrometer Engineering Model (PanFTS EM)* - Stanley Sander, JPL

SPOTLIGHT:

Successful Demonstration Flight for New Solar Radiance Instrument

On August 8, 2014 the HyperSpectral Imager for Climate Science (HySICS) instrument was carried aloft by high-altitude balloon to 122,000 feet over Fort Sumner, New Mexico, to demonstrate its capability to take science measurements. During the nearly 9-hour flight, HySICS made ultraviolet-to-solar irradiance measurements (350-2300nm wavelength range) of Earth, cross-calibrated by periodic measurements of the sun.

The flight was deemed an operational and science success, and the HySICS team has reported the collection of high quality science data. HySICS, developed by principal investigator Greg Kopp of the University of Colorado, could give insight into how much of the sun's radiative energy is reflected by the Earth's surface and atmosphere, an important component for climate research. Pending further data processing and analysis, HySICS may have achieved the most accurate solar radiance measurements (calibrated to the Sun to better than 0.2 percent radiometric accuracy) that have ever been made of the Earth.

NASA's Earth-observing satellites have collected Earth radiance measurements for years, but the highly-accurate radiance measurements enabled by HySICS will enable faster detection of climate trends – years instead of decades – than current radiance data allow.

HySICS' first flight took place in September 2013, also from the Columbia Scientific Balloon Facility in Fort Sumner. That engineering flight gave Kopp and his team flight experience and data necessary to refine the instrument in preparation for this year's science demonstration. Both flights also utilized the Wallops Arc-Second Pointing system, originally developed for astrophysics payloads, to ensure highly accurate pointing of the instrument.

Far left: The sun rises in Fort Sumner, NM, as the HySICS payload is readied for launch. **Near left:** Technicians fill the high-altitude balloon with helium. (Credits: NASA Wallops)

2014 in Review: Information Systems

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 19 active investments in FY14, 10 of which advanced one or more TRL over the past year.

In April 2014, a new AIST solicitation was released under the 2014 NASA Research Opportunities in Space and Earth Sciences (ROSES) omnibus announcement.

Proposals were sought in three core topic areas:

- Operations technologies that support the future challenges of operating NASA's Earth Science observing systems;
- Computational technologies that operate directly on Earth Science sensor data; and
- Data-Centric technologies that help transform observational data into scientific discoveries.

An announcement of awards is expected in early FY15.

The Next-Generation Real-Time Geodetic Station Sensor Web for Natural Hazards Research and Applications AIST project has successfully integrated 27 GPS meteorology stations (such as the one **shown at left**) into NOAA's Earth System Research Lab (ESRL) network in Southern California. GPS meteorology uses co-located air pressure and temperature measurements with precise position to estimate precipitable water vapor, or the amount of water in the atmosphere if it were to fall as rain.

Accurate estimates of precipitable water vapor are important to forecast rain totals and flooding risks. The networked metrology stations have reduced the uncertainty estimate of precipitable water vapor by 50% and NOAA has incorporated the new data into their monsoon forecasting models.

The project team is now working to outfit the GPS stations with geodetic modules that collect meteorological data and use a Kalman filter to estimate unknowns. The modules will measure ground displacement useful in the forecasting and research of tsunamis and earthquakes.

(Credit: Y. Bock, Scripps Institution of Oceanography)

SPOTLIGHT:

AIST Project Provides a Peek at California Drought

Water is increasingly in short supply in many parts of the United States. California is particularly dry – 2013 was the driest year on record and much of the state is experiencing an extended drought with little or no relief in sight. While rainfall measurements are relatively straightforward, many questions remain about how moisture is stored and distributed in Earth's soils, how ecosystems function in variable conditions, and how the water cycle is globally regulated. Answering these questions may help us monitor and forecast future droughts, formulate effective water policies, and improve climate change predictions.

Scheduled to launch in January 2015, NASA's Soil Moisture Active and Passive (SMAP) mission will map Earth's soil moisture from space and provide some of these answers. In advance of SMAP, an AIST project called SoilSCAPE is installing and testing ground networks of in-situ soil moisture sensors at several test sites. These smart wireless networks of sensors – sensor webs – are designed to communicate with each other to adaptively and efficiently measure soil moisture at various depths. The data from the SoilSCAPE test sites will be used to validate SMAP data.

One of the SoilSCAPE sites – Tonzi Ranch near Jackson, CA – is located in the lower foothills of the Sierra Nevada Mountains near the heart of the California drought. SoilSCAPE currently has five other networks nearby in central CA. SoilSCAPE's principal investigator Mahta Moghaddam and her team at the University of Southern California (MIT, University of Michigan, and ORNL DAAC also participate) have compiled soil moisture data from the Tonzi Ranch network that provides a unique look at the current drought from above and below the surface.

Web Feature:
See comparitive animations (below) of Tonzi Ranch soil moisture – winter 2013 vs. winter 2014 – here: http://1.usa.gov/1gTPDsO

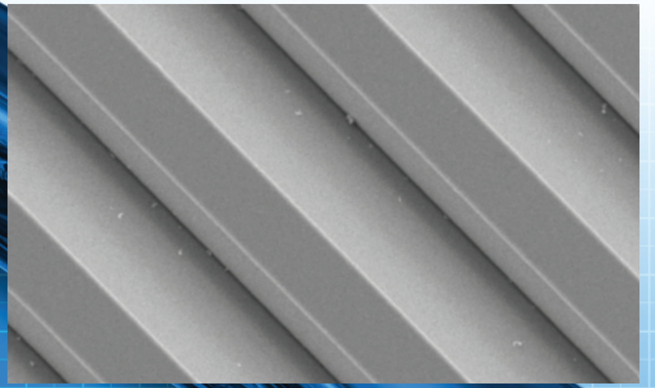
Above: The Tonzi Ranch SoilSCAPE site (Credit: M. Moghaddam, USC)

2014 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. The 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 aims to mature component technologies to a level that allows further development by other NASA programs or their integration into other technology projects, such as those selected by the Instrument Incubator Program. In other cases, the ACT produces component technologies of sufficient readiness that they can be directly infused into mission development or science campaign activities.

Below: A scanning electron micrograph (4,000x magnification) of grating grooves etched into silicon. These silicon immersion gratings are intended for a new generation of compact infrared spectrometers that could be used to study and monitor various greenhouse gasses (CO, CO_2, and CH_4) in Earth's atmosphere. The perfect shape and low roughness of the etched grooves means less light is scattered, and the small size of the gratings could enable future instruments that are much smaller – perhaps an order of magnitude smaller – than the current state of the art. (Credit: D. Jaffe, University of Texas)



In FY14, the ACT program portfolio held 15 investments, 3 of which were completed this year:

- *Advancement of the O_2 Subsystem to Demonstrate Retrieval of XCO_2 Using Simultaneous Laser Absorption Spectrometer Integrated Column Measurements of CO_2 and O_2* - Jeremy Dobler, ITT Excelis
- *Precision Deployable Mast for the SWOT KaRIn Instrument* - Gregory Agnes, JPL
- *Advanced Antenna for Digital Beamforming SAR* - Rafael Rincon, NASA GSFC

11 new ACT projects were selected in September through a competitive solicitation that received 82 proposals. These new awards, which will begin work in FY15, are as follows:

- *A 183 GHz Humidity Sounding Radar Transceiver* - Ken Cooper, JPL
- *Proof-of-Concept and Feasibility Demonstrations for an Avalanche Photodiode/Photoelastic Modulator-Based Imaging Polarimeter* - David Diner, JPL
- *Compact Magnet-Less Circulators for ACE and Other NASA Missions* - Anton Geiler, Metamagnetics, Incorporated
- *Modular Dual-Band Ku/Ka Antenna Tile with Digital Calibration (K-Tile)* - James Hoffman, JPL
- *Carbon Absolute Electrical Substitution Radiometers (CAESR)* - Greg Kopp, University of Colorado, Boulder
- *Wideband Radio Frequency Interference Detection for Microwave Radiometer Subsystem* - Priscilla Mohammed, Morgan State University
- *Ka Band Highly Constrained Deployable Antenna for RaInCube* - Yahya Rahmat-Samii, University of California, Los Angeles
- *A Compact Trace Gas Lidar for Simultaneous Measurements of Methane and Water Vapor Column Abundance* - Haris Riris, NASA GSFC
- *Beamsteerable GNSS Radio Occultation ASIC* - Michael Shaw, Gigoptics, Inc.
- *Lidar Orbital Angular Momentum Sensor* - Carl Weimer, Ball Aerospace & Technologies Corporation
- *SRI CubeSat Imaging Radar for Earth Science (SRI-CIRES)* - Lauren Wye, SRI International

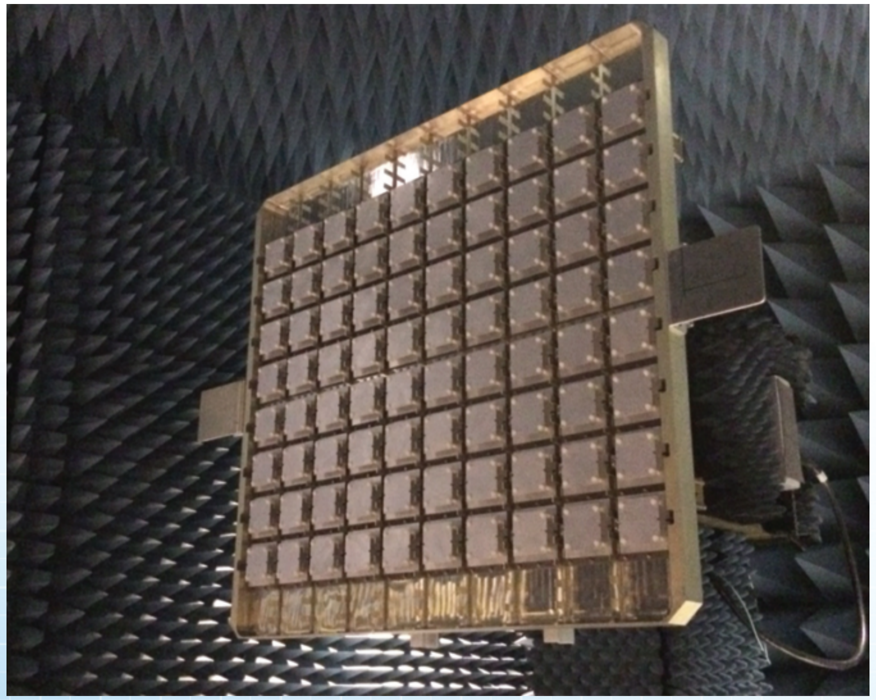
SPOTLIGHT:

Progress Toward a Digital Beamforming SAR

A recently-completed ACT project at the NASA Goddard Space Flight Center (GSFC) has designed, fabricated and tested an advanced L-band phased-array antenna for a future, next generation Digital Beamforming Synthetic Aperture Radar (DBSAR) instrument. Such an instrument could provide meter-resolution and fully polarimetric measurements of permafrost change, vegetation volumes and densities, and natural and anthropogenic changes to land cover.

Digital beamforming enables new Earth science measurement techniques, including single pass interferometry, increased swath and coverage areas, and simultaneous reception and processing of SAR and Global Navigation Satellite System (GNSS) signals. Multiple antenna beams can be synthesized simultaneously and an increase in measurement swath can be achieved without reducing the antenna gain. On an airborne platform, beams can also be synthesized on both sides of the flight track using a singe antenna.

The antenna was characterized earlier this year in the GSFC anechoic chamber and met design requirements – 500 MHz bandwidth and > 35 dB polarization isolation requirements. The project team, led by Rafael Rincon, is pursuing opportunities to test the antenna on an airplane.



At Left: The DBSAR L-Band antenna undergoing testing inside an anechoic chamber (Credit: R. Rincon, NASA GSFC)

2014 in Review: Space Validation

NASA has an ambitious vision for future Earth observations, with emerging technologies paving the way toward new Earth science measurements. With promising new capabilities, however, comes increased complexity and risk.

While ground and airborne testing of new technologies is common practice, the need for validation in the hazardous environment of space is critical and ongoing. Once validated in space, technologies are generally more adoptable, even beyond the intended mission.

From the start, ESTO has sought to facilitate space demonstrations of key technology projects through partnerships, such as with the NASA CubeSat Launch Initiative (CSLI), and follow-on projects, particularly under other NASA programs such as the Earth System Science Pathfinder Program (ESSP).

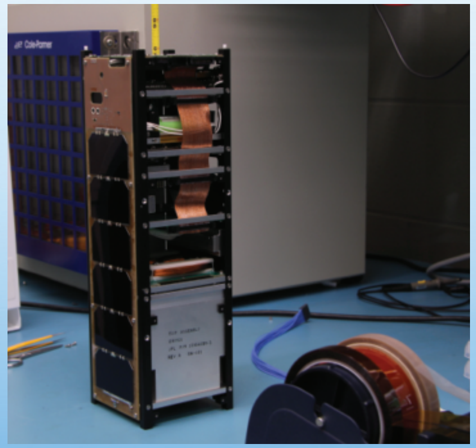
In 2012, ESTO created a nimble, competitive program called In-Space Validation of Earth Science Technologies (InVEST) to retire risk and space-validate technologies. The first InVEST solicitation, which sought small instruments and instrument subsystems relevant to Earth science measurements, targeted the CubeSat* platform. Twenty-four proposals were received, four of which were selected in 2013:

- *The Microwave Radiometer Technology Acceleration (MiRaTA) CubeSat* - William Blackwell, MIT Lincoln Laboratory
- *Advancing Climate Observation:Radiometer Assessment Using Vertically Aligned Nanotubes (RAVAN)* - Lars Dyrud, Johns Hopkins Applied Physics Laboratory
- *A Cubesat Flight Demonstration of a Photon Counting Infrared Detector (LMPC CubeSat)* - Renny Fields, The Aerospace Corporation
- *HyperAngular Rainbow Polarimeter HARP-CubeSat* - J. Vanderlei Martins, University of Maryland, Baltimore County

Another space validation project was added to the ESTO portfolio in FY2014:

- *IceCube: Spaceflight Validation of an 874-GHz Submillimeter Wave Radiometer for Ice Cloud Remote Sensing* - Dong Wu, NASA GSFC

The next InVEST solicitation is expected to be released in FY2015.



Left: The GEO-CAPE Readout Integrated Circuit Experiment (GRIFEX) CubeSat undergoing final development and testing at the University of Michigan (UM). GRIFEX is a 3-unit (3U) CubeSat* intended to verify the spaceborne performance of a state-of-the-art readout integrated circuit (ROIC) / Focal Plane Array (FPA) with in-pixel digitization and an unprecedented 16 kHz frame rate for imaging interferometry instruments and missions. The technology specifically targets the requirements of the GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission concept, and the ROIC is based upon a previous ESTO technology development project. The GRIFEX CubeSat will launch as an auxiliary payload to the NASA Soil Moisture Active Passive (SMAP) Earth science mission from Vandenberg Air Force Base in California, no earlier than January 2015. (Credit: J. Cutler, UM)

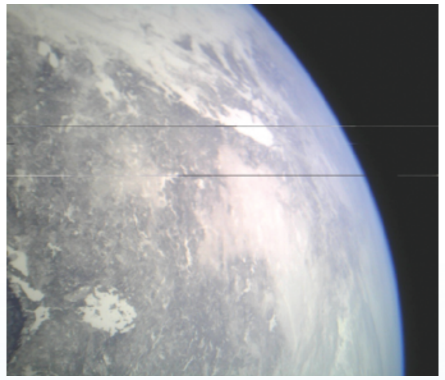
* A CUBESAT PRIMER

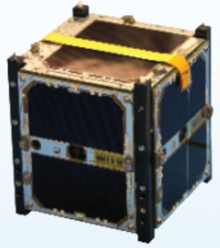
Normally launched as a secondary payload to a larger mission, a CubeSat is a type of nanosatellite often used for scientific research or technology validation. A basic 1 unit (1U) CubeSat measures 10x10x11cm with a mass of up to 1.33 kg. Multiple units can be combined to form 2U, 3U, and even 6U CubeSats. The CubeSat standard was created by California Polytechnic State University and Stanford University following the first launch of 6 CubeSats in 2003.

SPOTLIGHT:

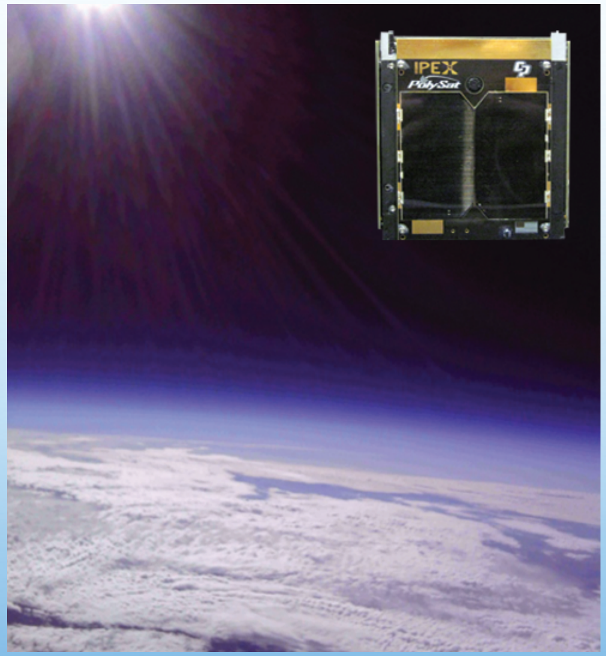
Two CubeSats Launch, Successfully Validate Technology in FY2014

Two 1U CubeSats – the Michigan Multipurpose Minisatellite (MCubed-2) CubeSat, a collaboration between the Jet Propulsion Lab (JPL) and the Univiversity of Michigan, and the Intelligent Payload Experiment (IPEX) CubeSat, developed by Cal Poly San Luis Obispo, JPL, and NASA GSFC – were launched in December 2013 as secondary payloads to the National Reconniaisance Office Launch 39 (NROL-39) from Vandenburg Air Force Base, CA. Both were successfully inserted into Earth orbit and achieved their baseline validation requirements.





MCubed-2 was developed to validate algorithm and processor technologies for the Multiangle Spectropolarimeric Imager (MSPI), a candidate instrument for the NASA Aerosol-Cloud-Ecosystem (ACE) mission concept. Its payload – the CubeSat On-Board Processing Validation Experiment (COVE) – is a polarimetry data processing algorithm implemented on a new radiation-hard-by-design FPGA (the first Xilinx Virtex 5QVTM to fly in space). This technology could reduce the future MSPI data downlink requirements by two orders of magnitude. MCubed-2/COVE acquired and processed sufficient imagery to characterize the performance of the hardware and software over extended temperature fluctuations, radiation, and long acquisition periods to satisfy the validation requirements. Top left: An image of snow-covered Midwest and Canada used in the first validation run on COVE (Credit: S. Kang, UM). Bottom left: The MCubed-2 Cubesat (Credit: D. Smith, UM).

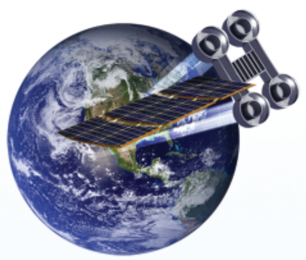


Right: The first image retrieved from IPEX (shown inset), taken December 6, 2013 (Credit: Cal Poly / JPL). IPEX was developed to advance the technology needed for the proposed Intelligent Payload Module (IPM). IPM could act as the onboard processing system for the NASA Hyperspectral Infrared Imager (HyspIRI) mission concept, a mission anticipated to collect five terabytes of data per day. IPEX features a Gumstix™ processor and five 3-megapixel cameras, and utilizes autonomy algorithms that will enable a greater than 20 times reduction in data downlink volume, an advance that could make near-real-time direct broadcast of low-latency HyspIRI data products possible. As of April 2014, over 400 images have been taken by IPEX, leading to over 31,000 generated and validated data products.

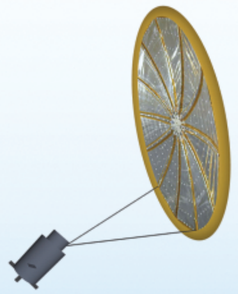
Future Challenges

For over 15 years, ESTO investments have anticipated science requirements to enable many new measurements and capabilities. ESTO technologies were already underway to address the priorities outlined by the 2007 NRC Decadal Survey for Earth science, the 2010 NASA Science Plan, and NASA's 2010 plan for a climate architecture: "Responding to the Challenge of Climate and Environmental Change." This is a testament to ESTO's broad-based, inclusive strategic planning. It is also the result of a commitment to monitor, and match investments to, the evolving needs of Earth science through engagement with the science community, development of technology requirements, and long-term investment planning.

Looking ahead, there are four broad technology areas that have the potential to expand, support, and even revolutionize the future of Earth science:

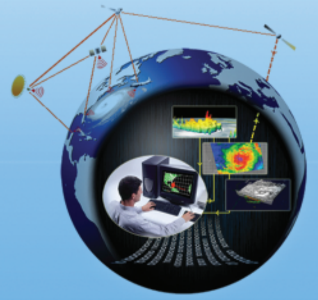


Active Remote Sensing Technologies to enable new measurements of the atmosphere, cryosphere and Earth's surface.
- Atmospheric chemistry using lidar vertical profiles
- Ice cap, glacier, sea ice, and snow characterization using radar and lidar
- Tropospheric vector winds using lidar
- Precipitation and cloud measurements using radar



Large Deployable Apertures for future weather, climate, and natural hazard measurements.
- Temperature, water vapor, and precipitation from geostationary orbit
- Soil moisture and sea surface salinity using L-band radar
- Surface deformation and vegetation using radar

Intelligent Distributed Systems using advanced communication, onboard processors, autonomous network control, data compression, and high density storage.
- Long-term weather and climate prediction linking observations to models
- Interconnected sensor webs that share information to enhance observations



Information Knowledge Capture through 3D visualization, holographic memory, and seamlessly linked models.
- Intelligent data fusion to merge multi-mission data
- Discovery tools to extract knowledge from large and complex data sets
- Real time science processing, archiving, and distribution of user products

Additional Resources

ESTO launched a new website in 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

esto.nasa.gov

National Aeronautics and Space Administration

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