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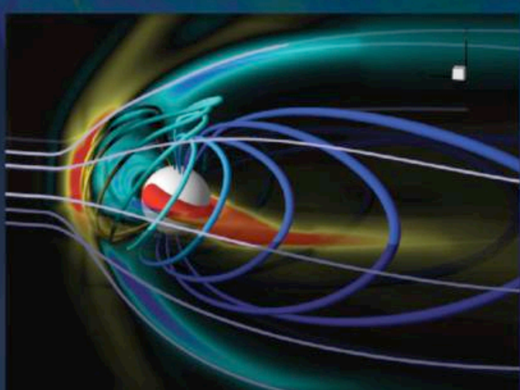

Earth-Sun System Technology Office (ESTO)

2005 Annual Report

Executive Summary

As reported in the pages that follow, 2005 has been another highly productive year for Earth-Sun system technology development. NASA's Earth-Sun System Technology Office (ESTO) graduated some 40 technology projects over the fiscal year, of which nearly 90% advanced at least one Technology Readiness Level (TRL) during the course of their funding. Competitive solicitations added 37 new projects to the ESTO portfolio: 23 to the Instrument Incubator Program (IIP) and 14 to the Advanced Component Technologies (ACT) program.

Two recent graduates deserve special attention for achievements in FY05. The Far Infrared Spectroscopy of the Troposphere (FIRST) instrument was test flown on a high-altitude balloon and recorded the first-ever complete infrared spectrum of the Earth, more than half of which is beyond the range of existing sensors. Also, the Land Information System, a high-performance land surface modeling and data assimilation system, was named co-winner of the NASA Software of the Year award.

ESTO has continued to build on its history of technology infusion success as well. In FY05, 24% of active ESTO technology projects achieved actual infusion in science measurements, live system demonstrations, or spin-off applications.

Finally, our program name was altered early this year – from "Earth Science..." to "Earth-Sun System..." – to reflect ESTO's new role as the lead technology office within the Earth-Sun System Division of the NASA Science Mission Directorate. As we approach the challenges of the coming year, we look forward to working closely with our colleagues across NASA and to forming new partnering and funding relationships across the nation.

George Komar
Program Director, ESTO

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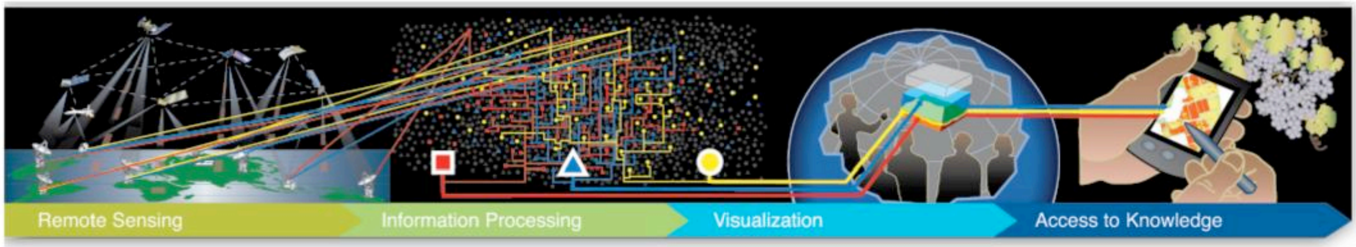


From instruments to data access, ESTO technologies enable a full range of scientific measurements

As the lead technology office within the Earth-Sun System Division of the NASA Science Mission Directorate, the Earth-Sun System Technology Office (or 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 to make those observations useful.

ESTO's approach to technology development is also end-to-end:

- Planning technology investments through comprehensive analyses of science requirements
- Developing technologies through competitive solicitations and partnership opportunities
- Making technologies available to scientists and mission managers for infusion

ESTO employs an open, flexible, science-driven strategy that relies on competitive, peer-reviewed solicitations to produce the best, cutting-edge technologies. In many 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 varied portfolio of over 450 emerging technologies that will enable and/or enhance future science measurements and an ever-growing number of infusion successes.

Each star represents one of the 463 projects (active and completed) in ESTO's portfolio as of April, 2005

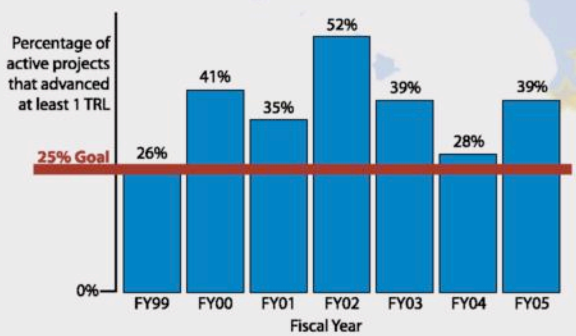
With more than 300 graduated technology investments completed and a current, active portfolio of over 100 projects, ESTO has continually built upon NASA's reputation for developing and advancing leading-edge technologies.

So, how did ESTO do this year?

Here are few of our successes for FY05, tied to NASA's performance goals for ESTO:

GOAL: Annually advance 25% of funded technology projects one Technology Readiness Level (TRL).

FY05 RESULTS: 39% of funded technology projects advanced at least one TRL.



GOAL: Mature 2-3 technologies to the point where they can be demonstrated in space or in an operational environment.

FY05 RESULTS: 24% (26) of funded technology projects achieved actual infusion. Examples include:

- Fabry-Perot interferometer for column CO2 underwent successful DC-8 flight over the California Central Valley

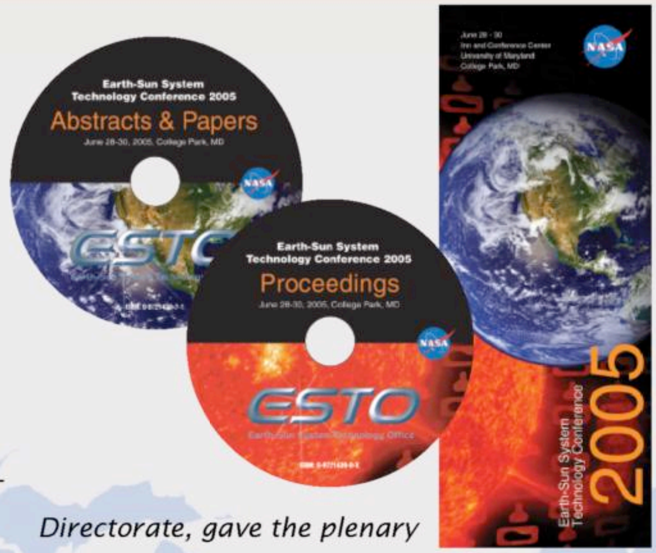
- An array of prototype smart antennae were deployed and successfully received S-Band signals from EO-1
- "Image Access Layer" program is now operating in production on the OnEarth WMS server, which is daily serving 5 - 10 million maps of Landsat 7 data, MODIS data, and other data sets to science users and the general public.

GOAL: Enable one new science measurement capability or significantly improve performance of an existing one.

FY05 RESULT: The Far IR Spectroscopy of the Troposphere (FIRST) instrument was successfully demonstrated on a balloon flight on June 7, 2005. FIRST measures infrared emissions from 10-100 microns, well beyond the range of any existing sensors. The instrument is designed to measure the far-infrared emission from the troposphere–key data for global change studies. (See page 5)

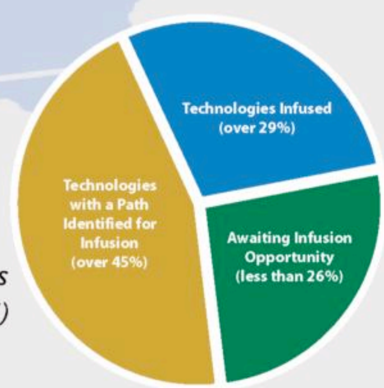
SPOTLIGHT: ESTC2005

ESTO held its fifth annual technology conference June 28th-30th, at the University of Maryland Inn and Conference Center in College Park. This year's conference – ESTC2005 (Earth-Sun System Technology Conference 2005) – included 59 technical papers presented in two parallel tracks: Information Technologies and Observation Technologies. The papers reflected a broad range of technologies and disciplines within the Earth and sun science areas. Dr. Mary Cleave, Director of the NASA Science Mission Directorate, gave the plenary address. Full conference proceedings for ESTC2005, as well as for past ESTO conferences are available at the ESTO website (http://esto.nasa.gov)

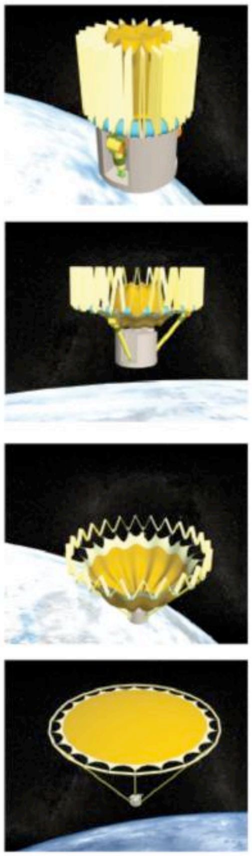


What are the drivers for ESTO's success?

- A diverse research community – principal investigators are drawn from nearly 100 organizations in 27 states.
- A commitment to advanced planning and technology infusion by thoroughly vetting technology requirements and actively seeking infusion opportunities.
- A strong focus on technology management results in steady, robust development progress – over 67% of completed projects advanced at least 1 Technology Readiness Level (TRL) over the lifetime of their funding.



ESTO's Infusion Success (366 completed projects through FY05)



Deployment scenario for NEXRAD, an innovative Doppler radar instrument for detailed monitoring of hurricanes and rainfall from a geostationary orbit.

The Instrument Incubator Program (IIP) provides funding for new instrument and measurement techniques, from the concept development through breadboard and flight demonstration. Instrument development of this scale outside of a mission stovepipe 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, thereby significantly reducing costs and schedule uncertainties.

In FY05, the IIP awarded funding for 23 new investigations for instrument development. The awards, selected from a field of 82 submitted proposals, focus on high-priority science areas, including aerosol and trace gas measurements in the lower troposphere, ice topographic mapping, and tropospheric winds measurements. The awarded investigations, which are to last three years, are as follows:

- Laser Sounder for Atmospheric CO^2 Measurements from Orbit
- Cascade Laser Systems in Conjunction with Integrated Electronics for Global Studies of Climate Forcing and Response Using UAVs as a Partner with Satellite and Adaptive Models
- Development of UAV-based Global Ozone Lidar Demonstrator (GOLD)
- A High-Accuracy Spectropolarimetric Camera for Aerosol Remote Sensing from Space
- Multi-Functional Fiber Laser Lidar (MFLL) for Ice Sheet Topographic Mapping
- TWiLiTE: Tropospheric Wind Lidar Technology Experiment
- Push-Broom Laser Altimeter Demonstration for Space-Based Cryospheric Topographic and Surface Property Mapping
- High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)
- Technology Development for a Combined High Spectral Resolution and Ozone Differential Absorption Lidar
- Development and Evaluation of a 2-Micron Differential Absorption Lidar for Profiling CO^2
- Glaciers and Ice Sheets Interferometric Radar
- Compact, Engineered, 2-Micron Coherent Doppler Wind Lidar Prototype for Field and Airborne Validation
- Tropospheric Infrared Mapping Spectrometers (TIMS) for CO Measurements
- Atom-interferometer Gravity Gradiometer
- A GNSS Remote-Sensing and Ultra-High-Accuracy POD Instrument (GRSPI)
- In-situ Net Flux Within the Atmosphere of the Earth
- A Ka-Band Digitally Beamformed Radar Interferometer for Topographic Mapping of Glaciers and Ice Sheets
- Large Aperture, Scanning, L-Band Synthetic Aperture Radar (SAR)
- Pathfinder Advanced Radar Ice Sounder (PARIS)
- Development of an Agile Digital Detector for RFI Detection and Mitigation on Spaceborne Radiometers

- Validation of Technique for Measurement of Tropospheric Winds Using Doppler Shift of the Oxygen A-band Absorption Lines
- Airborne Water, Aerosol Cloud and Carbon Dioxide Lidar
- Geostationary Imaging Fabry-Perot Spectrometer (GIFS)

The IIP also graduated eight projects in FY05, all of which advanced at least one Technology Readiness Level (TRL):

- Advanced Precipitation Radar Antenna (APRA)
- Microwave Observatory of Subcanopy and Subsurface (MOSS) UHF/VHF SAR
- Laser Absorption Spectrometer for Global-Scale Profiling of Tropospheric Carbon Dioxide
- ICOS, CAPS and CRDS: New Techniques for Precise, Low-Cost, Airborne, In Situ Mapping of Species for AURA Collaborative Science
- Digital Receiver with Interference Suppression for Microwave Radiometry
- Advanced Lightweight Rainfall Radiometer (LRR)
- Ultra Stable Microwave Radiometers (USMR) for Future Sea Surface Salinity Missions
- Fabry-Perot Interferometer for Column CO^2

SPOTLIGHT: FIRST (Far Infrared Spectroscopy of the Troposphere) Successfully Test Flown

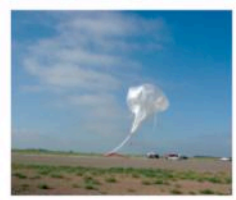
The IIP-funded FIRST (Far Infrared Spectroscopy of the Troposphere) instrument was successfully demonstrated on a high-altitude research balloon flight on June 7, 2005

FIRST measures infrared emissions from 10-100 microns, well beyond the range of any existing sensors. The instrument is designed to measure the far-infrared emission from the troposphere, which will provide key data for global change studies.

The balloon and payload was launched from the National Scientific Balloon Facility in Ft. Sumner, NM, and provided data from 90,000 ft for 4.5 hours, meeting the test objectives. During this time, the Aqua spacecraft (containing the AIRS instrument, which measures infrared emissions from 4 to 15 microns) passed overhead. The AIRS data from this pass will be combined with the FIRST data to provide the first-ever complete infrared emission spectrum of the Earth.

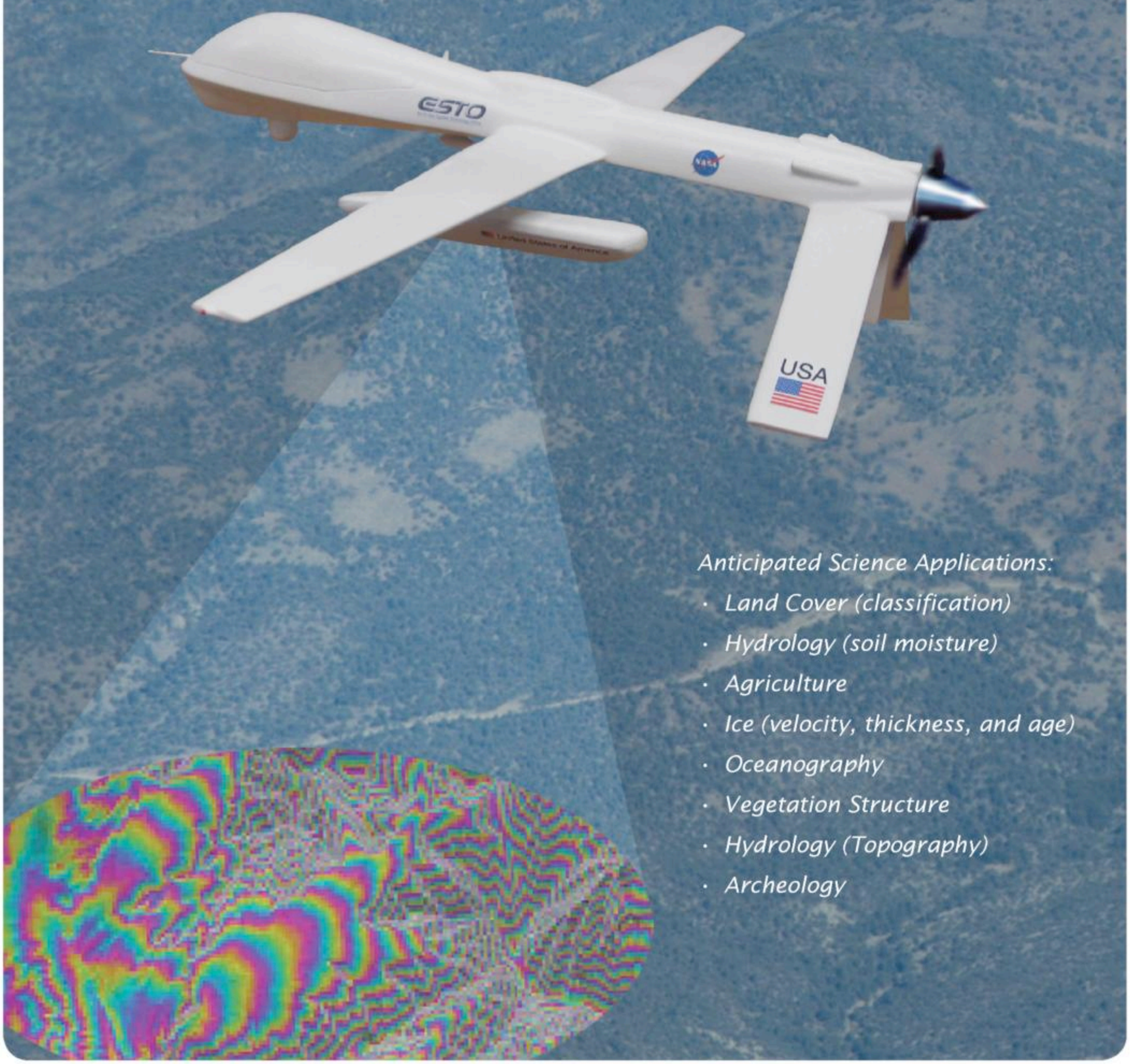
Based on the preliminary assessment, the instrument met its design goals. Complete data analysis is ongoing but initial looks at the data show far-infrared spectra rich in spectral features.




The FIRST instrument launching from Ft. Sumner, NM.

The UAVSAR (Uninhabited Aerial Vehicle, Synthetic Aperture Radar) project finds its origins in an Instrument Incubator Program (IIP) investment at the Jet Propulsion Laboratory entitled: "Repeat Pass Deformation Measurement Capability for an Airborne Platform." That IIP investment was singled out in 2004 for targeted funding – to develop two baseline systems, conduct flight testing on the NASA Gulfstream III, and integrate into a Predator-B UAV – and became the UAVSAR project. With the Gulfstream III flight testing slated to begin in early 2007, the UAVSAR project has met significant schedule requirements including: a requirements review, a Preliminary Design Review (PDR) of the instrument, pod, and platform; and a Critical Design Review (CDR) of the instrument.

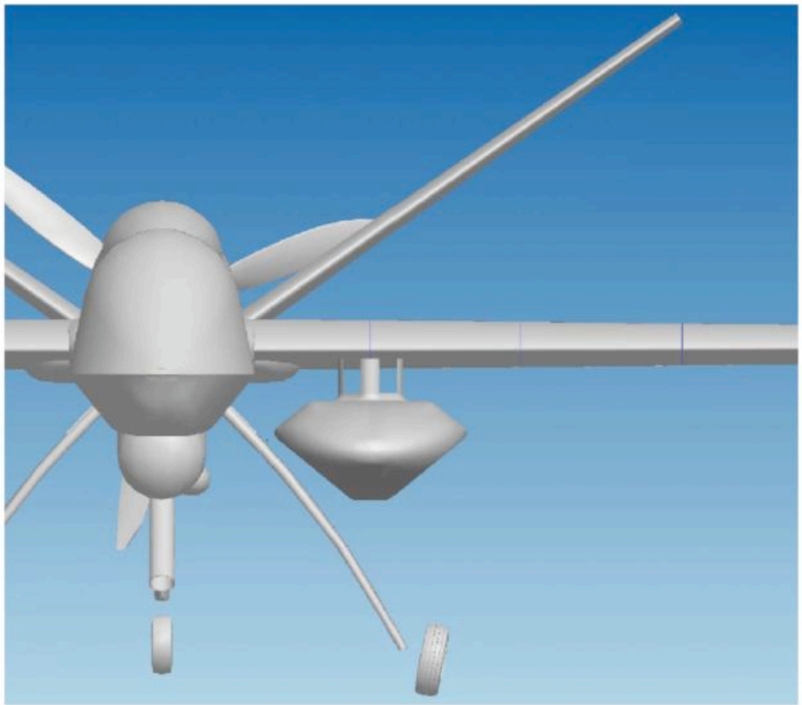


Anticipated Science Applications:

- *Land Cover (classification)*
- *Hydrology (soil moisture)*
- *Agriculture*
- *Ice (velocity, thickness, and age)*
- *Oceanography*
- *Vegetation Structure*
- *Hydrology (Topography)*
- *Archeology*

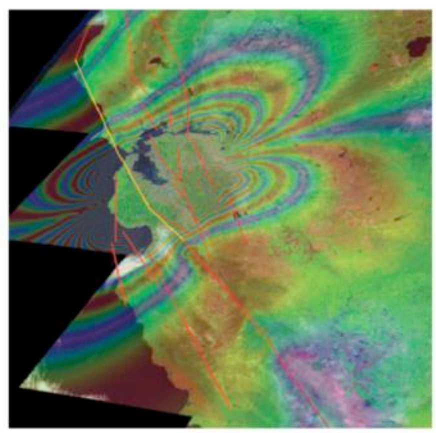
The UAVSAR will have the capability to conduct rapid repeat pass interferometry measurements with separations ranging from minutes to years, enabling the measurement of surface deformation to mm level accuracy. Current space-based assets have a repeat orbit cycle of 24 to 44 days, limiting their effectiveness in the study of rapidly deforming features.

The design of the UAVSAR focuses on two key challenges. First, repeat pass measurements will need to be taken from flight paths that are nearly identical. The instrument will utilize real-time GPS that interfaces with the platform flight management system (FMS) to confine the repeat flight path to within a 10 m tube. Second, the radar vector from the aircraft to the ground target area must be similar from pass to pass. This will be accomplished with an actively scanned antenna designed to support electronic steering of the antenna beam with a minimum of 1° increments over a range to exceed ±15° in the flight direction.



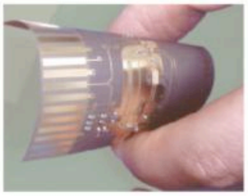
Elevation drawing depicts the relative size and location of the SAR package on a Predator-B UAV.

This illustration depicts synthetic aperture radar patterns of seismic deformations associated with a model earthquake on the San Francisco section of the San Andreas Fault (depicted in yellow).



Anticipated Technology Benefits:

- Enable a repeat pass in as little as 20 minutes
- Greatly reduced mass and volume to existing airborne SAR technologies
- Modular design to allow integration on multiple airborne platforms
- Pre-programmed, autonomous operation without need for a radar operator
- Flexible digital system that can trade data rate for performance and accept additional frequencies and parameters in the future



Transmit/receive (T/R) module on flexible membrane material for use in large, space-deployable antennas.

The Advanced Component Technology (ACT) program leads research, development, and testing of component- and subsystem-level technologies to advance the state-of-the-art of instruments, Earth- and space-based platforms, and information 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 FY05, ACT released a solicitation as part of the NASA ROSES (Research Opportunity for Space and Earth Science) 2005 announcement. 92 proposals were received of which 14 were selected for awards. These are:

- A Solid-State Terahertz Receiver for Atmospheric Spectroscopy
- Advanced Component Technology for Exploration of the Heliosphere Using Neutral Atom Imaging Arrays
- Aluminum Manganese TES Development for Large Scale Arrays of Microcalorimeters
- Adaptive Self-Correcting T/R module for Phase-Stable Array Antennas
- Lightweight, Low Power, High Speed Digital Signal Distribution Technology for Thinned Aperture Radiometer Application
- High-Precision Adaptive Control of Large Antenna Surface
- MEMS Actuated Wave Front Controller
- Miniature MMIC Low Mass/power Radiometer Modules for the 180 GHz GeoSTAR Array
- Ultra Low Noise Radiometers for Tropospheric and Stratospheric Limb Sounding
- Large Lightweight and Deployable Phased Arrays Using RF MEMS Switches
- Analog Radio- Frequency Interference Suppression System for Microwave Radiometers
- Shared Aperture Diffractive Optical Element (ShADOE) Multiplexed Telescope
- Advanced Performance Two- Channel Ku- and Ka- Band Dual-Downconverters for Interferometric Radar Applications
- Compact Ku-Band T/R Module for Wide-Swath High-Resolution Radar Imaging of Cold Land Processes

The ACT program also graduated two projects in FY05:

- Development of High Performance Laminated Electroformed Shape Memory Composite Materials for Lightweight and Deployable Optics
- Advanced UV and Visible Ultra-narrow Interference Filter Technology Development (awarded competitive funding by the Instrument Incubator Program for further development)

This latch for a space-deployable optical mirror was developed using contact mechanics and micro-slip friction models to achieve sub-micron precision and nanometer-level stability.

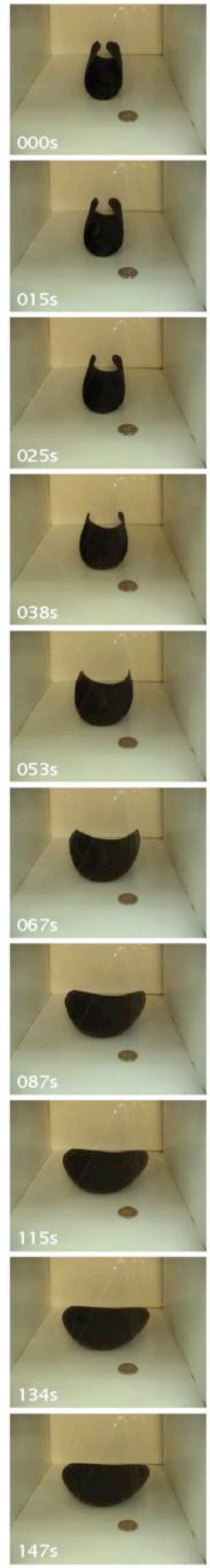
SPOTLIGHT: Shape Memory Composite Materials for Lightweight, Deployable Optics

Large, lightweight, deployable antennas will be a critical component in realizing a number of future science measurement objectives. This project demonstrates the applicability of new shape memory materials that can be stowed compactly for launch, and later deployed to a stiff and stable structure suitable for a wide range of applications.

The shape memory materials used in the production of these optics are similar to traditional carbon fiber-reinforced composites except that they include a shape memory polymer resin based on cyanate ester. The unique properties of this resin allow the optics to be put under high packaging strain without damage. The strain is induced by heating the material, flexing it mechanically, and then cooling it to "freeze" the strained material in a shape suitable for packaging. Deployment, or shape recovery, is achieved by re-heating the composite material, which releases its strain to return to its "normal," pre-packaged shape.

Anticipated Technology Benefits:

- *Lightweight, compact, and deployable - less than 5 kg per square meter packing enabled by resin deformations of 10-40%, reducing mission cost and enabling higher orbits.*
- *Enables larger apertures that can enhance instrument capabilities*
- *Manufacturing process that relies on a master optic makes reproduction fast and inexpensive*
- *Combines high optical surface accuracy with a stiff monolithic structure*
- *Eliminates the need for complex deployment mechanisms*
- *Can be stowed and deployed in a configuration that protects optical surfaces from abrasion or damage*

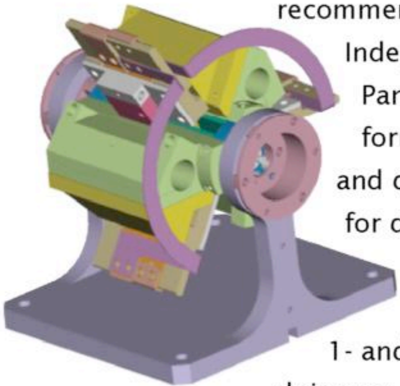


Time lapse of nickel/composite laminate deployment at 100˚C

Year in Review: Lasers

The Laser Risk Reduction Program (LRRP) was established in 2002 by the NASA administrator under the recommendation of the Earth Science Independent Laser Review Panel. LRRP works to formalize design, testing, and development procedures for durable laser/lidar systems and architectures, particularly in the critical 1- and 2- micron wavelengths. In doing so, the LRRP aims to:

- demonstrate laser technologies that can be reliably and confidently infused;
- prepare technologies well in advance of missions;
- maintain NASA's in-house laser expertise and capabilities; investigate science-technology trade-offs; and
- test engineering flight models in final configurations.



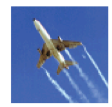
Solid model of a high-energy, high-efficiency, conductively cooled 2-micron laser for space lidar applications

Laser/lidar remote sensing techniques can satisfy a variety of measurement and operational requirements:

Earth Science: Clouds/Aerosols, Tropospheric Winds, Ozone, Carbon Dioxide, Biomass, Water Vapor, Land, Ice, and Ocean, Surface Mapping, and Laser Altimetry

Space Science: Surface Materials, Physical State, Surface Topography, Molecular Species, and Atmospheric Composition and Dynamics

Exploration: Lander Guidance/Control, Atmospheric Winds, Biochemical Identification, Optical Communication, and Automated Rendezvous & Docking



Aeronautics: Turbulence Detection, Wind Shear Detection, and Wake Vortices

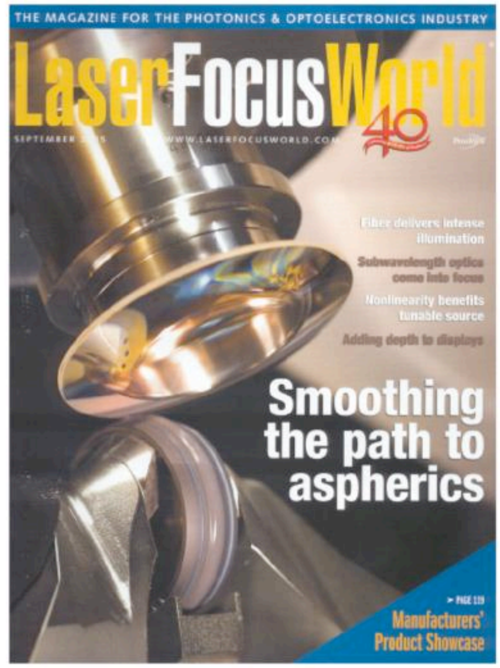
The LRRP currently funds 27 projects at NASA Goddard Space Flight Center and NASA Langley Research Center. Partners and collaborators include: American University, Boston College, the Jet Propulsion Laboratory, Johns Hopkins University Applied Physics Laboratory, Montana State University, Sandia National Laboratory, the University of Maryland, and numerous industrial partners. The investments also cover a broad range of laser/lidar challenge areas, including:

- High-performance 1- and 2- Micron Lasers
- High-reliability Pump Laser Diode Arrays
- Space Radiation Tolerance
- Frequency Control and Wavelength Conversion
- Electrical Efficiency
- Heat Removal and Thermal Management
- Contamination Tolerance
- Photoreceiver and Detector Development

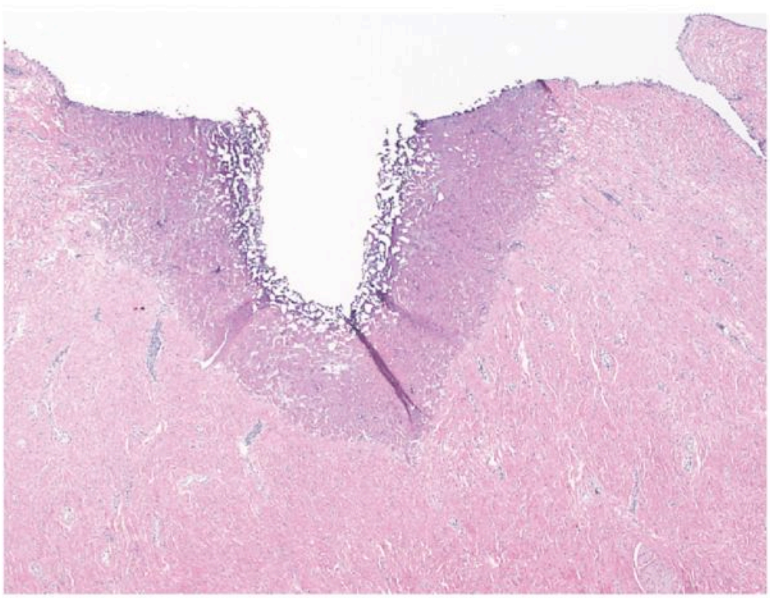
SPOTLIGHT: Thulium Fiber Laser Spins-Off to Support Medical Applications

A 40 watt, 1.94 micron Thulium (Tm) fiber laser, developed by IPG Photonics with LRRP funding, was demonstrated as an emerging tool for urologic procedures by Dr. Nathanial Fried of the Johns Hopkins School of Medicine. Originally developed for wind measurements, the laser system has received attention from the medical community for its promise in prostate and other cancer surgeries.

The Tm fiber laser is, according to Fried, "a promising new laser technology that may find its niche in medicine as a single, compact laser platform capable of performing multiple applications, including precise incision, rapid vaporization, and adequate coagulation for hemostasis during soft-tissue procedures." In addition, when compared to current tools, the Tm fiber laser system is much smaller, eye-safe, more efficient, and is a better match to tissue absorption lines, which improves precision – leading to firm commitments in the medical community to pursue the technology.



An article in Laser Focus World (September, 2005), "Fiber lasers find opportunities in medical applications", showcased Dr. Fried's work in exploring the feasibility of the laser.



Histological image showing the laser's impact on a tissue sample. The Tm fiber laser leaves a clean, distinct cut, or kerf, with little damage to the surrounding tissue

Advanced information systems are used to process, archive, access, visualize, and communicate science data. Advanced computing and communications concepts that permit the transmission 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.

In FY05, the AIST program held some 39 investments, several of which graduated over the course of the year, including:

- Planning and Scheduling of Coordinated Science Observations
- Merging the NetCDF and HDF5 Libraries to Achieve Gains in Performance and Interoperability

The AIST program plans to add to these investment numbers in 2006 with the release of an additional solicitation, as part of the NASA ROSES (Research Opportunity for Space and Earth Science) announcement.

The Aqua Model-Based Advisor, developed at NASA Goddard Space Flight Center with AIST funding, helps safeguard the AQUA satellite by constantly monitoring it's flight software and alerting mission operators of errors via email. The technology can be readily modified for use in almost any remote system where complexity requires advanced monitoring tools.

In addition, the end of FY05 marks the graduation of 26 major investments in the computational technologies area (formerly the ESTO Computational Technologies Project). Among these graduates are: the award-winning Land Information System; the Earth Science and Space Weather Modeling Framework projects; and the QuakeSim earthquake modeling portal. In the coming years, AIST will build on this work by actively pursuing technologies in computational, modeling and visualization areas.

SPOTLIGHT: 2005 NASA Software of the Year Co-Winner: Land Information System

NASA selected two teams to receive the agency's Software of the Year Award. A team from NASA's Goddard Space Flight Center, Greenbelt, Md., and funded by AIST, was recognized for their Land Information System Software (LIS) V4.0.

The LIS software is a high-performance land surface modeling and data assimilation system. LIS realistically predicts the water and energy cycles, including runoff, evaporation from plants and soil, and heat storage in the ground. This enables observation-driven modeling to help revolutionize the nation's weather and climate forecasting systems.

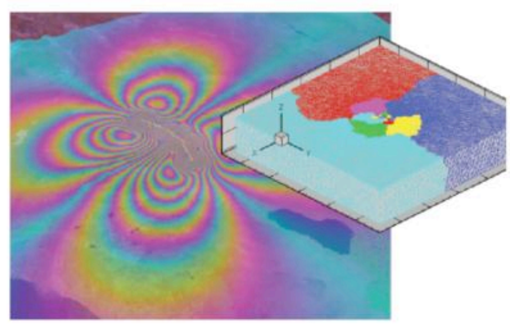
The LIS has helped advance NASA's software engineering principles and practices, while promoting portability, interoperability and scalability. LIS is being used by the science teams from the orbiting Gravity Recovery and Climate Experiment (GRACE), the Tropical Rainfall Measurement Mission (TRMM) and the Aqua satellite.

SPOTLIGHT: QuakeSim project

Novel space-based assets and in situ techniques make measurements of Earth's tectonic processes more precise and more productive than ever before. QuakeSim is a web-services based geophysical modeling environment that can enable a better understanding of these measurements, provide insights into tectonic activity, and pave the way to reliable earthquake forecasts.

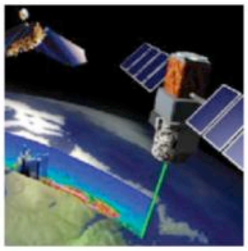
The QuakeSim portal includes a wide range of tools, including: simulation and analysis software; a federated database providing access to earthquake fault, GPS, and seismic data; and visualization tools. This portal architecture offers flexibility to expand available resources, such as the addition of data and the inclusion of new modeling codes. Three major simulation tools – Virtual California, Geophysical Finite Element Simulation Tool (GeoFEST), and PARK – are under continuing development and are available online at http://quakesim.jpl.nasa.gov.

Finite element mesh (right) used in a Landers earthquake simulation and an interferogram from a GeoFEST finite element model of the displacement during the1992 Landers, California event.



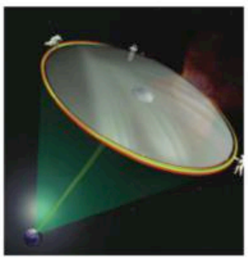
Future Challenges

While ESTO is uniquely situated to pursue a wide range of technology requirements, we have identified five crosscutting technology areas that will serve a multitude of science disciplines:



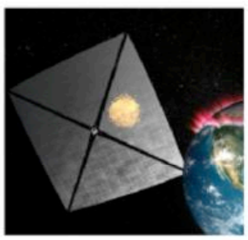
Remote Sensing Technologies to enable measurements of the atmosphere, hydrosphere, biosphere, lithosphere, and magnetosphere.

- Atmospheric chemistry using interferometry from L1
- Snow water equivalent and snow wetness using Radar from LEO
- Soil moisture and sea salinity measurements using P-band from Geo



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

- Tropospheric winds, temperature, and moisture using Dial-Lidar from Geo
- Soil moisture and sea salinity measurements using P-band from Geo
- Tropospheric chemistry using Lidar from Geo

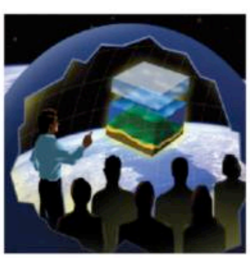


Platform Technologies to enable measurements from unique vantage points.

- High Delta-V propulsion
- Advanced navigation and control
- High-performance on-board processing
- Advanced solar collection efficiency

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 prediction linking observations to numerical models
- Space weather monitoring and prediction linking observations to numerical models



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 materials is available online at the recently updated ESTO homepage – http://esto.nasa.gov – including:

Information about ESTO solicitations and awards

Abstracts, papers and presentations from the 2005 Earth-Sun System Technology Conference as well as from previous ESTO conferences.

The Earth Science Technology Integrated Planning System (ESTIPS), an evolving database of science require-ments linked to technology investments

Fully searchable database of active ESTO investments

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