Science Mission Directorate

Earth Science Technology Program Overview

Presentation to MSFC

Amy Walton
Earth Science Technology Program
June 6, 2006

Overall Approach to Technology Development

A Flexible, Science-driven Technology Strategy

- Open, peer-reviewed competitive solicitations enable selection of best-of-class technology investments
- Active management of technology projects: a cost-effective approach to technology development and validation
- Energetic communication with the technology customer community
- This approach has resulted in:
  - a portfolio of emerging technologies that will enhance and/or enable future science measurements
  - a growing number of infusion successes: technologies are infused into a mission by competitive selection of science PIs or mission managers, not the Technology Program

Implementation - Program Elements

Observational Technologies:

- **Advanced Technology Initiatives (ATI) -** provides for concept studies and development of component and subsystem technologies (Advanced Component Technology (ACT) Program) for instruments and platforms

- **Instrument Incubator Program (IIP) -** provides new instrument and measurement techniques, including lab development and airborne validation

Information Systems Technologies:

- **Advanced Information Systems Technologies (AIST) -** provides innovative on-orbit and ground capabilities for the communication, processing, and management of remotely sensed data and the efficient generation of data products and knowledge

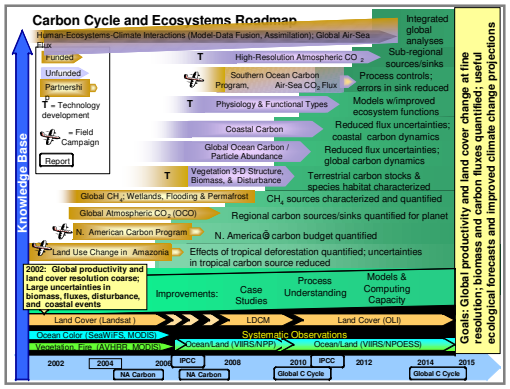
- **Computational Technologies (CT) -** provides techniques and systems that enable high performance throughput, archiving, data manipulation, and visualization of very large, highly distributed remotely sensed data sets consistent with modeling needs

Competitively Selected Earth Science Technologies

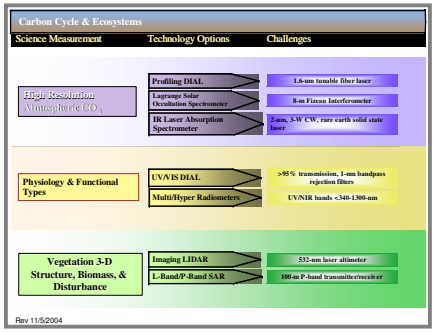
NRA Solicitations	Focus
IIP Round 1 (Instruments) '98 27 awards, $39M	Open, unconstrained solicitation; covering active and passive optical and active and passive microwave instruments
IIP Round 2 (Instruments) '01 11awards, $30M	Microwave radiometry, radar, laser/lidar instruments
IIP Round 3 (Instruments) '02 9 awards, $22M	Topography and surface change, gravity field measurements, sea ice thickness, snow cover, GEO (trop profiles, atm-temp-moisture and rainfall, coastal region), L1 or L2 innovation
IIP Round 4 (Instruments) '04 23 awards, $60M	Atmospheric aerosols and trace gases, ice topographic mapping, and tropospheric winds (ex. lidar, radar, gravity gradiometry)
ATI Component Technology (ACT Round 1) '99 23 awards, $17M	Core instrument technology; covering active and passive optical, and active and passive microwave instrument components
ACT Round 2 (Components) '02 14 awards, $15M	Antenna, electronics, detectors, and optics components
ACT Round 3 (Components) '05 14 awards, $12M	Sun-Solar System in situ measurements and remote sensing instrumentation, and active and passive microwave antennas and instrument electronics for Earth Science.
AIST Round 1 (Info Systems) '99 30 awards, $26M	On-board space-based information systems applications including data processing, organization, analysis, storage, and transmission; intelligent sensor and platform control; and network configuration
AIST Round 2 (Info Systems) '02 21 awards, $23M	Space/ground-based, computational technology
Mini-AIST (Info Systems) '04 6 awards, $2M	Ocean Biology and Biogeochemistry Data Mining Data Mining for Climate and Weather Models
Computational Technology '02 11 teams, $23M	Fundamental problems in science and engineering, with broad scientific and economic impact, whose solution can be advanced by high-performance computing

The Development Process

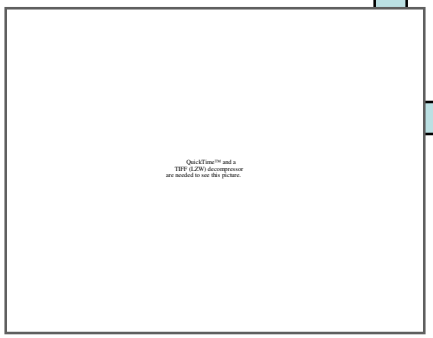
Starting with the **science** focus area **roadmap**…



… science measurement challenges (science roadmap Ts) and technology requirements database information are used to identify technology options and key challenges…



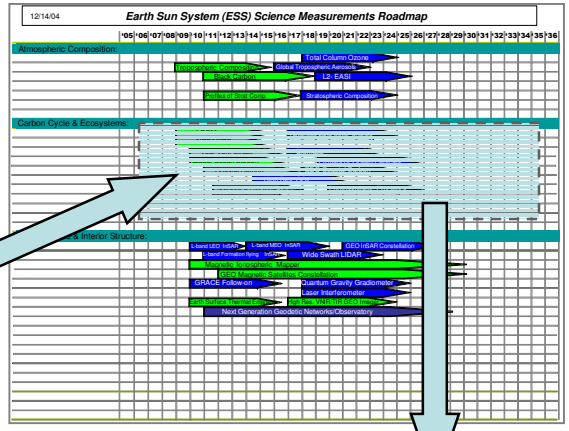
Technology requirements database (ESTIPS)

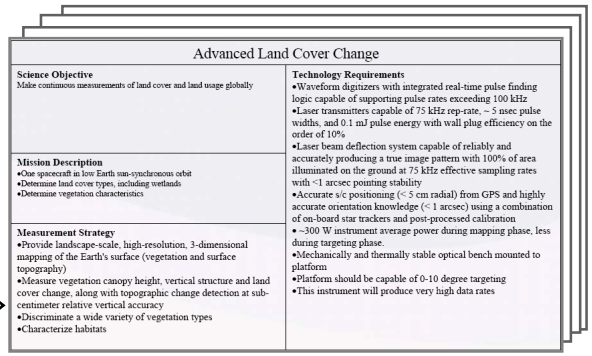


*… information on the science roadmap is used to create a **matrix of science objectives**, and possible measurement scenarios…*

Carbon Cycle & Ecosystems Science Questions	Carbon Cycle & Ecosystems Scientific Outcomes	Carbon Cycle & Ecosystems New Measurements & Activities	Mission Target Date	Near-term Measurements	Far-term Measurements (2016 and Beyond)
How are global ecosystems changing?	Document Global Productivity	Measurements of Ocean Color Properties, Vegetation Properties, and Fire	Systematic Observation	**NPP (VIIRS) 2006 NPOESS (VIIRS) 2010**	NPOESS
	Document Global Land Cover Change	Land Cover & Land Cover Change	Systematic Observation	**LDCM 2009**	Land Cover (OLI)
	Quantify the North American carbon budget	North American Carbon Program (Field Campaign)	2007		
	CH_4 sources characterized and quantified	Global CH_4: Wetlands, Flooding, & Permafrost	2009	***LEO SAR or InSAR could address in part***	
	Terrestrial carbon stocks	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	Biomass
	Reduce flux uncertainties in global carbon dynamics	Global Ocean Carbon/Particle Abundance Mission	2010	**Global Ocean Carbon 2010**	
What changes are occurring in global land cover and land use, and what are their causes?	Quantify the effects of tropical deforestation	Land Use Change in Amazonia (LBA Field Campaign)	2006		
	Document Global Land Cover Change	Land Cover & Land Cover Change	Systematic Observation	**LDCM 2009**	Land Cover (OLI)
	Species habitat characterized	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	
	Reduced carbon flux uncertainties and global carbon dynamics	Global Ocean Carbon / Particle Abundance	2010	**Global Ocean Carbon 2010**	
	Reduced carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon 2011**	GEO Coastal Carbon
	Models with improved ecosystem functions	Physiology & Functional Types	2011	**Physiology & Functional Types 2011**	Laser-Induced Fluorescence
	Process controls and errors in Southern Ocean sink reduced	Southern Ocean Carbon Program; Air-Sea CO_2 Flux	2012		
	Sub-regional carbon sources and sinks	High-Resolution CO_2	2013	**High-Resolution CO_2 2012**	High-Resolution CO_2
What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?	Reduced carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon Mission 2011**	GEO Coastal Carbon
	Integrated global analyses of consequences	Global Models with Human-Ecosystems-Climate Interactions	2013		
What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?	Reduce flux uncertainties in coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon Mission 2011**	GEO Coastal Carbon
	Integrated global analyses of consequences	Global Models with Human-Ecosystems-Climate Interactions	2013		
How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?	Regional carbon sources/sinks quantified for planet	Global Atmospheric CO_2 (OCO)	2008	**OCO 2008**	High Resolution CO_2
	Sub-regional carbon sources/sinks quantified for planet	High Resolution Atmospheric CO2	2012	**High Resolution CO_2 2012**	High Resolution CO_2
	Models with improved ecosystem functions	Physiology and Functional Types	2011	**Physiology & Functional Types 2011**	Laser-Induced Fluorescence
	Process controls and reduced errors in Southern Ocean carbon sink	Southern Ocean Carbon Program (Field Campaign)	2012		
	Integrated global analyses	Human-Ecosystem-Climate Interactions (Model-Data Fusion, Assimilation); Global Air-Sea Flux	2013		

*… the measurement scenarios may be summarized as a **list of measurement/mission options**…*





Advanced Land Cover Change

Science Objective
Make continuous measurements of land cover and land usage globally

Mission Description
- One spacecraft in low Earth sun-synchronous orbit
- Determine land cover types, including wetlands
- Determine vegetation characteristics

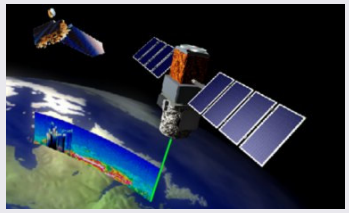
Measurement Strategy
- Provide landscape-scale, high-resolution, 3-dimensional mapping of the Earth's surface (vegetation and surface topography)
- Measure vegetation canopy height, vertical structure and land cover change, along with topographic change detection at sub-centimeter relative vertical accuracy
- Discriminate a wide variety of vegetation types
- Characterize habitats

Technology Requirements
- Waveform digitizers with integrated real-time pulse finding logic capable of supporting pulse rates exceeding 100 kHz
- Laser transmitters capable of 75 kHz rep-rate, ~ 5 nsec pulse widths, and 0.1 mJ pulse energy with wall plug efficiency on the order of 10%
- Laser beam deflection system capable of reliably and accurately producing a true image pattern with 100% of area illuminated on the ground at 75 kHz effective sampling rates with <1 arcsec pointing stability
- Accurate s/c positioning (< 5 cm radial) from GPS and highly accurate orientation knowledge (< 1 arcsec) using a combination of on-board star trackers and post-processed calibration
- ~300 W instrument average power during mapping phase, less during targeting phase.
- Mechanically and thermally stable optical bench mounted to platform
- Platform should be capable of 0-10 degree targeting
- This instrument will produce very high data rates

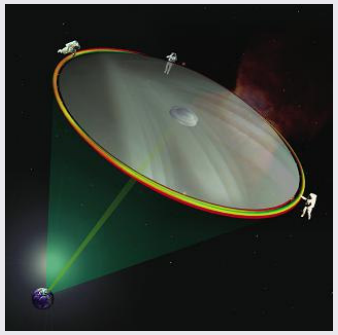
*… and a "**quad chart**" of summary information prepared for each measurement/mission option…*

Technology Priorities

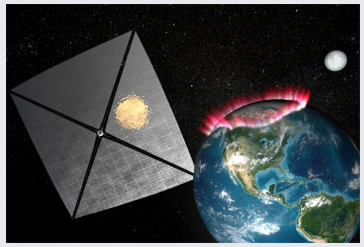
- **Active Remote Sensing Technologies** to enable atmospheric, cryospheric and earth surface measurements



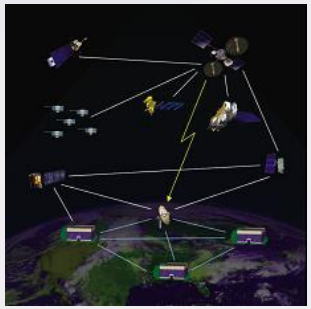
- **Large Deployables** to enable future weather, climate, and natural hazards measurements



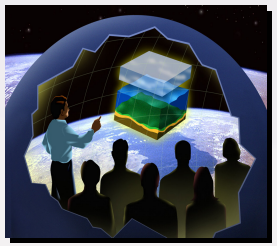
- **Platforms** to enable measurements from unique vantage points



- **Intelligent Distributed Systems** using advanced communication, on-board radiation-tolerant reprogrammable processors, autonomous operations and network control, data compression, high density storage



- **Information Knowledge Capture** through 3-D visualization, holographic memory and seamlessly linked models



Measuring Progress

Technology Advancement: Technology Readiness Levels
(TRL 1 = basic research; TRL 9 = flight qualified)

Infusion into missions, instruments, proposals, flight experiments

Training and education of next-generation researchers
(student involvement)

Broad participation

- Across types of organizations
- Across regions

Technology Investments (FY 05)

Instruments:	**83**
Info Systems:	**31**
Comp. Tech.:	**27**
Platforms:	**1**
Studies:	**1**
Total:	**143**

ESTO

JPL (33)
- Instruments 17
- Info Systems 6
- CT 9
- Platforms 1

GSFC (36)
- Instruments 23
- Info Systems 4
- CT 8
- Studies 1

LaRC (18)
- Instruments 17
- Info Systems 1

GRC (1)
- Info Systems 1

ARC (2)
- Info Systems 2

Federal Labs (7)
- Aerospace Corp. (Instruments - 1)
- Air Force Research Lab (Instruments - 1; Info Systems - 1)
- Lawrence Berkeley NL (CT - 1)
- NCAR (Info Systems - 2; CT - 1)

Large Corp. (8)
- Ball Aerospace (Instruments - 3)
- Draper Labs (Info Systems - 1)
- ITT Industries (Info Sys - 1; Instru. 1)
- Lockheed Martin (Info Sys - 1; Instru. 1)

Small Corp. (15)
- Aerodyne Research (Instru. - 1)
- ASRC Aerospace Corp. (Instru. - 1)
- AER Inc. (Info Systems - 1)
- Barr Associates, Inc (Instruments - 1)
- BBN Technologies (Info Systems - 1)
- GST (CT - 2)
- ISR Inc. (Info Systems - 2)
- Lite Cycles, Inc. (Instruments - 1)
- Polatomic (Instruments - 1)
- Q-Peak, Inc. (Instruments - 1)
- QorTek Inc (Instruments - 1)
- SES, Inc. (Instruments - 1)
- Spectrum Astro (Info Systems - 1)

Academia (23)
- Cal Institute of Tech (CT - 1)
- Carnegie Mellon (Info Systems - 1)
- George Mason U. (Info Systems - 1)
- Georgia Tech (Instruments - 1)
- Harvard Univ. (Instruments - 2)
- JHU-Applied Physics Lab (Instruments - 2)
- MIT (CT - 1)
- Ohio State Univ. (Instruments - 2)
- U. of Alaska (Info Systems - 1)
- U. of California, Los Angeles (CT - 1)
- U. of Colorado, Boulder (Instruments - 2)
- U. of Illinois at Urbana-Champaign (Info Systems - 1; CT - 1)
- U. of Maryland (CT - 1)
- U. of Michigan (Instruments - 2; CT - 1)
- U. of Oklahoma (Info Systems - 1)
- U. of Southern California/ISI (Info Systems - 1)

Results to Date for all of ESTO

A diverse research community

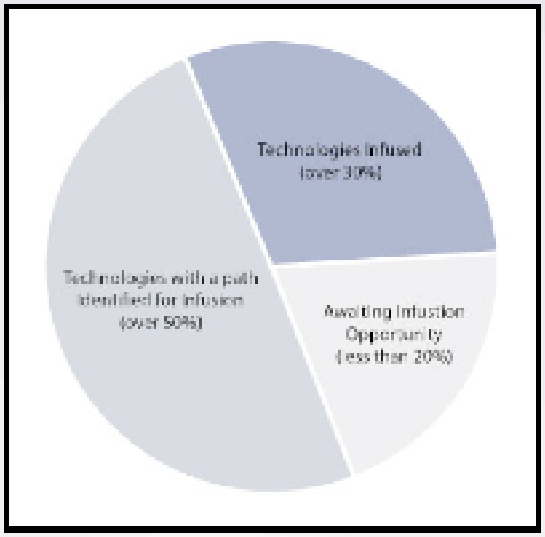
- Principal Investigators from almost 100 different organizations
- Participants located in 27 states

Regularly exceeds performance metrics set by NASA

- Over 70% of all activities advanced at least 1 TRL
- At least 1-2 new measurements enabled each year

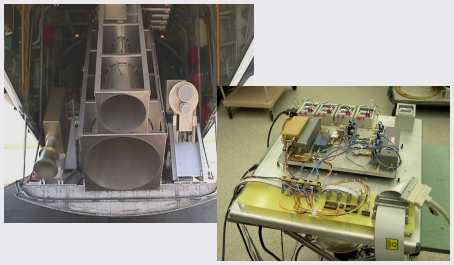
Inverts the traditional 80/20 rule-of-thumb for infusion success

- 30% already infused into missions/campaigns/ESSP proposals
- Over 50% of additional projects have path identified for infusion
- Technologies selected for infusion by Principal Investigators and mission managers, *not* ESTO

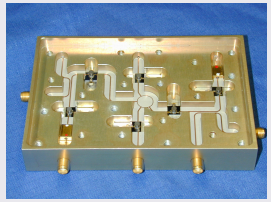


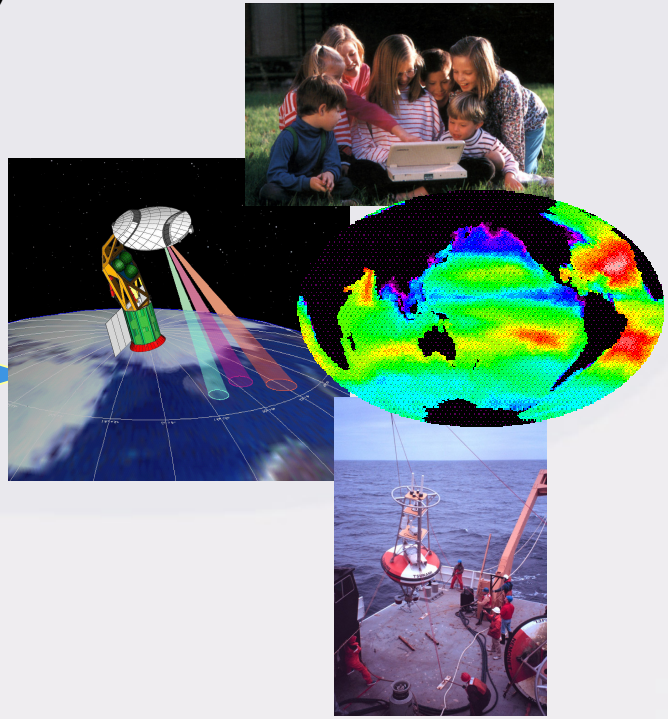
ESTO Infusion Into A Flight Mission

IIP-2 Bill Wilson
Ultra-Stable Radiometers



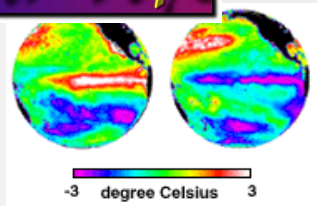
ATI-99 Controlled-Correlation Calibration Subsystem (CCCS)
Ed Kim & Jeff Piepmeier



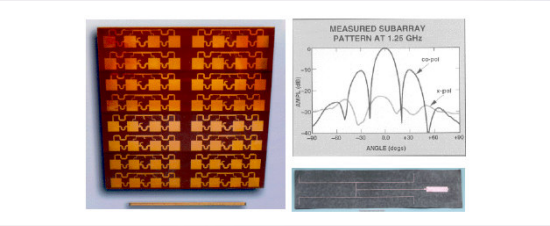


Aquarius ESSP

ParVox



CT In-House Team-Peggy Li
Parallel Volume Rendering



ACT - Simon Yueh
Lightweight Feed For Future Salinity Missions

Aquarius
Chet Koblinsky, PI
Yi Chao, Project Scientist

Example Infusions: Missions

Six Instrument Incubator projects related to ESSP-3 proposals

Ultra Stable Microwave Radiometer -->

AQUARIUS (sea surface salinity)

Low Mass, Low Power Radar (OSIRIS) -->

HYDROS (soil moisture)

Delay Doppler-Phase Radar Altimeter (D2P)

Gas and Aerosol Monitoring Sensorcraft (GAMS)

Self-Calibrating H2O and O3 Near Earth Remote Sensor (SCH_2OO_3NERS) - an integrated UV-IR spectrograph and imager

Wide Field Imaging Spectrometer (WFIS)

CALIPSO: Portable Diode Laser Array Test Facility
used to evaluate/validate the CALIPSO flight laser

OSTM: Wide Swath Altimeter
planned for Ocean Surface Topography Mission

Example Infusions: Field Campaigns/ Flight Validations

The Second Generation Precipitation Radar (PR-2) and High-Altitude MMIC Sounding Radiometer (HAMSR)
flew during CAMEX-4

PANTHER (Peroxyacetyl Nitrate and other Trace Hydrohalocarbons ExpeRiment)
flew during SOLVE II

The Delay Doppler Phase (D2P) radar altimeter
flew as part of the Laser and Radar Altimeter campaign
participated in CRYOVEX

The Integrated Cavity Output Spectroscopy (ICOS) instrument (a laser based instrument for measuring trace species, such as water vapor isotopes)
used as part of CR-AVE (Costa Rica - Aura Validation Experiment)
flown on a WB-57

Fabry-Perot Interferometer for Column Carbon Dioxide Technology Development
aircraft flight validation on DC-8

Lightweight Rainfall Radiometer instrument
aircraft flight validation on DC-8

Unique Far-Infrared Spectroscopy Instrument (FIRST)
balloon flight

Radio Frequency Interference (RFI) mitigation technology
airborne tests (funded by IPO)

Example Infusions: ACT, AIST, CT

Components

High Speed A/D converters selected for GSFC Lidar Observatory for Winds Instrument

Flight Ethernet Switch selected by Earth Science for GPM and JWST

Information Technology

- Advanced SSR SchEduling Tool (ASSET) reduced the manually intensive activity of planning solid state recorder (SSR) buffer playback for the Terra spacecraft: what was once a 20 work-hour task now takes only one hour
- Space LAN Technology (based on FPGAs) and industry Ethernet standards) selected by Earth Science for GPM and JWST
- Ultra low-power and radiation mitigation tools used by Cross-Track Infrared Sounder (CRIS) on NPP and NPOESS, and licensed by industry (Xilinx, SEAKR, General Dynamics, ITT Industries,…)

Computing Technology

- RIVA visualization software used to display earthquake modeling and observation results.
- PYRAMID parallel mesh library (tools for solution of large science applications using finite element analysis techniques) now available via Open Channel Foundation (OCF)
- The Image Access Layer software (used in association with the On Earth WMS server) is now serving 5-10 million maps of Earth data from NASA instruments every day

Examples: SBIR

Current Awards

- Very Low Power, Highly Integrated Multichannel Scaler: Modify the Advanced Photon Counting System (APCS) of Cloud Physics Lidar (CPL) and the Goddard Lidar Observatory for Winds (GLOW) lidar for use in a Proteus-based platform.

- Full Spectropolarimetric validation and performance enhancements for the Hyperspectral Polarimeter for Aerosol Retrievals (HySPAR): Validate uplooking HySPAR aerosol retrievals against co-located AERONET sensor

- Compact Modular Airborne DIAL Sensor for Ozone Measurements: Demonstrate two wavelength O_3 DIAL operating in 285 – 305 nm region

- High-Power, Single-Frequency UV Laser Transmitter: Design, package, and build laser power supply for Direct Detection Doppler Lidar (D^3L) flight at 60,000 feet.

- 349-nm Source for Direct Detection Measurement of Winds: Continue development of the 349-nm single-frequency UV transmitter with emphasis on frequency stability to meet the Doppler lidar requirements

- ***Upcoming Solicitation***
- SBIR 2006 solicitation will address all six focus areas. Science areas these topics cover are: Cloud & aerosol, wind profile, land topography, ozone, water vapor, carbon dioxide, etc.

- The instrument technology topics are:
    - 1) Lidar Remote Sensing
    - 2) Active Microwave
    - 3) Passive Optics
    - 4) Passive Microwave
    - 5) Earth In Situ Sensors

There are also topics to cover platform technologies and data management and visualization

What Seems to Work

Setting Directions

- ***Clear connection to science needs***
- *specific areas of emphasis*

Soliciting Ideas

- ***competitive, peer-reviewed proposals***
- *overlapping of award periods*
- *funding at requested levels*

Guiding Progress

- ***distributed management***
- *periodic independent reviews*
- *automated reporting*
- *metrics*

Encouraging Utilization

- ***collaborations***

Summary

The Earth Science Technology Office (ESTO):

- *Performs strategic technology planning for Earth Science*
- *Implements focused technology development for the Earth Science Division*
- *Coordinates with other NASA Mission Directorates and participating Agencies*

The technology strategy relies upon:

- *An open, science-driven competition for awards*
- *Partnering among industry, academic, and NASA center participants*

Have made significant progress:

- *Facilitate rapid development of new, less costly, and less resource intensive scientific capabilities for Earth science.*
- *Pursue and infuse emerging technologies to enable new measurements.*
- *Reduce instrument development time and cost for future science missions.*

Technology Enables Our Future