National Aeronautics and Space Administration

2010 annual report

Earth Science Technology Office

On the Cover (top to bottom):

- *Earth Observing-1 satellite image of the 2009 Red River flooding near Fargo, ND, and Moorhead, MN, made possible, in part, by the activation of the SensorWeb 3G technology (see page 12) - image credit: The Earth Observatory*
- *Detail of the molded, central core for a corrugated mirror (see page 14) - image credit: ITT Geospatial Systems*
- *The NASA ER-2 aircraft with the AirMSPI camera onboard (see page 10) - Image Credit: Jet Propulsion Lab*
- *Long Beach, CA, as seen by the AirMSPI camera (see page 10) - Image Credit: Jet Propulsion Lab*
- *A hyperspectral imager under development to meet the goals of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission (see pages 7-8) - image credit: Greg Kopp, University of Colorado*
- *The uplooking input of the INFLAME instrument (see pages 7-8) poking through a wing tip tank port on a LearJet aircraft - image credit: Marty Mlynczak, NASA Langley Research Center*
- *Return signal of controlled laser shots from the Electronically Steerable Flash Lidar (see page 5) - image credit: Carl Weimer, Ball Aerospace and Technology Corp*
- *Detail of a radiometer receiver module for use in an ocean altimetry mission, such as the Surface Water and Ocean Topography Decadal Survey Mission (see page 13) - image credit: D. Albers and A. Lee, Colorado State University*

Executive Summary

As reported in the pages that follow, fiscal year 2010 (FY10) has been another productive year for NASA Earth science technology development. Recent activities within the Earth Science Technology Office (ESTO) have centered on guidance provided by the first-ever Decadal Survey for Earth science – "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 and applications: "Responding to the Challenge of Climate and Environmental Change."

At the release of the Decadal Survey in 2007, we were pleased to note that existing ESTO investments already applied directly to the 18 recommended mission concepts. Since 2007, more than 60 new technologies have been added to the portfolio to further address the requirements and measurement goals of the Decadal Survey. Many of these technologies are maturing to the point that they are ready to make significant contributions to the Decadal Survey missions.

New technology investments are also on their way: the Instrument Incubator Program is on track to announce a new set of awards in early FY11 and solicitations are expected soon for both the Advanced Component Technologies program and the Advanced Information Systems Technology Program.

ESTO also continues to build upon a strong history of technology development and infusion. In FY10, 37% of active ESTO technology projects advanced at least one Technology Readiness Level (TRL) and many projects have achieved actual infusion into science measurements, system demonstrations, or other applications. Of the over 535 completed projects in the ESTO portfolio 36% have already been infused and an additional 44% have a path identified for future infusion.

We are proud of the contributions that our principal investigators make for the future of Earth science and we look forward to another year of continued innovation in FY11.

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

Contents

About ESTO

From instruments to data access, ESTO technologies enable a full range of scientific measurements

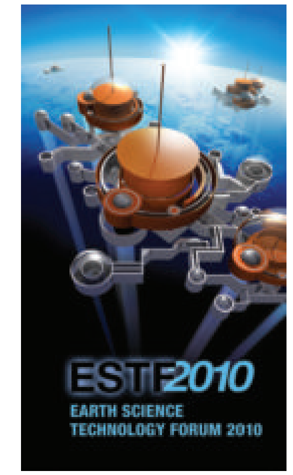
As the technology function within the Earth Science Division of the NASA Science Mission Directorate, the Earth Science Technology Office (ESTO) performs strategic technology planning and manages the development of a range of advanced technologies for future science measurements and operational requirements. ESTO technology investments attempt to address the full science measurement process: from the instruments and platforms needed to make observations to the data systems and information products that make those observations useful.

ESTO applies a rigorous approach to technology development:

- Planning technology investments through comprehensive analyses of science requirements
- Selecting and funding technologies through competitive solicitations and partnership opportunities
- Actively managing funded technology development projects
- Facilitating the infusion of mature technologies into science campaigns and missions.

ESTO employs an open, flexible, science-driven strategy that relies on competitive, peer-reviewed solicitations to produce the best cutting-edge technologies. In some cases, investments are leveraged through partnerships to mitigate financial risk and to create a broader audience for technology infusion.

The results speak for themselves: a broad portfolio of over 600 emerging technologies (active and completed) ready to enable and/or enhance future science measurements as well as an ever-growing number of infusion successes.

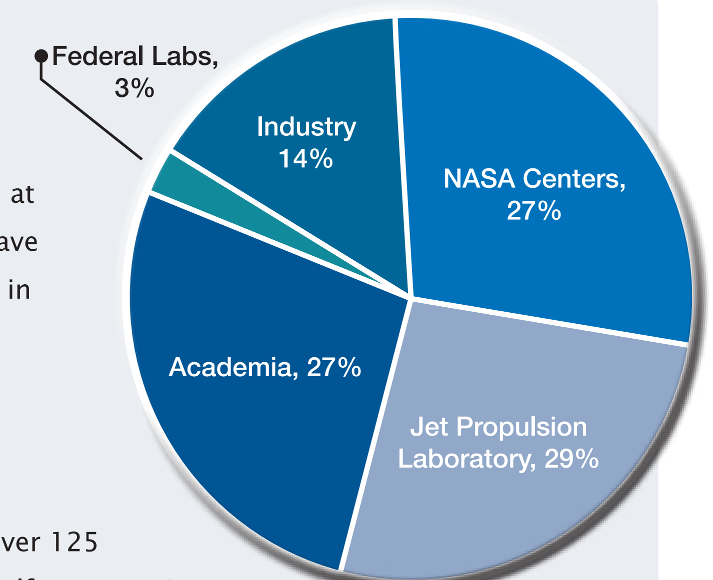


The 2010 Technology Forum

The 2010 Earth Science Technology Forum (ESTF2010) was held June 22-24 in Arlington, VA. This annual event showcases the wide array of technology research and development related to NASA Earth science endeavors. Total registration in 2010 was well over 200 and plenary talks were given by Michael Freilich, Director of the NASA Earth Science Division, and Robert Braun, NASA's Chief Technologist. Full proceedings are available at the ESTO website at: esto.nasa.gov/events.html

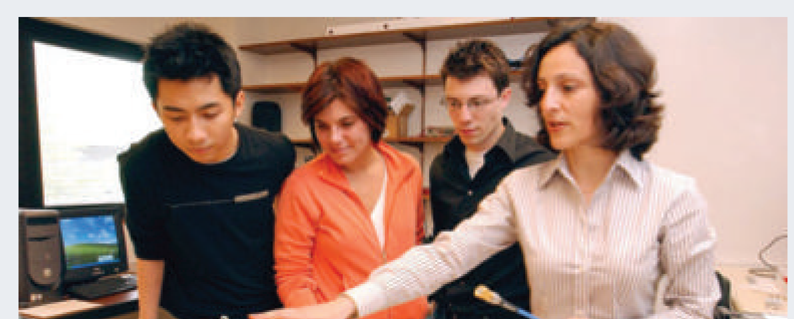
ESTO Investigators

ESTO's nearly 400 current principal investigators (PIs), co-investigators (Co-Is), and partners represent a diverse set of institutions – see graph at right. Over the past decade, ESTO PIs and Co-Is have performed technology development and research in nearly every state and the District of Columbia.



Student Participation

In 2010 alone, ESTO-funded projects supported over 125 students from more than 30 institutions. About half are pursuing doctorates while others are working toward masters or undergraduate degrees.




Images Courtesy Mahta Moghaddam, University of Michigan

2010 Metrics

With more than 535 completed technology investments and a current, active portfolio of nearly 70 projects, ESTO is driving innovation, enabling future Earth science measurements, and strengthening NASA's reputation for developing and advancing leading-edge technologies.

How did ESTO do this year? Here are a few of our successes for fiscal year 2010 (FY10), tied to NASA's performance goals for ESTO:

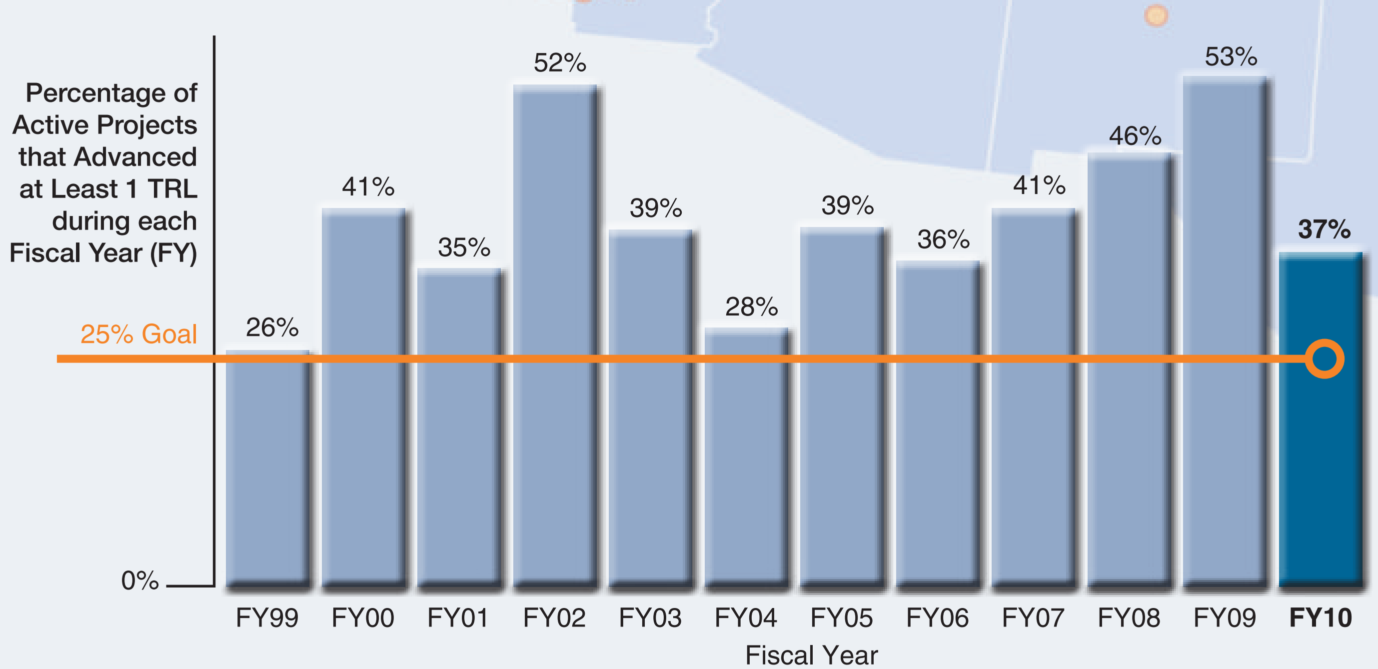
Each dot represents one of the over 600 projects (active and completed) in the ESTO portfolio.

GOAL:

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

FY10 RESULT:

37% of ESTO technology projects which were funded during FY10 advanced one or more TRL over the course of the fiscal year, about the annual average for the ESTO portfolio. Nearly 7% of the FY10 projects advanced two or more TRL levels. See the graph below for yearly comparisons. [Note: because of the variable periodicity of solicitations and other factors, any apparent multi-year trends are not meaningful]



GOAL:

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

FY10 RESULT:

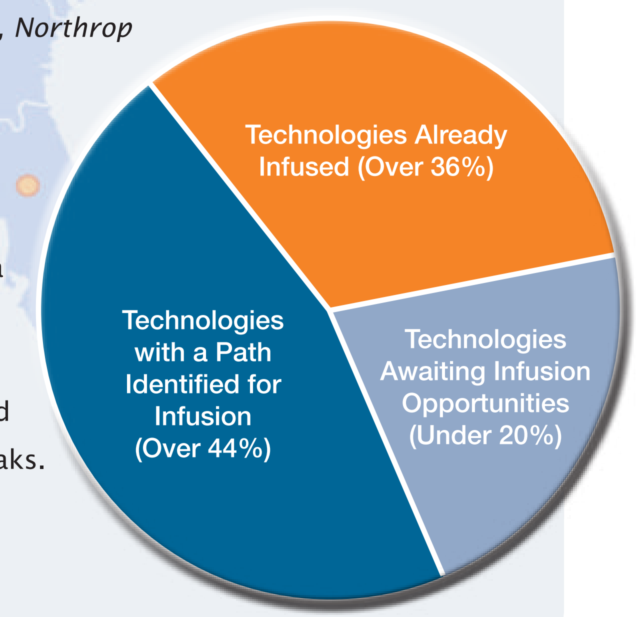
Many ESTO projects achieved infusion into space missions or airborne science campaigns in FY10. A few notable examples:

- Several ESTO technologies were infused in the NASA Genesis and Rapid Intensification Process (GRIP) experiment, a six week airborne campaign to study hurricanes. These projects include: the Doppler Aerosol WiNd lidar *(Principal Investigator (PI): M. Kavaya, NASA Langley Research Center)*, the High-Altitude Imaging Wind and Rain Airborne Profiler *(PI: G. Heymsfield, NASA Goddard Space Flight Center)*, and the The Real Time Mission Monitor *(PI: M. Goodman, NASA Marshall Space Flight Center)*. See page 6 to learn more about ESTO technologies in the airborne GRIP campaign.

- In 2010, the **Sensor-Analysis-Model Interoperability Technology Suite (SAMITS)** – a set of information system technologies for accessing, processing, and analyzing data based on distributed services and web service standards – was used in the design and development of the Atmospheric Composition Portal, an online tool of the Committee on Earth Observation Satellites that provides access to atmospheric composition data. *(PI: S. Falke, Northrop Grumman Corp.)*

- SensorWeb 3G (featured on page 12) was used to develop the Namibian Flood SensorWeb Early Warning pilot project, an international partnership between NASA, UN-Spider, the Namibia Department of Hydrology, the Canadian Space Agency, the Ukraine Space Research Institute, DRL (Germany), and others. The project provides near-real-time data and forecasts on flood risk as well as on the potential for water borne disease outbreaks. *(PI: D. Mandl, NASA Goddard Space Flight Center).*

ESTO's Infusion Success - drawn from over 535 completed projects through FY10



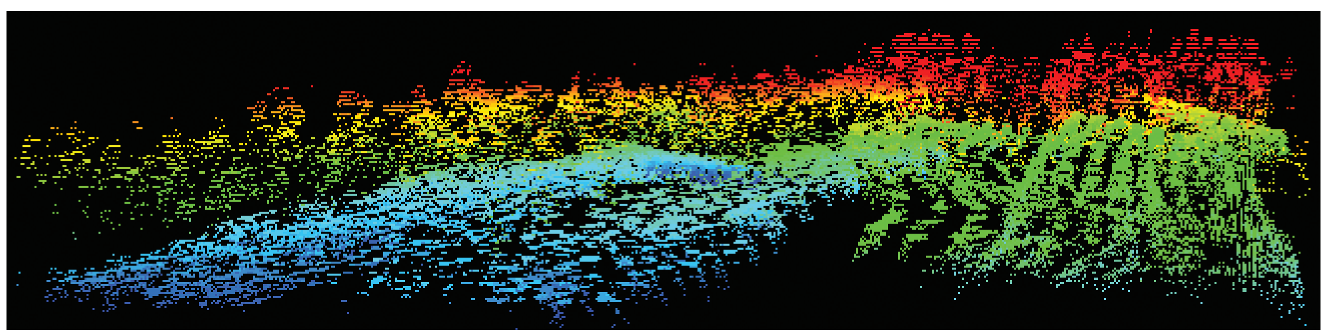
2010 Metrics Continued

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

FY10 RESULT: Several ESTO projects satisfied this goal for FY10. Here are two notable examples:

Above: the ESFL optical head. Below: ESFL data taken over the USDA Manitou Experimental Forest in Colorado. (Images courtesy Carl Weimer)

- The Electronically Steerable Flash LIDAR (ESFL) demonstrated its capacity for improved vegetation measurements on a series of airborne test flights. Using a single laser to create multiple beams, the ESFL system can instantaneously sample numerous cross-track ground footprints. This approach provides a traditional intensity measurement combined with a range (distance) measurement to produce a 3-dimensional view of vegetation that shows height, density, and shape. The multiple beams are also independently controllable and steerable for a variety of footprint coverage options. *(PI: C. Weimer, Ball Aerospace Corporation)*



Above, one of the two INFLAME instruments is mounted in the wing tip tank of the Learjet aircraft. (Image courtesy Marty Mlynczak)

- The In-Situ Net FLux within the AtMosphere of the Earth (INFLAME) project successfully completed a groundbreaking demonstration flight in January on a Learjet out of Newport News, VA. The INFLAME instruments are Michelson interferometers designed to directly measure the net flux of visible and infrared radiation within the atmosphere – the difference between upwelling and downwelling radiation. Net flux measurements are difficult to make, but they are critical to understanding radiation processes that are central to climate studies. INFLAME may be used for calibration and validation measurements for the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Decadal Survey mission. *(PI: M. Mlynczak, NASA Langley Research Center (LaRC))*

Chasing Hurricanes: ESTO Technologies Support 2010 GRIP Campaign

For six weeks beginning in August 2010, NASA's Genesis and Rapid Intensification Process (GRIP) field campaign sent three aircraft – a Global Hawk UAV, a DC-8, and a WB-57F – and numerous instruments on a series of flights to study tropical cyclones and the processes that lead to the creation and intensification of hurricanes. The measurements they took provided an unprecedented, sustained look at hurricane formation and development. Several of the GRIP instruments were developed with ESTO funding:

- *The **Doppler Aerosol WiNd lidar (DAWN)** is a 2-micron doppler lidar that can take vertical profiles of vectored horizontal winds. DAWN flew on NASA's DC-8 aircraft. (PI: M. Kavaya, NASA LaRC)*

- *The **Airborne Second Generation Precipitation Radar (APR-2)**, which also flew on the DC-8, is an advanced radar system that obtained the first-ever simultaneous measurements of rain intensity and fall velocity profiles during the 4th Convection and Moisture Experiment in 2001. (PI: E. Im, Jet Propulsion Lab)*

- *The **High Altitude MMIC Sounding Radiometer (HAMSR)**, which flew on a NASA Global Hawk UAV, is a microwave atmospheric sounder that provides measurements used to infer the 3-D distribution of temperature, water vapor, and liquid water in the atmosphere. (PI: B. Lambrigsten, Jet Propulsion Lab)*

- *Also on the Global Hawk, the **High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)** is a dual-frequency doppler radar capable of measuring tropospheric winds within precipitation regions, as well as ocean surface winds. (PI: G. Heymsfield, NASA Goddard Space Flight Center)*

*Another GRIP instrument – the Hurricane Imaging Radiometer instrument on board the NASA WB-57 – incorporated a groundbreaking ESTO subsystem technology: the **Agile Digital Detector (ADD) for Radio Frequency Interference**. ADD helps produce clearer microwave measurements, particularly over areas where wireless signals tend to crowd the spectrum. (PI: C. Ruf, University of Michigan)*

*GRIP also utilized a novel mission-monitoring tool funded by ESTO: The **Real Time Mission Monitor (RTMM)** integrates data sets, weather information, vehicle operations data, and model and forecast outputs to help manage field experiments. RTMM optimized decision making for GRIP by presenting timely data and visualizations and improving real-time situational awareness of the assets. (PI: M. Goodman, NASA Marshall Space Flight Center)*

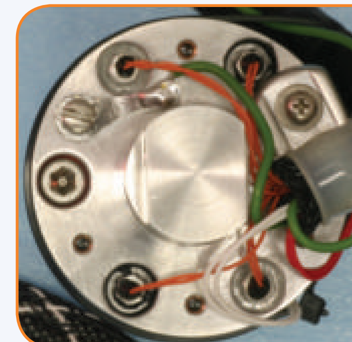
Enabling CLARREO

10 Years of Technology Investments for Radiation Budget Measurements

In 2017, NASA plans to launch the first in a series of satellites that will comprise the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission. CLARREO will measure the amount of energy entering and leaving the atmosphere – Earth's radiation budget – more accurately than ever before, providing a reliable benchmark for the climate record going forward and improving climate prediction and modelling.

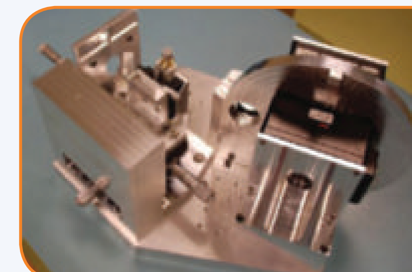
For nearly a decade, ESTO projects have pursued the technologies needed for radiation budget measurements. In many ways, the early technology projects enabled the designation of CLARREO as a mission concept in 2007. Below is a timeline of ESTO technology investments related to radiation measurements, including recent awards focused more specifically for CLARREO, with highlights of key projects.

Visit the ESTO website - esto.nasa.gov - to browse a series of interactive charts that show how ESTO investments are enabling all 18 of the Decadal Survey mission concepts.



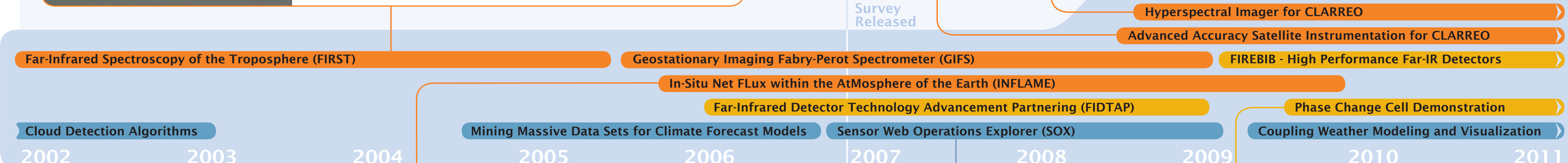
The **Advanced Accuracy Satellite Instrumentation for the CLARREO Mission** project seeks to develop and test several key calibration subsystems, such as temperature calibration for the blackbody cavity shown at left, dual absolute radiance interferometers, and an emissivity module. *(PI: H. Revercomb, University of Wisconsin)*

The **Calibrated Observations of Radiance Spectra from the Atmosphere in the far-InfraRed (CORSAIR)** project is developing a set of technologies central to CLARREO: infrared detector elements, blackbody radiance standards, and robust optical beamsplitters with continuous high efficiency over the full spectral range. *(PI: M. Mlynczak, NASA LaRC)*



Another project is designing and building a **Hyperspectral Imager to Meet CLARREO Goals of High Absolute Accuracy and On-Orbit SI Traceability** (left) as well as investigating attenuation methods and validating the solar cross-calibration approach for the CLARREO Mission concept. *(PI: G. Kopp, University of Colorado LASP)*

The **Far-Infrared Spectroscopy of the Troposphere (FIRST)** instrument, an early airborne precursor to CLARREO, was demonstrated in 2005 on a high-altitude research balloon (left) and provided the first-ever high resolution measurement of the complete infrared emission spectrum of the Earth, including the key far-infrared region from 15 to 100 microns that contains over 50% of Earth's long-wave radiation. More recently, FIRST was installed at 17,500 ft atop the Cerro Toco Plateau in Chile as part of the Atmospheric Radiation Measurement Program's Radiative Heating in Underexplored Bands Campaign - II (RHUBC-II), funded by the Department of Energy. *(PI: M. Mlynczak, NASA Langley Research Center (LaRC))*



The **In-Situ Net FLux within the AtMosphere of the Earth (INFLAME)** project has developed an airborne Fourier Transform Spectrometer that can directly measure the difference between upwelling and down-welling radiation – the net radiation flux – in the lower atmosphere. INFLAME was installed in the wingtip tanks of a LearJet (shown left) and successfully demonstrated in 2010. As an airborne instrument, INFLAME may provide critically needed calibration/validation data for the CLARREO mission. *(PI: M. Mlynczak, NASA LaRC)*

The **Sensor Web Operations Explorer (SOX)** is a comprehensive sensor web simulator that helps explore various observations scenarios, measurement qualities, and science impacts well in advance of mission development. SOX is currently being used to study a variety of mission concepts and the CLARREO mission plans to utilize SOX to explore overall mission design as well as to provide virtual observations to evaluate climate model uncertainties. *(PI: M. Lee, Jet Propulsion Laboratory)*

The CLARREO mission proposes to use phase change reference standards (melt cells) to recalibrate its on-board temperature sensors; but these cells have never been tested in space. In 2011, this project will conduct **Thermal Phase Change Cell Demonstrations Onboard the International Space Station (ISS)** and achieve in-space testing of two melt cell designs. *(PI: M. Mlynczak, NASA LaRC)*

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 of a flight project consistently leads to smaller, less resource intensive, and easier to build 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 program included 35 active projects in FY10 and more will be added in early FY11. A competitive solicitation for IIP awards was released in February 2010 as part of the NASA Research Opportunities in Space and Earth Sciences (ROSES) research announcement.

The 2010 solicitation broadly 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.

12 projects graduated from funding in FY10 and, of these, 8 advanced at least 1 TRL during the course of funding. The FY10 graduates are as follows:

Above, the NASA P-3 aircraft readies for a test flight of the Pathfinder Advanced Radar Ice Sounder (PARIS) over the Greenland ice sheet in May 2007. PARIS went on to provide the first field demonstration of radar sounding of both ice sheet layering and basal (bottom) topography from an airborne platform. In 2009, PARIS was tapped to join several other instruments in the NASA Ice Bridge campaign, a six-year airborne survey of Earth's polar ice. (Image Credit and PI: Keith Raney, Applied Physics Laboratory)

- **Advancement of Optical Component Control for Imaging Spectrometers - A. Larar, NASA Langley Research Center (LaRC)**
- **Strategic Investments toward Lidar Detectors for ACE - C. Hostetler, NASA LaRC**
- **Risk Reduction of CO Column Observation Sensor for ASCENDS - W. Cook, NASA LaRC**
- **Pathfinder Advanced Radar Ice Sounder (PARIS) - K. Raney, Johns Hopkins University Applied Physics Lab**
- **A High-Repetition, Rate-Seeded Optical Fiber Amplifier (SOFiA) for the LIST Mission and Satellite Laser Ranging - B. Coyle, NASA Goddard Space Flight Center (GSFC)**
- **VADER: A Systems Level Approach for DESDynI's Advanced Laser Architecture Development - B. Coyle, NASA GSFC**
- **885 nm Diode Pumped Ceramic Nd:YAG Single Frequency Laser Transmitter - A. Yu, NASA GSFC**
- **A Deployable 4 Meter 180 to 680 GHz Antenna for SMLS - R. Cofield, Jet Propulsion Lab**
- **Technology Development for a Combined High Spectral Resolution and Ozone Differential Absorption Lidar - C. Hostetler, NASA LaRC**
- **In-situ Net Flux Within the Atmosphere of the Earth (INFLAME) - M. Mlynczak, NASA LaRC**
- **High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) - G. Heymsfield, NASA GSFC**
- **Ground Based CO2 Profiling by 2-micron Coherent DIAL Technique - J. Yu, NASA LaRC**

SPOTLIGHT: A Novel Camera for Atmospheric Aerosol Detection

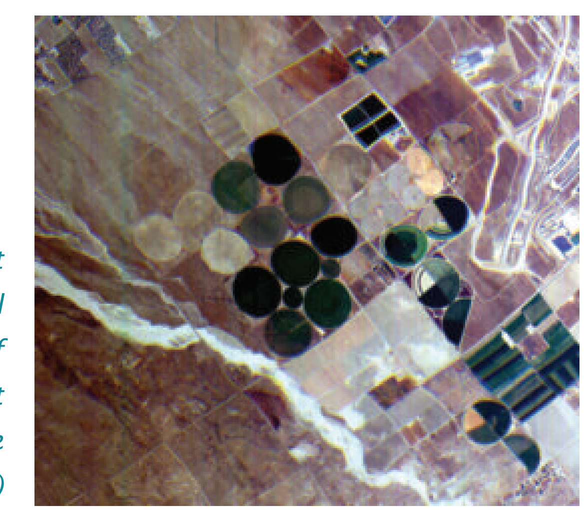
Above, the NASA ER-2 with the AirMSPI camera in the forward payload bay, just under the nose of the aircraft. (Image Credit: Jet Propulsion Lab)

In early October 2010, an airborne prototype of the Multi-angle SpectroPolarimetric Imager (MSPI) flew on a successful two-hour 'checkout' flight over southern California. MSPI, a candidate instrument for the Aerosol-Cloud-Ecosystems (ACE) Decadal Survey mission, uses a novel polarimetric imaging camera to detect aerosols in the atmosphere. MSPI could also be used to directly study clouds as well as surface features.

The impact that aerosols have on clouds is one of the largest unknowns in the study of global climate change. Aerosols can affect cloud formation and the amount of rain and snow produced. They can also make clouds brighter and more reflective, so that less sunlight reaches the Earth.

The aerosol detection technique used by MSPI, and its airborne prototype (AirMSPI) built under the NASA Airborne Instrument Technology Transition Program, was developed with IIP funding (PI: D. Diner, Jet Propulsion Lab) and finds heritage in several other IIP-funded tasks. AirMSPI uses eight spectral bands, three of them polarimetric, to distinguish light scattered by aerosols in the atmosphere from light reflected by the Earth's surface. The camera is also mounted in a rotating drum to provide a multi-angle view.

Additional test flights of the AirMSPI are expected in FY11.



The image at right, acquired by AirMSPI on its first test flight, combines the blue, green, and red spectral bands to give the 'natural' effect of light reflected off the surface. Note this image is not corrected for aircraft altitude fluctuations, which give a wavering appearance to surface features. (Image Credit: Jet Propulsion Lab)

Instruments

This field near Canton, Oklahoma, is the site of a new, "smart" sensor web called SoilSCAPE that measures soil moisture at various depths at over 20 locations. Installed in early August 2010, SoilSCAPE can adaptively sample soil moisture and control its own duty-cycle based on feedback of local conditions. In addition to demonstrating sensor web technology, the system's intended use is to validate measurements taken by airborne and spaceborne soil moisture sensors, including potentially those of the Soil Moisture Active-Passive (SMAP) Decadal Survey mission. (Image Credit and PI: Mahta Moghaddam, University of Michigan)

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 virtually 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.

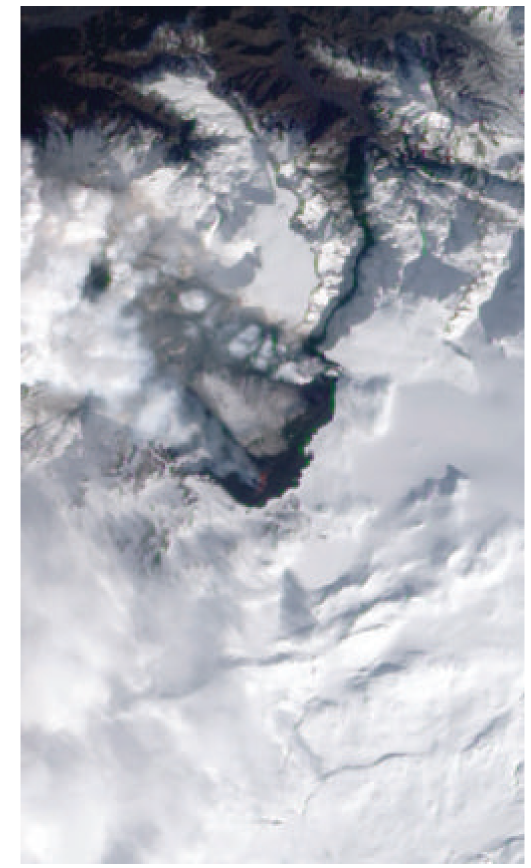
The AIST program held 37 active investments in FY10, 16 of which graduated from ESTO funding. All of the FY10 graduates advanced at least one TRL over their course of funding and half of them advanced three or more TRL levels. The graduates are as follows:

- **Reconfigurable Sensor Networks for Fault-Tolerant In-Situ Sampling - A. Howard, Georgia Tech Research Corp**
- **Secure, Autonomous Controller for Integrating Distributed Sensor Webs -W. Ivancic, NASA Glenn Research Center**
- **Harnessing the Sensor Web through Model-based Observation - R. Morris, NASA Ames Research Center**
- **An Adaptive, Negotiating Multi-Agent System for Sensor Webs - C. Tsatsoulis, University of North Texas**
- **A Smart Sensor Web for Ocean Observation: System Design, Modeling, and Optimization - P. Arabshahi, University of Washington**
- **An Objectively Optimized Sensor Web - D. Lary, University of Maryland, Baltimore County**
- **Soil Moisture Smart Sensor Web Using Data Assimilation and Optimal Control - M. Moghaddam, University of Michigan**
- **Sensor Web Dynamic Replanning - S. Kolitz, Draper Laboratory**
- **A General Framework and System Prototypes for the Self-Adaptive Earth Predictive Systems (SEPS) - L. Di, George Mason University**
- **Implementation Issues and Validation of SIGMA in Space Network Environment - M. Atiquzzaman, University of Oklahoma**
- **Efficient Sensor Web Communication Strategies Based on Jointly Optimized Distributed Wavelet Transform and Routing - A. Ortega, University of Southern California**
- **Optimized Autonomous Space - In-situ Sensorweb - W. Song, Washington State University**
- **The Multi-agent Architecture for Coordinated, Responsive Observations - D. Suri, Lockheed Martin Space Systems Company**
- **End-to-End Design and Objective Evaluation of Sensor Web Modeling and Data Assimilation System Architectures - M. Seablom, NASA Goddard Space Flight Center**
- **Sensor-Analysis-Model Interoperability Technology Suite (SAMITS) - S. Falke, Northrop Grumman IT**
- **Semantically-Enabled Scientific Data Integration - P. Fox, Rensselaer Polytechnic Institute**

AIST plans to release a new solicitation in FY11 to further address requirements of the Decadal Survey mission concepts, as well as other scientific and societal needs.

SPOTLIGHT: Sensor Web Project Generating Interest and Benefiting Society

SensorWeb 3G – an ongoing AIST project that couples satellite, airborne, UAV, and in-situ sensors with science models and advanced software – is proving the value of fully integrated, real-time Earth observations and providing a glimpse of how future Earth science systems might function. It is also producing a host of pilot projects and applications that are being used today for societal benefit.



On March 24, 2010, the Advanced Land Imager on board NASA's EO-1 satellite captured this clear, cloud-free image of the eruption of Iceland's Eyjafjallajökull volcano. This near real-time data acquisition of the flood was made possible, in part, by the activation of the SensorWeb 3G technology in response to a manual request. (Image Credit: NASA Earth Observatory; PI: D. Mandl, NASA Goddard Space Flight Center)

SensorWeb 3G demonstrates rapid, low cost ways to network and control various sensors and instruments into 'webs' that combine the multiple observations with models to give a more complete view of real-time situations. These sensor webs enable autonomous triggering of observations from space, airborne, and in-situ instruments in response to unfolding events. In particular, NASA's Earth Observing 1 (EO-1) satellite is being used to prototype many of these capabilities. In turn, Sensor Web 3G is effectively automating EO-1 observations and the EO-1 mission.

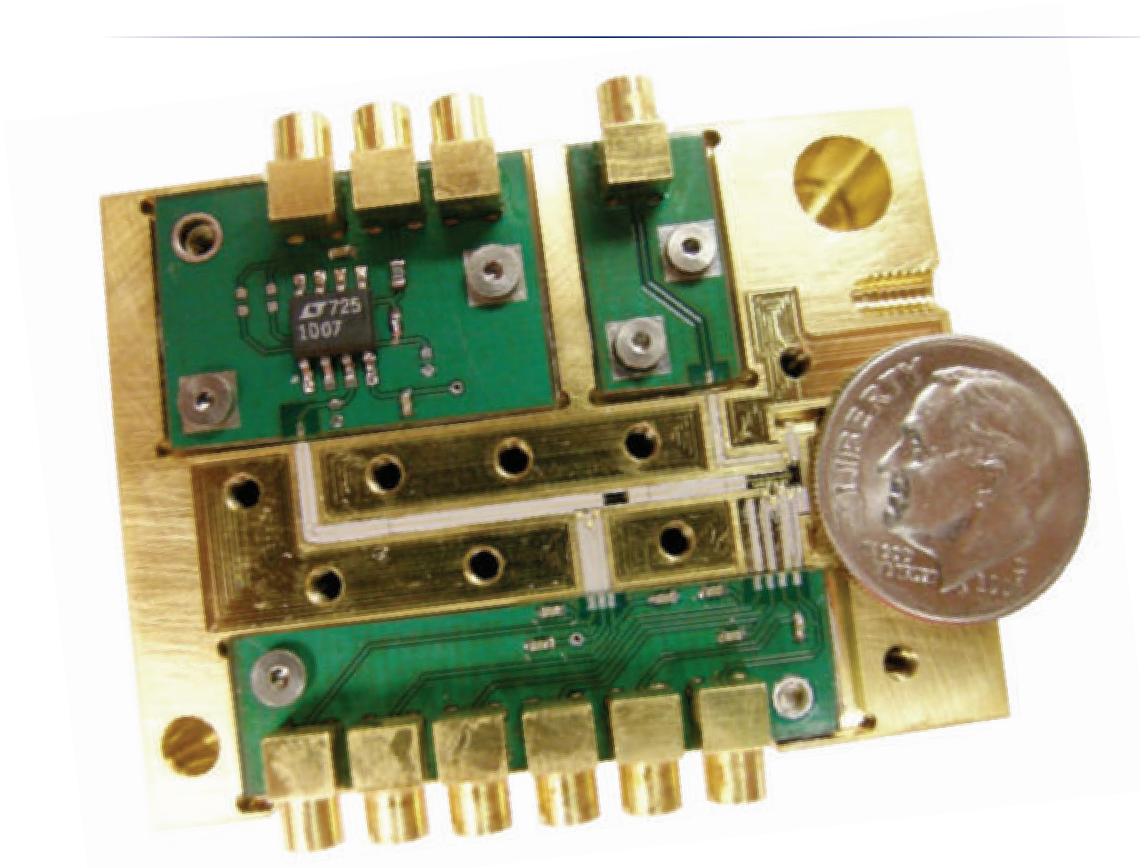
Over the past several years, the project prototyped various capabilities in demonstration mode and provided valuable satellite imagery to first-responders or post-event analysts for numerous natural and man-made disasters: the Station Fire in California, Australian fires and floods, the Red River flood, the Samoa tsunami, mudslides in Honduras and Guatemala, the eruption of the Eyjafjallajökull volcano (see image at left), and Hurricane Jimena in Baja Mexico.

The project team is participating in a variety of natural hazard programs, pilot projects, and workshops around the world to further infuse the SensorWeb 3G concept into regional and continental disaster management systems. For example, they are working with numerous international and domestic partners to build the Namibian Early Warning Flood SensorWeb, the Caribbean Satellite Disaster pilot project, and the Fire SensorWeb pilot project. They are also developing a concept for a Disease SensorWeb, which could trigger early warning for diseases, such as malaria, based on changing vegetation and environmental conditions.

2010 in Review: **Components**

The Advanced Component Technology (ACT) program leads research, development, and testing of component- and subsystem-level technologies for future state-of-the-art Earth science instruments and instrument systems. The ACT program focuses on projects that reduce risk, cost, size, mass, and development time of technologies to enable their eventual infusion into missions.

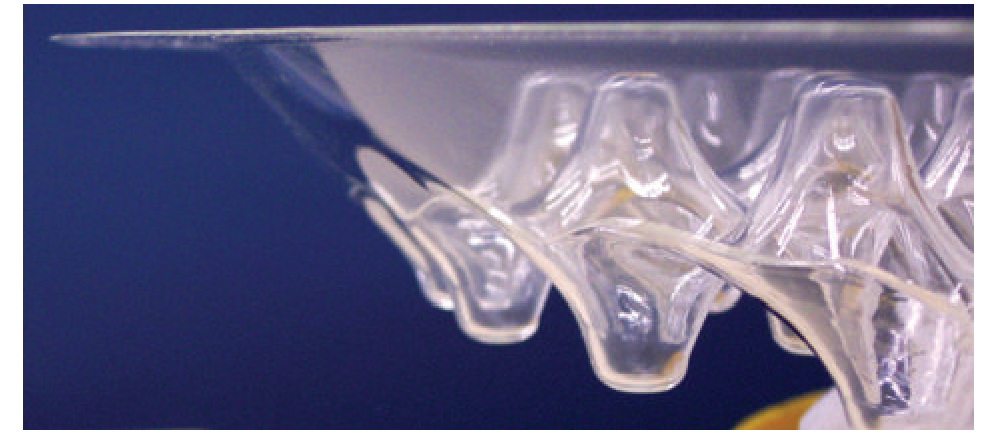
In FY10, the ACT program portfolio held a total of 18 investments. More projects will be added to the portfolio in FY11-FY12 as the ACT program plans to release a new solicitation to address future requirements. One component technology graduated from funding this year – **A Low Cost, Ultra-Light-weight, Optically Fast f/1.2, Corrugated Mirror Telescope Array for Lidar and Passive Earth Science Missions, R. Egerman, ITT Geospatial Systems** – and is featured on the opposing page.



Space-borne ocean altimeters, which measure the height of Earth's oceans, are not effective when water vapor is present in the troposphere. To get around this problem, the altimeters are partnered with microwave radiometers, typically in the 18-37 GHz range, that detect and quantify the effect of water vapor on the altimeter signal. Even so, altimetry measurements remain heavily compromised near the coast and over land. Above is a multi-chip radiometer receiver module, developed with ACT funding, that incorporates a higher frequency (92 GHz) to help improve retrievals in coastal regions and enable retrievals over land – key requirements for the Surface Water and Ocean Topography (SWOT) Decadal Survey mission concept. (Image Credit: D. Albers and A. Lee, Colorado State University; PI: S. Reising, Colorado State University)

SPOTLIGHT: A New, Lightweight Approach for Mirror Telescope Arrays

Mirrored telescope arrays are critical components for future Lidar and passive Earth science missions. The conventional manufacturing processes used to fabricate these kinds of large (greater than 0.5m) and lightweight (5 to 50Kg per square meter) are often measured in months to years and millions of dollars. This ACT project (PI: R. Egerman, ITT Geospatial Systems) demonstrated a new approach to mirror fabrication using borosilicate, an inexpensive and easy-to-work glass to develop new mirror designs.



Above, the molded, central core for a corrugated mirror. This layer gives the mirror its depth and provides stiffness while reducing weight.

The manufacturing process involves fusing together a stiff, lightweight, 3-layer face sheet, a molded corrugated core layer, and a molded back face sheet at high temperature. The corrugated core adds depth and provides excellent stiffness-to-weight to the finished mirror. The 3-layer construction of the face sheet also reduces mass by up to 70% over conventional methods while maintaining stiffness.

Above, a side view of a 0.5m mirror and, right, detail of the 3-layer front face sheet.

The process uses a fraction of the time and cost of more traditional mirrors as well. The project team selected a readily available, commercial sheet glass material commonly used for flat panel televisions and displays. The molding and fusing process is readily repeatable and could easily be scaled up for high volume manufacturing.

By the end of the funding period, the project team had fabricated seven 0.5m corrugated mirror blanks with a 1.95m radius of curvature, two of which were polished. They also developed a mount concept. Corrugated mirrors of this kind may prove suitable for use by the ASCENDS Decadal Survey mission, as well as by other missions where mirror telescope arrays are required.

Above, one of the 0.5m mirrors shown with a spray-silver coating after final polishing and ion figuring. (All images courtesy ITT Geospatial Systems)

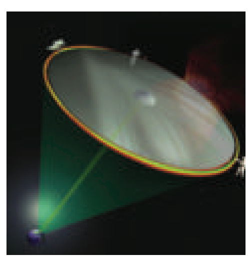
Future Challenges

For over a decade, ESTO investments have been reducing the technology risk for nearly all the measurements recommended by the Decadal Survey. This is a testament to ESTO's best practices for technology development: competitive, peer-reviewed solicitations; active technology management; and broad-based, inclusive strategic planning. ESTO continues to monitor, and match investments to, the evolving needs of Earth science through engagement with the science community, development of technology requirements, and strategic planning for long-term investments.

In addition to the science measurement goals established by the NRC Decadal Survey and other strategic planning documents, ESTO has identified four broad areas that have the capacity to expand and support a multitude of Earth science disciplines:

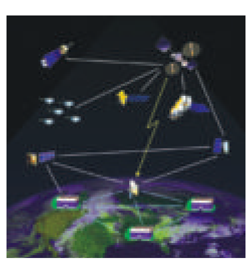
Active Remote Sensing Technologies to enable measurements of the atmosphere, hydrosphere, biosphere, and lithosphere.

- Atmospheric chemistry using lidar vertical profiles
- Ice cap, glacier, sea ice, and snow characterization using radar and lidar
- Tropospheric vector winds using lidar



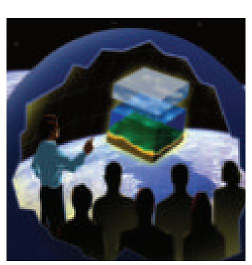
Large Deployable Apertures to enable future weather, climate, and natural hazards measurements.

- Temperature, water vapor, and precipitation from geostationary orbit
- Soil moisture and sea surface salinity using L-band
- Surface deformation and vegetation using radar



Intelligent Distributed Systems using advanced communication, on-board radiation-tolerant reprogrammable processors, autonomous operations and network control, data compression, 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 novel visualizations, memory and storage advances, 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 to drive decision support systems

Additional Resources

A wealth of additional information is available online at the ESTO website: esto.nasa.gov

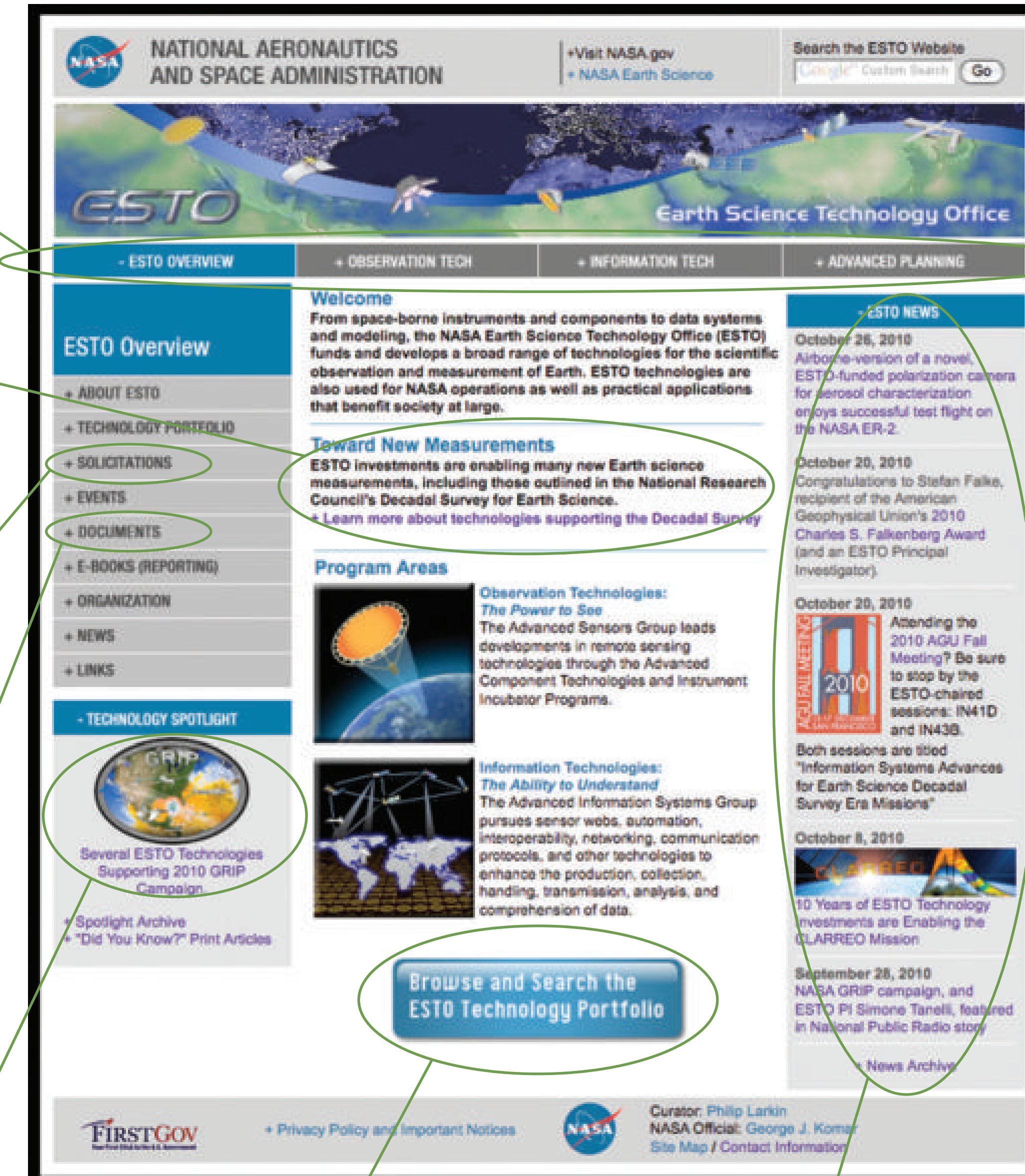
More about ESTO's approach to technology development, ESTO programs, and strategic planning

An interactive tool that shows ESTO's linkages to the NRC Decadal Survey

Information about ESTO solicitations and awards

A compilation of useful reports, presentations, and other documents on technology development for NASA Earth science

Timely features on current ESTO technology progress and infusions



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