National Aeronautics and Space Administration

2011 annual report

Earth Science Technology Office

On the Cover:

1) An optic from the Shared Aperture Diffractive Optical Element (ShADOE) telescope (see page 7) - credit: B. Gentry, NASA GSFC
2) The PolZero time-domain polarization scrambler (see page 14) - credit: R. Illing, Ball Aerospace
3) The Optical Autocovariance Wind Lidar (OAWL) in a WB-57 aircraft pallet (see pages 6-8) - credit: S. Tucker, Ball Aerospace
4) The M-Cubed CubeSat developed by the University of Michgan (see page 12) - credit: Michigan Exploration Laboratory
5) The TWiLiTE instrument on the NASA ER2 aircraft (see page 7) - credit: B. Gentry, NASA GSFC
6) The Doppler Aerosol Wind Lidar (DAWN) on the NASA DC-8 aircraft (see page 8) - credit: M. Kavaya, NASA LaRC
7) False-color image of a laser shot (see page 5) - credit J. Dobler, ITT Geospatial Systems
8) Fisheye lens image of CO2 and O2 instruments on NASA DC-8 aircraft.(see page 5) - credit: J. Dobler, ITT Geospatial Systems
9) Line-of-sight wind speed data taken by the OAWL instrument in 2011 (see pages 6-8) - credit: S. Tucker, Ball Aerospace
10) Model output of permanent ground displacement from the 8/23/11 magnitude 5.8 earthquake near Mineral, VA (see page 11) - credit: A. Donnellan, Jet Propulsion Laboratory

Executive Summary

As reported in the pages that follow, fiscal year 2011 (FY11) has been another productive year for NASA Earth science technology development.

Activities within the Earth Science Technology Office (ESTO) continue to center 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: "Responding to the Challenge of Climate and Environmental Change." This year saw significant technology achievements and demonstrations in many Earth science disciplines, including Doppler wind lidar. We have highlighted that work in a special section titled "Toward 3D-Winds: Technology Investments for Future Global Wind Measurements" on pages 7-8.

31 new investments were added to the ESTO portfolio in FY11 through solicitations under the Instrument Incubator Program (IIP) and the Advanced Component Technologies (ACT) program. The Advanced Information Systems Technology (AIST) program plans to award new projects in FY12, some of which may receive additional funding through a partnership with the NASA Applied Sciences Program to build end user applications.

ESTO also continues to build upon a strong history of technology development and infusion. In FY11 exactly 50% of active ESTO technology projects advanced at least one Technology Readiness Level (TRL) and many projects have achieved infusion into science measurements, system demonstrations, or other applications. Of the over 550 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 our principal investigators make for the future of Earth science and we look forward to another year of continued innovation in FY12.

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

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About ESTO

From instruments to data access, ESTO's technology portfolio enables end-to-end 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 infusion of maturing technologies into science campaigns and missions.

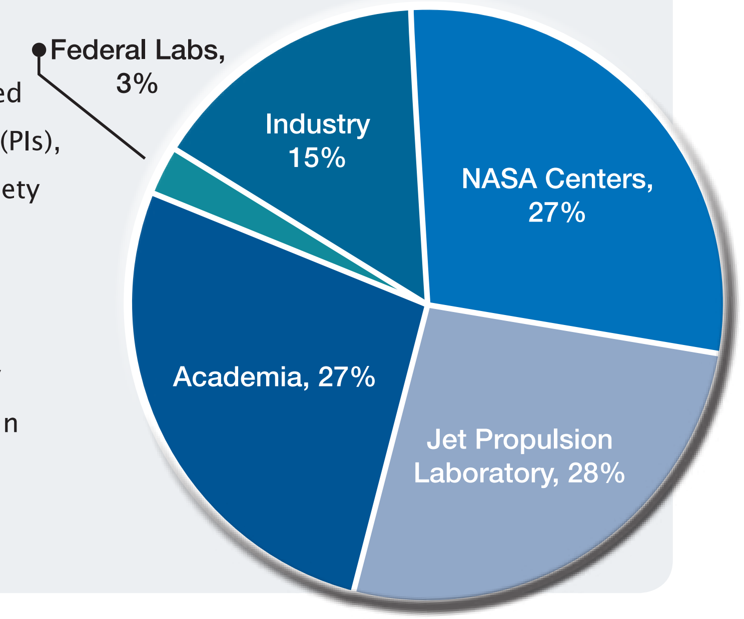
ESTO employs an open, flexible, science-driven strategy that relies on competitive, peer-reviewed solicitations to produce the best cutting-edge technologies. In some cases, investments are leveraged through partnerships to mitigate financial risk and to create a broader audience for technology infusion.

The results speak for themselves: a broad portfolio of over 655 emerging technologies (from 105 active projects and over 550 completed progects) ready to enable and/or enhance future science measurements as well as an ever-growing number of technology infusion successes.

ESTO Investigators

ESTO's 105 active projects included the combined efforts of more than 490 principal investigators (PIs), co-investigators (Co-Is), and partners from a variety of institutions. The graph at right shows the distribution of active projects by institution.

Over the past 12 years, ESTO-funded technology research and development has been performed in nearly every state and the District of Columbia.



Student Participation

Student participation in ESTO projects has always been substantial, with nearly 400 students at 92 institutions involved in ESTO-funded work since 1998. Nearly 50 graduate-level degrees have been earned to date by students working on ESTO projects. In 2011 alone, 86 students were actively involved with ESTO projects. About half of the students are pursuing doctorates while the remainder are working toward masters' or undergraduate degrees.

Images Courtesy Michigan Exploration Laboratory, University of Michigan.
(See page 12 to learn about their project, the Michigan Multipurpose Minisat)

2011 Metrics

Each dot represents one of the over 655 projects (active and completed) in the ESTO portfolio.

With more than 550 completed technology investments and a current, active portfolio of 105 projects, ESTO is driving innovation, enabling future Earth science measurements, and strengthening NASA's reputation for developing and advancing leading-edge technologies.

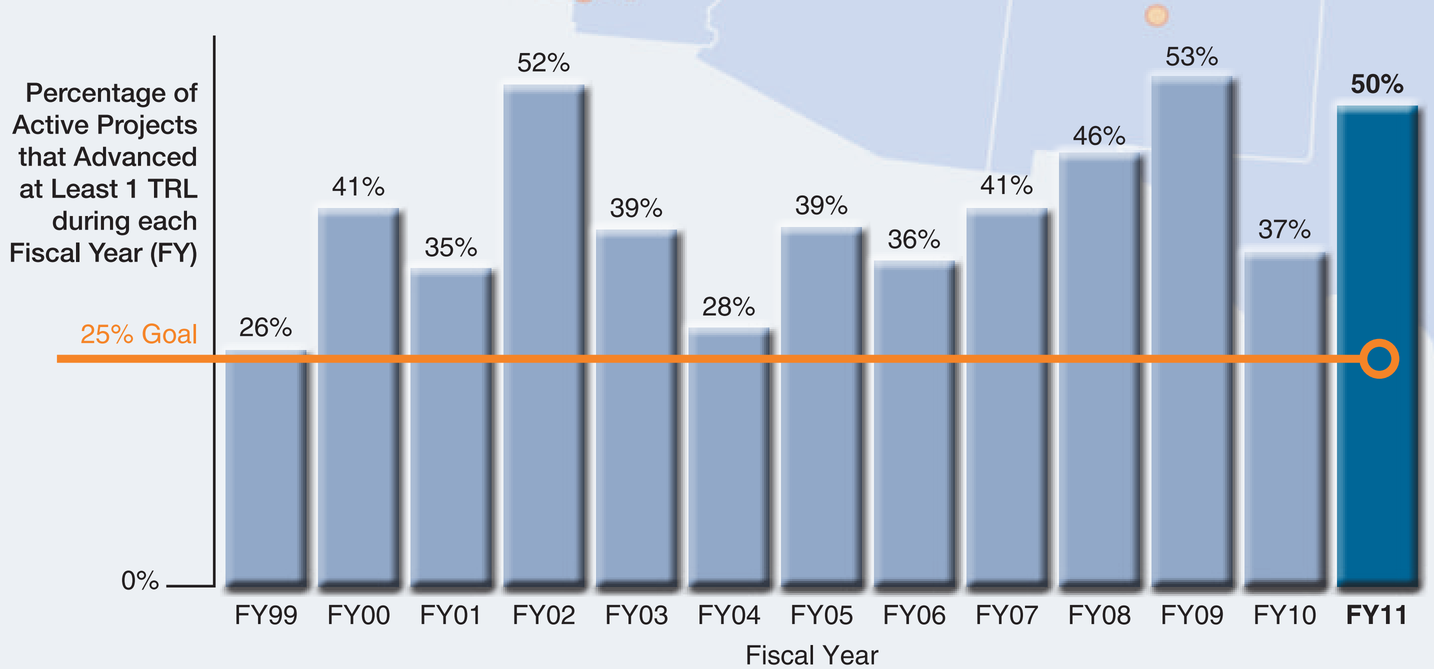
How did ESTO do this year? Here are a few of our successes for fiscal year 2011 (FY11), tied to NASA's performance goals for ESTO:

GOAL:

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

FY11 RESULT:

50% of ESTO technology projects which were funded during FY11 advanced one or more TRL over the course of the fiscal year, double the annual goal for this metric. Additionally, 12% of the FY11 projects advanced more than one TRL. See the graph below for yearly comparisons. [Note: because of the variable periodicity of solicitations and other factors, 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.

FY11 RESULT:

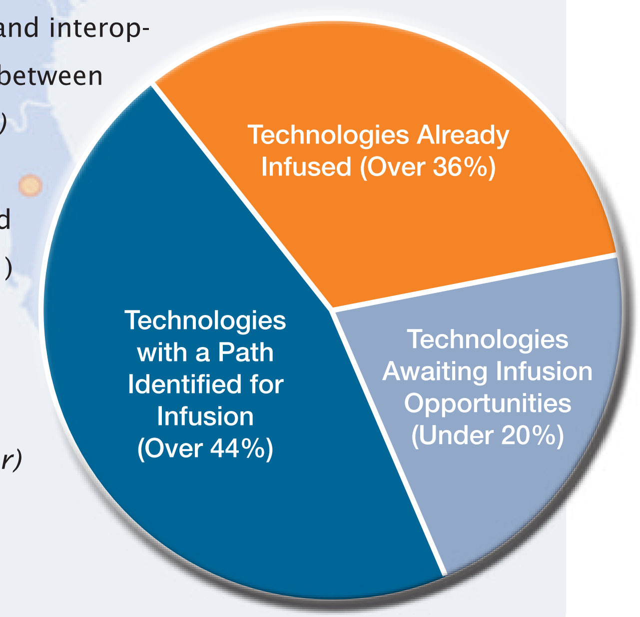
At least eight ESTO projects achieved infusion into space missions or airborne science campaigns in FY11. A few notable examples:

- The **Real Time Mission Monitor (RTMM)**, an information systems project, was utilized by two field campaigns in FY11: the Light Precipitation Evaluation Experiment (LPVEx) and the Winter Storms and Pacific Atmospheric Rivers (WISPARS) experiment. RTMM is a tool that autonomously integrates data sets, weather information, vehicle operation data, and model and forecast outputs to help manage field experiments that involve a variety of space, airborne and ground assets. During both campaigns, RTMM optimized decision making by presenting timely data and visualizations and improving real-time situational awareness. *(PI: M. Goodman, NASA Marshall Space Flight Center).*

- Processing strategies developed by the **Multi-Sensor Data Synergy Advisor (MDSA)** project are being used to improve the quality and usability of selected atmospheric data products from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments onboard the Terra and Aqua satellites. MDSA is a series of information systems tools that enable data access and interoperability, provide data provenance, and improve comparisons between data sets. *(PI: G. Leptoukh, NASA Goddard Space Flight Center)*

- The **CO2 Laser Sounder for the ASCENDS Mission** participated in three airborne science campaigns (in 2009, 2010, and 2011) to demonstrate the approach as a precursor to the Active Sensing of CO2 Emissions over Nights, Days and Seasons (ASCENDS) mission as well as serve as a test-bed for advanced components. *(PI: J. Abshire, NASA Goddard Space Flight Center)*

ESTO's infusion success - drawn from over 550 completed projects through FY11



2011 Metrics (continued)

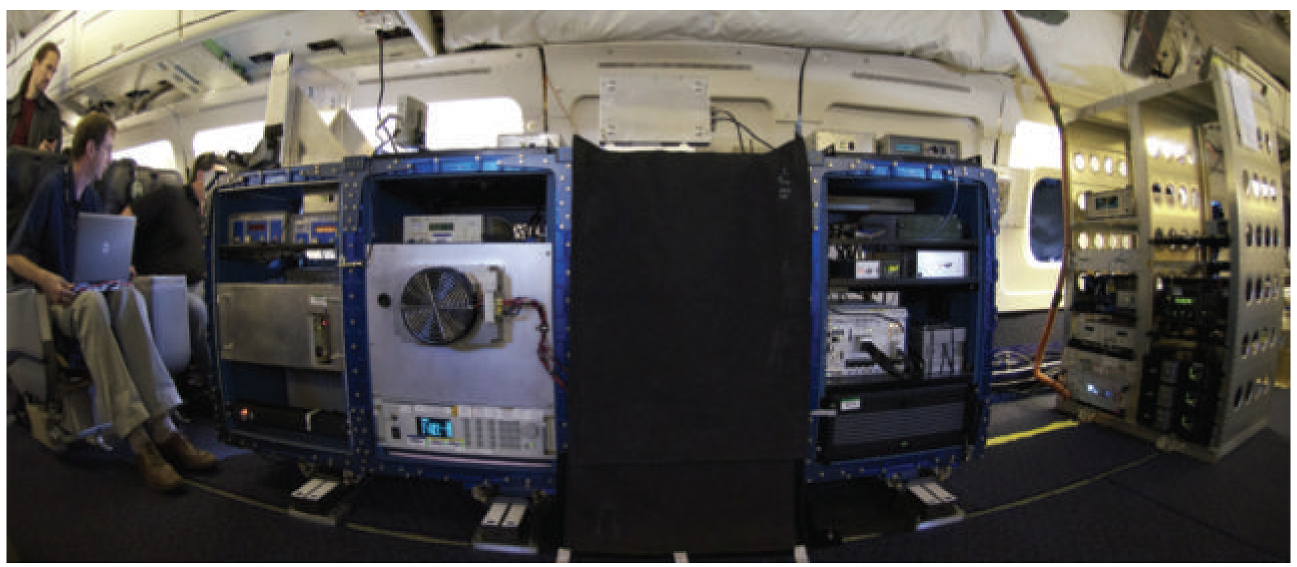
GOAL:

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

FY11 RESULT:

As many as 10 ESTO projects satisfied this goal for FY11. Two notable examples:

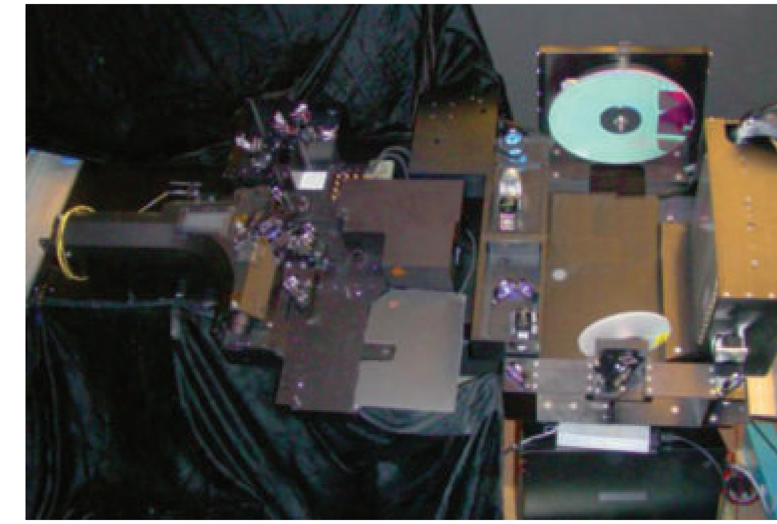
- The first airborne measurements of atmospheric O2 in the 1.26 micron band were demonstrated on board the NASA DC-8 aircraft during the ASCENDS II atmospheric sampling instrument validation flights in summer 2011. This groundbreaking demonstration was made possible by a new narrow-linewidth, high-power-high-efficiency fiber amplifier for an O2 lidar instrument. The transmitter might eventually be incorporated into the ASCENDS satellite mission. The concept for this mission, as recommended by the 2007 NRC Decadal Survey for Earth Science, calls for concurrent, on-board measurements of O2 in order to identify pressure and density effects on CO2 mixing ratio measurements. *(PI: J. Dobler, ITT Geospatial Systems)*



Above: Fisheye lens image of CO2 and O2 components integrated on the NASA DC-8 aircraft. (Image credit: J. Dobler)

Left: Crew and scientists prepare for takeoff inside the NASA DC-8 on Sunday August 7, 2011 (Image credit: E. Schaller)

- During two weeks of ground testing at the Colorado Table Mountain Field Site and Radio Quiet Zone in July 2011, an emerging lidar technology, the **Optical Autocovariance Wind Lidar (OAWL)**, made line-of-sight wind measurements alongside NOAA's mini-MOPA coherent detection Doppler lidar, an established reference wind lidar. OAWL uses a 355 nm laser to measure winds from aerosol backscatter with precision similar to coherent Doppler wind Lidar. The OAWL system may offer an alternative to the two-laser design currently proposed in the NASA 3D-Winds mission concept. *(PI: S. Tucker, Ball Aerospace)*



The OAWL Instrument in the lab (Image credit: S. Tucker)i

[Learn more about OAWL and future wind measurements on pages 7-8] →

Spotlight: The 2011 Technology Forum

The 2011 Earth Science Technology Forum (ESTF2011) was held June 21-23 in Pasadena, CA, and drew more than 230 attendees from universities, industry, NASA centers, and other government agencies. This annual event showcases the wide array of technology research and development related to NASA Earth science endeavors.

The forum included over 75 presentations within two parallel tracks of sessions. Charles Elachi, Director of the Jet Propulsion Laboratory (JPL), gave the Plenary Address. Luncheon talks by Jack Dangermond of Esri and Richard Terrile of JPL described the rapidly evolving power of computing capabilities for intelligent web maps and intelligent machines, respectively. Full proceedings are available at the ESTO website at: esto.nasa.gov/events.html

Toward 3D-Winds

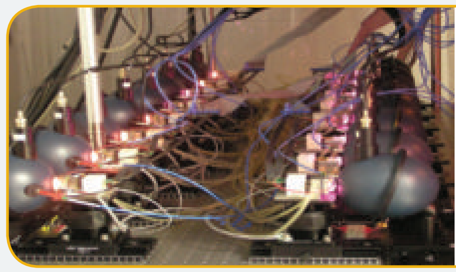
Technology Investments for Future Global Wind Measurements

The accurate, reliable, long-term weather forecasts of tomorrow will depend largely on improved measurements of wind speed and direction within the troposphere, the lowest 5 - 12 miles of the atmosphere. Current *in-situ* and airborne wind sensors, including balloon-sondes and drop-sondes, work well for localized measurements. It would be far too cumbersome and costly, however, to use these kinds of instruments globally at anywhere near the needed coverage, particularly over the oceans. Space-borne microwave scatterometers, such as the SeaWinds instruments on QuikSCAT and ADEOS II satellites, infer wind speed and direction by measuring ocean surface roughness. But this method provides a limited, 2-dimensional look at winds at or just above the surface of the ocean. To make 3-dimensional, spaceborne global wind measurements a reality, a new kind of instrument is required.

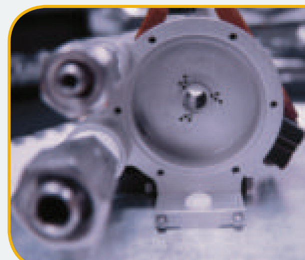
Doppler wind lidar (DWL) shows the most promise for 3-dimensional, truly global, tropospheric wind measurements from space. DWL systems are not new; they have been used on the ground, on ships, and on airplanes for years.

Coherent DWL, which is used extensively to study the lower troposphere, bounces a near-infrared (1.5 - 10 µm) laser off the aerosols in the atmosphere to measure how fast they (and thus the wind) are moving. This technique works well where aerosols are plentiful. Another technique, direct detection DWL, uses ultraviolet (355 nm) laser light to detect the motion of the constituent molecules in the atmosphere. Though coherent DWL is more precise, direct detection can measure winds where coherent DWL cannot: regions of ‘clean’ air with few aerosols. One concept for the future NASA 3D-Winds Decadal Survey mission proposes, therefore, that one of each instrument type fly together to measure winds across a variety of atmospheric conditions.

As illustrated in the timeline below, ESTO investments in coherent and direct detection DWL have been paving the way for a 3D-Winds mission for over a decade. And an emerging technology – the Optical Autocovariance Wind Lidar (OAWL), which seeks to measure both aerosol and molecular winds with a single 355 nm laser – may offer a cost-effective alternative to the two-instrument approach.



Early advances in diodes (left) and materials evolved into well-engineered, ruggedized, packaged transmitters for 2 µm laser systems. *[PI: F. Amzajerdian, NASA Langley Research Center (LaRC)]*



This 2 µm laser head, with heritage from several ESTO tasks, became part of the DAWN transmitter (right). *[PI: U. Singh, LaRC]*

The **Doppler Aerosol Wind Lidar (DAWN)** is an airborne coherent-detection, wind-profiling Doppler lidar system using state-of-the-art 2-micron pulsed laser technology. In 2008, DAWN participated in a joint ground demonstration with the Tropospheric Wind Lidar Technology Experiment instrument (see bottom left). In 2010, DAWN was deployed on NASA’s DC-8 aircraft (at left) in support of the NASA Genesis and Rapid Intensification Processes (GRIP) flight campaign to study hurricane development. *[PI: M. Kavaya, NASA LaRC]*

2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Coherent Detection
2 µm Laser • Aerosol Winds

- Doppler Aerosol Wind Lidar (DAWN)
- 2 µm Laser Testbed Development
- Laser Diode Risk Reduction
- Lidar Photoreceiver and Sensor Development
- Doppler Aerosol Wind Lidar Airborne Demonstration
- Advanced Optical Heterodyne Receiver
- Integrated Lidar Photoreceiver

Direct Detection
355 nm (UV) Laser • Molecular Winds

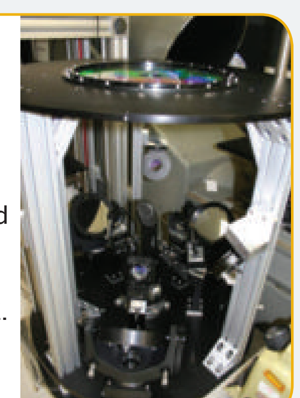
- Tropospheric Wind Lidar Technology Experiment (TWiLiTE)
- Shared Aperture Diffractive Optical Elements (ShADOE)
- Hybrid Doppler Wind Lidar Transceiver for 355 nm and 2 µm Systems
- Thermal Control and Monitoring for Laser Systems

Optical Autocovariance
355 nm (UV) Laser • Aerosol & Molecular Winds

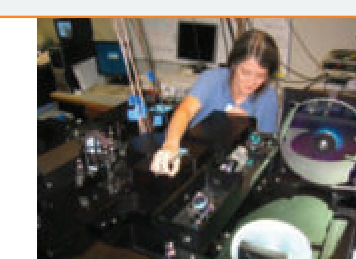
- Fabry-Perot Etalon Receiver
- OAWL Augmentation & Demo
- Optical Autocovariance Wind Lidar (OAWL)

The **Tropospheric Wind Lidar Technology Experiment (TWiLiTE)** is an airborne direct-detection Doppler lidar instrument that was successfully demonstrated on the NASA ER2 aircraft in 2009 (left). TWiLiTE participated in a 2008 ground demonstration with the Doppler Aerosol Wind Lidar (see top right). *[PI: B. Gentry, NASA Goddard Space Flight Center (GSFC)]*

In 2009, the **Shared Aperture Diffractive Optical Elements (ShADOE)** project demonstrated a lab breadboard, four-field -of-view telescope (right), which was later used by TWiLiTE. *[PI: B. Gentry, NASA GSFC]*



During two weeks of ground testing in July 2011, the **Optical Autocovariance Wind Lidar (OAWL)** (shown right in the lab) made line-of-sight aerosol wind measurements alongside a reference wind lidar from NOAA. OAWL is scheduled for airborne validation tests in early FY12 onboard the NASA WB-57 aircraft, again in conjunction with a reference ground system. Two component technology projects were awarded by ESTO in 2011 to augment OAWL with molecular wind detection capability and provide further demonstrations. *[PI: C. Grund / S. Tucker, Ball Aerospace]*



Instruments   Components

2011 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, 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 IIP included 38 active projects in FY11. 16 of these 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 new awards, selected from a total of 83 proposals, are as follows (grouped by remote sensing technology category):

ACTIVE

Laser

- *ASCENDS Lidar: Acceleration and Demonstrations of Key Space Lidar Technologies*, J. Abshire, NASA Goddard Space Flight Center (GSFC)
- *ASCENDS CarbonHawk Experiment Simulator (ACES)*, N. Prasad, NASA Langley Research Center

Radar

- *An 8-40 GHz Wideband Instrument for Snow Measurements (WISM)*, T. Durham, Harris Corporation
- *EcoSAR The first P-band Digital Beamforming Polarimetric Interferometric SAR instrument to measure Ecosystem Structure, Biomass and Water*, T. Fatoyinbo, NASA GSFC
- *Antenna Technologies for 3D Imaging, Wide Swath Radar Supporting ACE*, P. Racette, NASA GSFC

PASSIVE

Microwave

- *A Deployable 4-Meter 180 to 680 GHz Antenna for the Scanning Microwave Limb Sounder*, R. Cofield, Jet Propulsion Laboratory (JPL)
- *Risk Reduction for the PATH Mission*, B. Lambrigtsen, JPL
- *Development of an Internally-Calibrated Wide-Band Airborne Microwave Radiometer to Provide High-Resolution Wet-Tropospheric Path Delay Measurements for SWOT*, S. Reising, Colorado State University

Optical

- *Aircraft Deployable UV-SWIR Multiangle Spectropolarimetric Imager*, D. Diner, JPL
- *The Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) for Earth Science*, S. Hook, JPL
- *HyperSpectral Imager for Climate Science (HySICS)*, G. Kopp, University of Colorado Boulder
- *Prototype Sensor Development for Geostationary Trace Gas and Aerosol Sensor Optimization (GEO-TASO) for the GEO-CAPE Mission*, J. Leitch, Ball Aerospace and Technologies Corporation
- *Development of an Ocean Radiometer for Carbon Assessment (ORCA) Prototype*, C. McClain, NASA GSFC
- *Panchromatic Fourier Transform Spectrometer Engineering Model (PanFTS EM) Instrument for the Geostationary Coastal and Air Pollution Events (GEO-CAPE) Mission*, S. Sander, JPL
- *Multi-Slit Offner Spectrometer*, T. Valle, Ball Aerospace and Technologies Corporation

OTHER

- *Atomic Gravity Gradiometer for Earth Gravity Mapping and Monitoring Measurements*, N. Yu, JPL

Five projects graduated from funding in FY11, all of which advanced at least one Technology Readiness Level (TRL) during the course of funding. The FY11 graduates are as follows:

- *Airborne Demonstration of an Autonomous Operation Coherent Doppler Lidar that is a Precursor to a Space-Based Wind Profiling Instrument*, M. Kavaya, NASA Langley Research Center
- *CO2 Laser Sounder for ASCENDS Mission - Technology Development and Airborne Demonstration*, J. Abshire, NASA Goddard Space Flight Center
- *An Electronically Steerable Flash Lidar*, C. Weimer, Ball Aerospace & Technologies Corporation
- *Development of Lightweight, 3-D Integrated X-Band Radar Using SiGe Chips and RF MEMS Circuits For Snow Accumulation Measurements*, I. Papapolymerou, Georgia Institute of Technology
- *A Hyperspectral Imager to Meet CLARREO Goals of High Absolute Accuracy and On-Orbit SI Traceability*, G. Kopp, University of Colorado, LASP

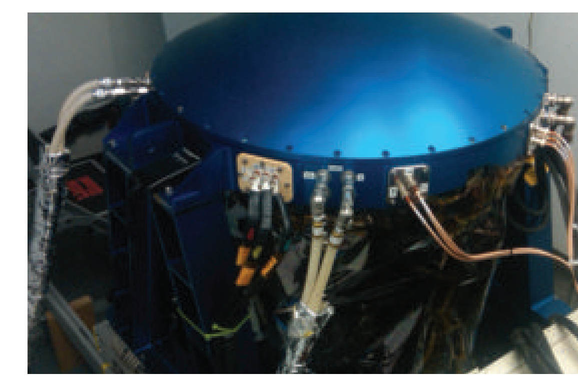
SPOTLIGHT: Doppler Wind Lidar Deployed to Map Potential Wind Farm Sites

In Virginia, State and Federal regulators have set aside over 140,000 acres off the Virginia coast for future offshore wind turbines. The area, which will be divided into blocks for lease by wind energy companies, may eventually provide up to 10 percent of the state's electricity. But the turbines likely won't be built until utility companies can determine which areas contain the strongest, most consistent, and, therefore, most valuable winds. George Hagerman, director of offshore wind research for the Virginia Coastal Energy Research Consortium (VCERC), turned to NASA for help.

In September 2011, ESTO investigator Grady Koch installed a 2 μm Coherent Doppler Lidar system – known as the Doppler Aerosol Wind (DAWN) lidar (see page 8) – at the Fort Story military base on the Virginia coast. Developed at the NASA Langley Research Center primarily for airborne campaigns, the system uses a high-powered laser to measure the speed and direction of aerosols carried by the wind.

The initial data returns show effective wind detection as far as 12 km off the coast. By scanning the beam up and down, Koch was able to profile winds at various altitudes above the ocean surface to correspond to the height of a wind turbine. This was a critical achievement since wind speeds at the height of turbine blade heights vary significantly from those at the surface.

The data gathered during the month-long deployment will be carefully compared to in situ weather stations on shore and out at sea. If the measurements are accurate, the VCERC hopes to permanently place a similar system 13 miles offshore at the Chesapeake Light Tower.



Top to bottom: the trailer containing the Doppler lidar system positioned on a bluff at Fort Story, VA, overlooking the Atlantic Ocean; the lidar inside the trailer; and Grady Koch monitoring the data returns. (All Images Credit: G. Koch)

Instruments

2011 in Review: **Information Systems**

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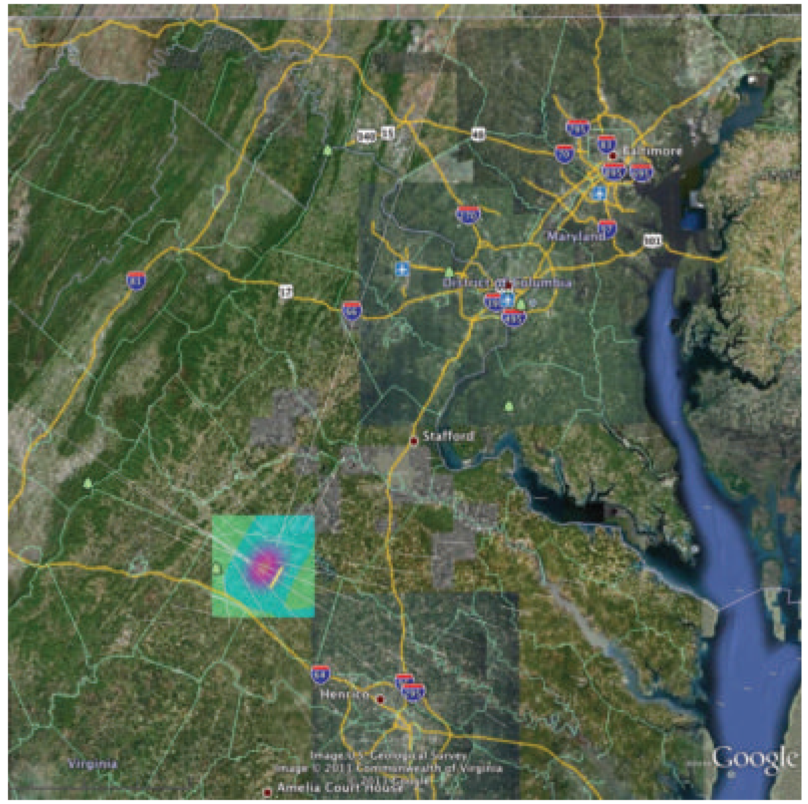
Advanced information systems play a critical role in the collection, handling, and management of large amounts of Earth science data, in space and on the ground. Advanced computing and transmission concepts that permit the dissemination and management of terabytes of data are essential to NASA's vision of a 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 26 active investments in FY11, nearly half of which have already advanced at least one Technology Readiness Level (TRL) to date; two projects have advanced 2 TRLs. No AIST projects graduated from funding in FY11.

A solicitation, now closed, for new information systems proposals was released in February 2011. Solicited topic categories included advanced data processing, data services management, sensor web systems, and operations management technologies. Awards are expected by mid-FY12.



Centered near Mineral, Virginia, the Aug. 23, 2011, magnitude 5.8 earthquake was felt up and down the eastern seaboard of the United States. In addition to shaking, earthquakes also cause permanent ground movements that can be measured. In some areas where earthquakes are common, such as California, GPS and radar systems are in place to make careful measurements of the motion of the Earth's surface. The Aug. 23 earthquake was not observed by these techniques, but a computer model funded by AIST was used to estimate the permanent displacement.

The model was generated by the QuakeSim project at the Jet Propulsion Laboratory (JPL), a computational framework for modeling and understanding earthquake and tectonic processes. QuakeSim focuses on deformation of Earth's crust, which can be measured using airborne and spaceborne technologies, and uses models and data to better understand earthquake hazard, stress transfer between faults, and ground disturbance following earthquakes.

The QuakeSim project estimates the total permanent ground movement in Washington, D.C., to have been about 0.02 inches to the northwest and downwards. The area near the epicenter at Mineral, VA., may have moved up to 2.8 inches northwest and upward in a dome 10 miles long by 5 miles wide extending to the northeast. (Image Credit: NASA/JPL/Google; PI: A. Donnellan, JPL)

SPOTLIGHT: CubeSat to Validate On-Board Processing Algorithm in Space

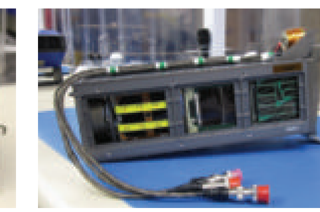
As satellite measurements of Earth become increasingly complex, many future missions will generate volumes of data too large to be transmitted to the ground by current methods. The Multi-angle Spectropolarimetric Imager (MSPI) instrument, for example (a candidate for the NASA Aerosol - Cloud - Ecosystems (ACE) mission under study with funding from the Instrument Incubator Program) could potentially produce 95 MB per second from each of its nine cameras. One solution to the downlink problem is to conduct the first stage of data processing onboard the satellite.

An AIST-funded project led by Paula Pingree at the Jet Propulsion Laboratory has developed a data processing algorithm to do just that. Designed specifically for MSPI, and paired with a commercial radiation-hardened Field Programmable Gate Array (FPGA) from Xilinx, the algorithm could effectively reduce downlink requirements by two orders of magnitude.

But how to test it in space? Enter M-Cubed, the Michigan Multipurpose Minisat. M-Cubed is a CubeSat: a 10 × 10 × 11 cm mini-satellite designed to be launched as an auxiliary payload of a larger satellite. Built with ESTO funding by students at the University of Michigan's Student Space Systems Fabrication Lab, M-Cubed contains the FPGA with the MSPI algorithm and a small camera – a stand-in for MSPI *that will take mid-resolution color images of Earth.*

M-Cubed was successfully launched on October 28, 2011, aboard the Delta II rocket that ferried NASA's NPOESS Preparatory Project (NPP) mission into space. In all, the NPP mission contained three Poly Picosatellite Orbital Deployers (P-PODs), each capable of deploying up to three CubeSats.

During its multi-month flight, M-Cubed will validate the MSPI onboard processing system and pave the way for future high-data-rate Earth science missions.



Top: the M-Cubed CubeSat, complete with deployable measuring tape antennae, and the M-Cubed packaged into a P-POD with two other CubeSats. (Images Credit: Michigan Exploration Laboratory)

Bottom: the NPP satellite is fitted into the Delta II nose cone. Note the P-PODs highlighted in the lower right of the image. (Image Credit: M.P. Mackley)

Information Systems

2011 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 FY11, the ACT program portfolio held a total of 31 investments. 15 of these were selected in September 2011 through a competitive solicitation that received 96 proposals. The new investments, which will be formally awarded in FY12, are (grouped by remote sensing technology category):

ACTIVE

Laser

- *High Power Mid-IR Laser Development 2.8 to 3.5 Microns*, J. Anderson, Harvard University
- *Combined HSRL and Optical Autocovariance Wind Lidar (HOAWL) Demonstration*, T. Delker, Ball Aerospace & Technologies Corporation
- *Advancement of the O2 Subsystem to Demonstrate Retrieval of XCO2 Using Simultaneous Laser Absorption Spectrometer Integrated Column Measurements of CO2 and O2*, J. Dobler, ITT Industries
- *A Compact Remote Sensing Lidar for High Resolution Measurements of Methane*, H. Riris, NASA Goddard Space Flight Center
- *Design and Fabrication of a Breadboard, Fully Conductively Cooled, 2-Micron, Pulsed Laser for the 3-D Winds Decadal Survey Mission*, U. Singh, NASA Langley Research Center
- *A 2-Micron Pulsed Laser Transmitter for Direct Detection Column CO2 Measurement from Space*, J. Yu, NASA Langley Research Center

Radar

- *Advanced W-Band Gallium Nitride Monolithic Microwave Integrated Circuits (MMICs) for Cloud Doppler Radar Supporting ACE*, K. Fung, Jet Propulsion Laboratory
- *High Efficiency, Digitally Calibrated TR Modules Enabling Lightweight SweepSAR Architectures for DESDynI-Class Radar Instruments*, J. Hoffman, Jet Propulsion Laboratory
- *Advanced Antenna for Digital Beamforming SAR*, R. Rincon, NASA Goddard Space Flight Center

PASSIVE

Microwave

- *Precision Deployable Mast for the SWOT KaRIn Instrument*, G. Agnes, Jet Propulsion Laboratory
- *Demonstration of a Hyperspectral Microwave Receiver Subsystem*, W. Blackwell, Massachusetts Institute of Technology Lincoln Laboratory
- *Advanced Amplifier Based Receiver Front Ends for Submillimeter-Wave Sounders*, G. Chattopadhyay, Jet Propulsion Laboratory

Optical

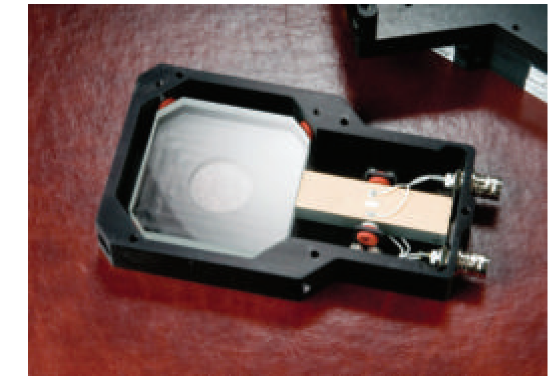
- *Development of Immersion Gratings to Enable a Compact Architecture for High Spectral and Spatial Resolution Imaging*, D. Jaffe, University of Texas
- *HgCdTe Infrared Avalanche Photodiode Single Photon Detector Arrays for the LIST and Other Decadal Missions*, X. Sun, NASA Goddard Space Flight Center
- *Fabry-Perot for the Integrated Direct Detection Lidar (FIDDL)*, S. Tucker, Ball Aerospace & Technologies Corporation

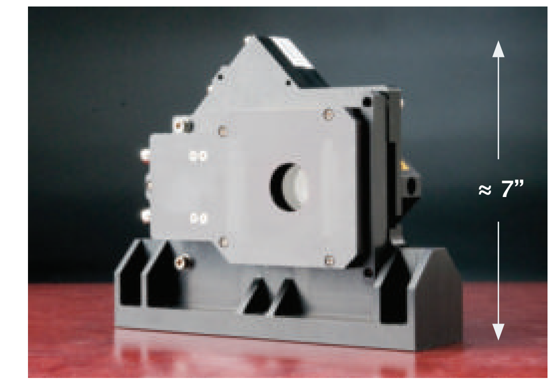
Three projects graduated from funding in FY11, all of which advanced at least one Technology Readiness Level (TRL) during the course of funding. The ACT FY11 graduates are as follows:

- *PolZero: Time-Domain Polarization Scrambler for Wavelength-Diverse Sensors*, R. Illing, Ball Aerospace & Technologies Corporation
- *Detector Technology Development for Cloud-Aerosol Transport Lidar*, M. McGill, NASA Goddard Space Flight Center
- *Laser Remote Sensing of O2 for Determination of CO2 Mixing Ratio and Sensing of Climate Species*, J. Dobler, ITT Industries

SPOTLIGHT: Method to Minimize Polarization Effects is Successfully Demonstrated

As sunlight is scattered, absorbed, and reflected by the Earth's surface and atmosphere, each interaction imparts a unique signature on the light observed by satellite-borne sensors. For instance, light reflected from calm water can be highly polarized at some views, and unpolarized at others. Just as polarized sunglasses block light waves moving in particular planes, many remote-sensing instruments are also sensitive to polarized light and their measurements can have serious errors without some kind of polarization correction.





Above top, PolZero optics.
Above bottom, the assembled flight unit.

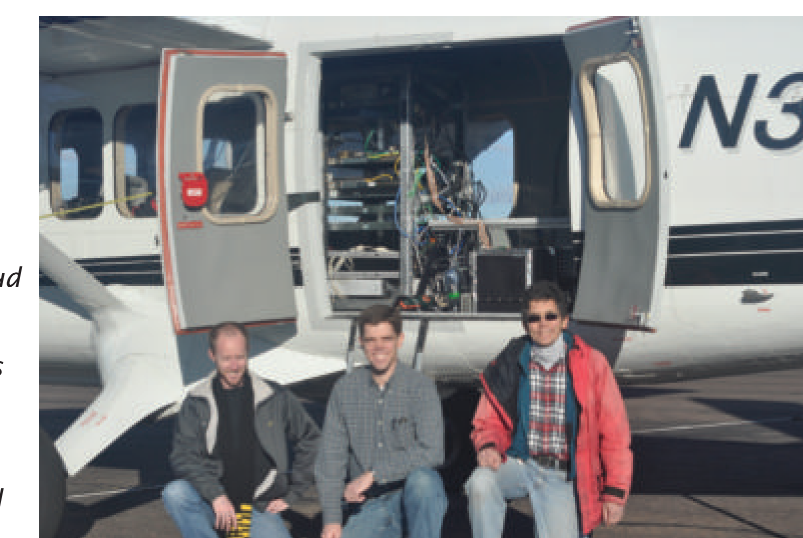
In general there are two ways to approach the problem: 1) measure the polarization of incoming light and adjust the data accordingly, or 2) neutralize the polarization up front before the instrument measures it. A new technology called PolZero has successfully demonstrated the latter approach.

PolZero is a time-domain polarization scrambler. Put more simply: it scrambles the polarization of light entering an instrument so measurement accuracy is not affected, particularly as observation angles change with time. The technique was tested and demonstrated by Ball Aerospace using custom components from Hinds Instruments, Inc.

In November 2010, PolZero was integrated with the GLIMMER (GLobal IMager for Marine Ecosystem Research) spectrometer for a series of aircraft test flights. In this role, PolZero significantly reduced polarization sensitivity without affecting measurement quality.

Below, PolZero team readies for a flight on the Twin Otter aircraft.

(All Images Credit: R. Illing)



Moving forward, ***PolZero could be a candidate component for several future satellite instruments****, such as: the spectrometers for the Aerosol - Cloud - Ecosystems (ACE) mission, the Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission, and the Global Atmospheric Composition Mission (GACM) as well as for the Hyperspectral Infrared Imager (HyspIRI) mission.*

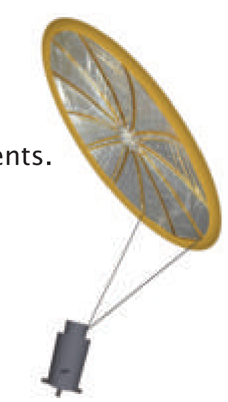
Future Challenges

For more than a decade, 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.

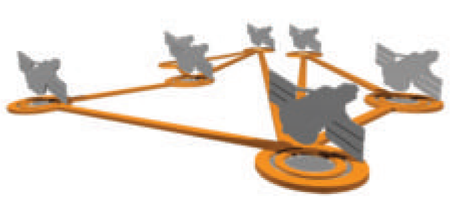
- Atmospheric chemistry using lidar vertical profiles
- Ice cap, glacier, sea ice, and snow characterization using radar and lidar
- Tropospheric vector winds using lidar
- Precipitation and cloud measurements using radar



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

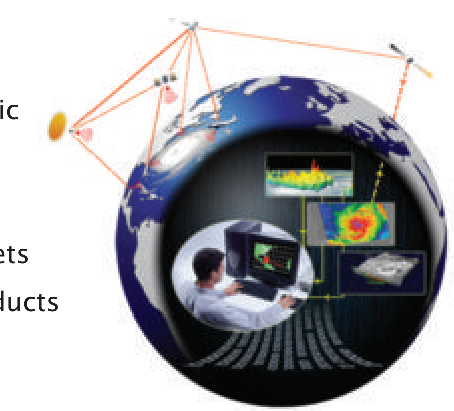
Intelligent Distributed Systems using advanced communication, on-board processors, autonomous network control, data compression, and high density storage.



- 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

Additional information is available online at the ESTO website:

visit esto.nasa.gov

National Aeronautics and Space Administration

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