

# ESTO Investments in the NRC Decadal Survey Tier 2/Tier 3

AIAA SPACE 2010 - Future NASA Earth Science Missions and Enabling Activities



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NASA Earth Science Technology Office

# Introduction

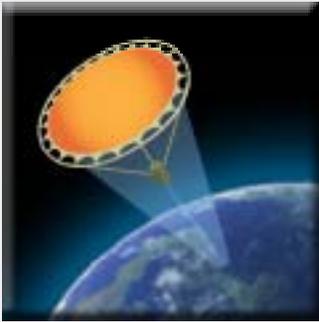
- The Earth Science Technology Office (ESTO) is a *science-driven, competed, actively managed and dynamically communicated technology program*
  - Competitive, peer-reviewed proposals enable selection of best-of-class technology investments
  - Risk is retired before major dollars are invested: a cost-effective approach to technology development and validation
- Upon publication of the Earth Science Decadal Survey in 2007, ESTO investments already supported all 18 of the recommended mission concepts. Since then, ESTO has further focused its Instrument, Component and Information Technology solicitations on Decadal Survey measurements

***This has resulted in the award of 58 technology projects representing an investment of over \$105M directly related to the Earth Science Decadal Survey.***



# ESTO Programs

## Observation Technologies:



### **Instrument Incubator Program (IIP)**

provides robust new instruments and measurement techniques

### **Advanced Component Technologies (ACT)**

provides development of critical component and subsystem technologies for instruments and platforms.

## Information Technologies:



### **Advanced Information Systems Technology (AIST)**

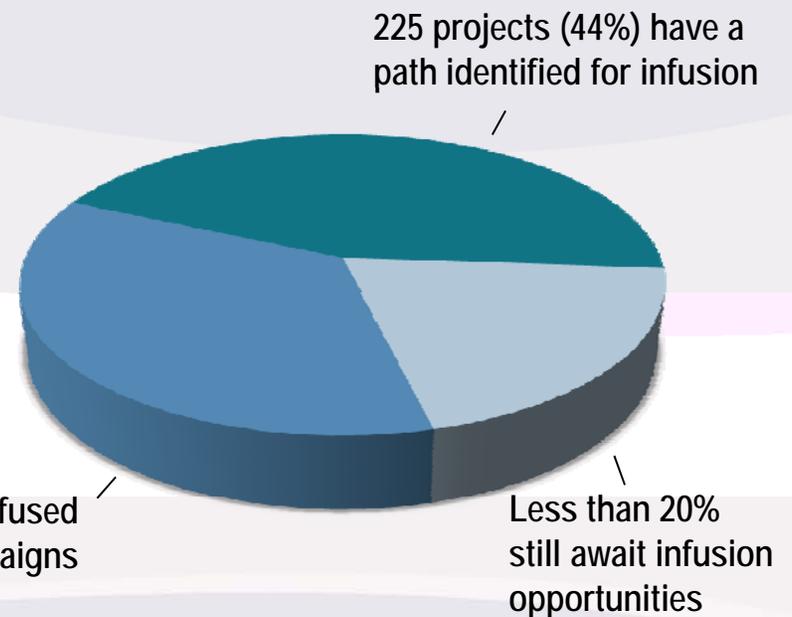
provides innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products and knowledge



# Progress to Date

Over the past eleven years, ESTO has issued fourteen competitive research solicitations, and funded and managed development on a wide range of technologies:

- 507 Projects Completed to Date (through FY09)
  - Principal Investigators from 98 different organizations located in 33 states and the District of Columbia:
    - 44 academic institutions
    - 39 companies
    - 10 national laboratories
    - 5 NASA centers
  - 369 projects (73%) advanced at least 1 technology readiness level (TRL)
  - A steady record of infusion success →



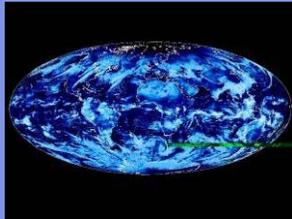


# Technology Investments For the Decadal Survey



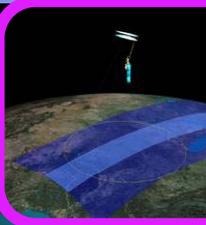
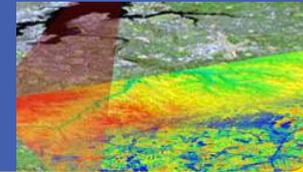
# NASA Earth Science Decadal Survey Missions

Climate Absolute  
Radiance and  
Refractivity  
Observatory  
(**CLARREO**)



Hyperspectral  
Infrared Imager  
(**HYSPIRI**)

LIDAR Surface  
Topography  
(**LIST**)



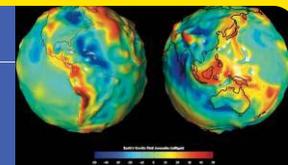
Soil Moisture Active  
Passive (**SMAP**)

Active Sensing of  
CO2 Emissions  
(**ASCENDS**)

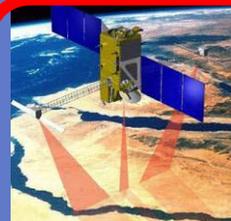
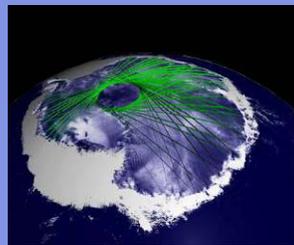


Precipitation and  
All-Weather  
Temperature and  
Humidity (**PATH**)

Gravity Recovery  
and Climate  
Experiment - II  
(**GRACE - II**)



Ice, Cloud, and  
land Elevation  
Satellite II  
(**ICESat-II**)



Surface Water  
and Ocean  
Topography  
(**SWOT**)



Snow and Cold  
Land Processes  
(**SCLP**)

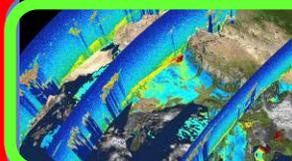
Geostationary  
Coastal and Air  
Pollution Events  
(**GEO-CAPE**)



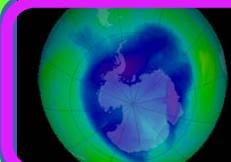
Three-Dimensional  
Winds from Space  
Lidar (**3D-Winds**)



Deformation,  
Ecosystem  
Structure and  
Dynamics of  
Ice (**DESDynI**)



Aerosol - Cloud  
Ecosystems  
(**ACE**)



Global Atmospheric  
Composition Mission  
(**GACM**)

Lasers

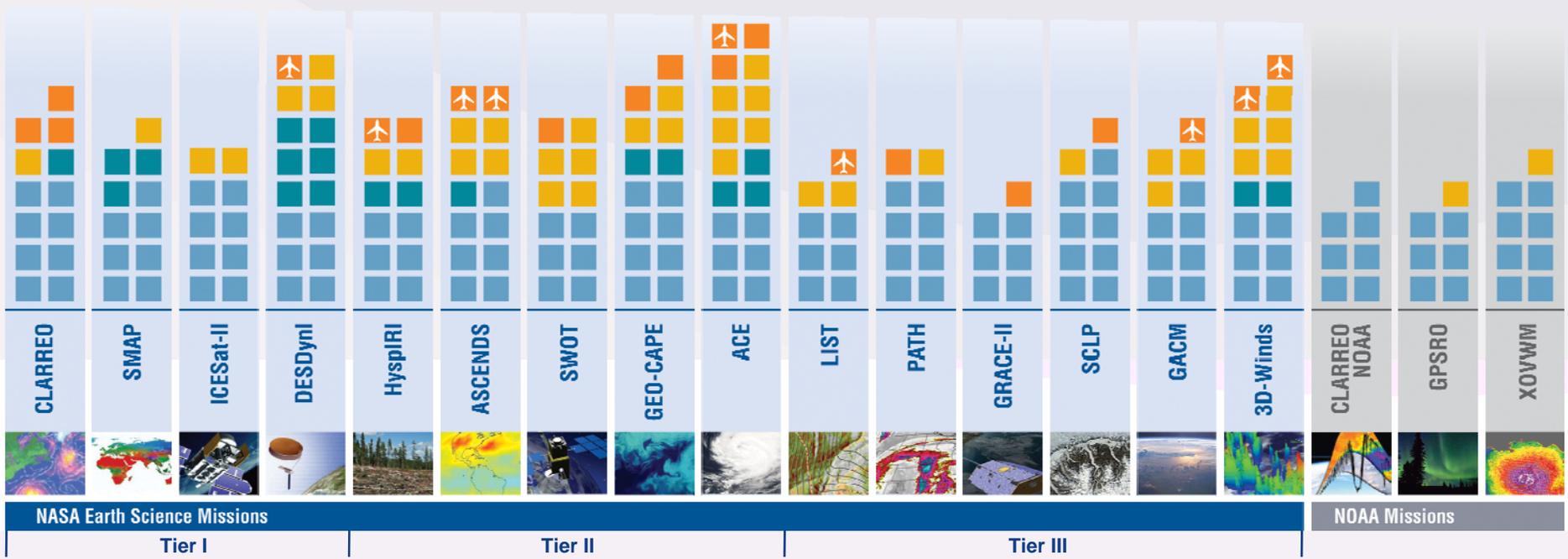
Radars

Passive Optics

Passive Microwave

# Current ESTO Investments: Enabling the Decadal Survey

-  Instrument Technology Investments  
*(Instrument Incubator Program Solicitation)*
  -  Instrument Investments that include planned airborne testing  
*(2007 Instrument Incubator Program Solicitation)*
  -  Component Technology Investments  
*(2008 Advanced Component Technologies Program Solicitation)*
  -  Information Systems Technology Investments with Direct Applicability  
*(2008 Advanced Information System Technologies Program Solicitation)*
  -  Information Systems Technology Investments with Secondary Applicability  
*(2008 Advanced Information System Technologies Program Solicitation)*
- (Note that individual Component and Information Systems Technologies often apply to more than one mission.)*



NASA Earth Science Missions

NOAA Missions

Tier I

Tier II

Tier III



# Current ESTO Investments: Enabling ASCENDS

CO<sub>2</sub> Laser Sounder for ASCENDS Mission: Technology Development and Airborne Demonstration  
- *James Abshire, NASA GSFC*

Laser Remote Sensing of O<sub>2</sub> for Determination of CO<sub>2</sub> Mixing Ratio and Sensing of Climate Species  
- *Jeremy Dobler, ITT Geospatial Systems*

Ultra-Sensitive Near-Infrared Optical Receiver Using Avalanche Photodiodes (APDs)  
- *Michael Krainak, NASA GSFC*

Geostatistical Data Fusion for Remote Sensing Applications  
- *Amy Braverman, JPL*

Technology Infusion for the Real Time Mission Monitor  
- *Michael Goodman, NASA MSFC*

Sensor Web 3G to Provide Cost-Effective Customized Data Products for Decadal Missions  
- *Dan Mandl, NASA GSFC*

Instrument Simulator Suite for Atmospheric Remote Sensing (ISSARS)  
- *Simone Tanelli, JPL*

Novel Laser Approach for Precision CO<sub>2</sub> Column Measurement  
- *William S. Heaps, NASA GSFC*

A Low Cost, Ultra-Lightweight, Optically Fast f/1.6, Corrugated Mirror Telescope Array for Lida and Passive Earth Science  
- *Robert Egerman, ITT Space Systems*

CO<sub>2</sub> Laser Absorption Spectroscopy Sensor (CLASS) Instrument Technology Maturation for the ASCENDS Mission  
- *Mark Phillips, Lockheed Martin Coherent Technologies*

Autonomous, On-Board Processing for Sensor Systems  
- *Matthew French, University of Southern California (USC)/Information Sciences Institution (ISI)*

Real-Time and Store-and-Forward Delivery of Unmanned Airborne Vehicle Sensor Data  
- *Will Ivancic, NASA GRC*

Anomaly Detection and Analysis Framework for Terrestrial Observation and Prediction System (TOPS)  
- *Ramakrishna Nemani, NASA ARC*

On-Board Processing to Optimize Imaging System Data Processing and Instrument Design  
- *Paula Pingree, JPL*



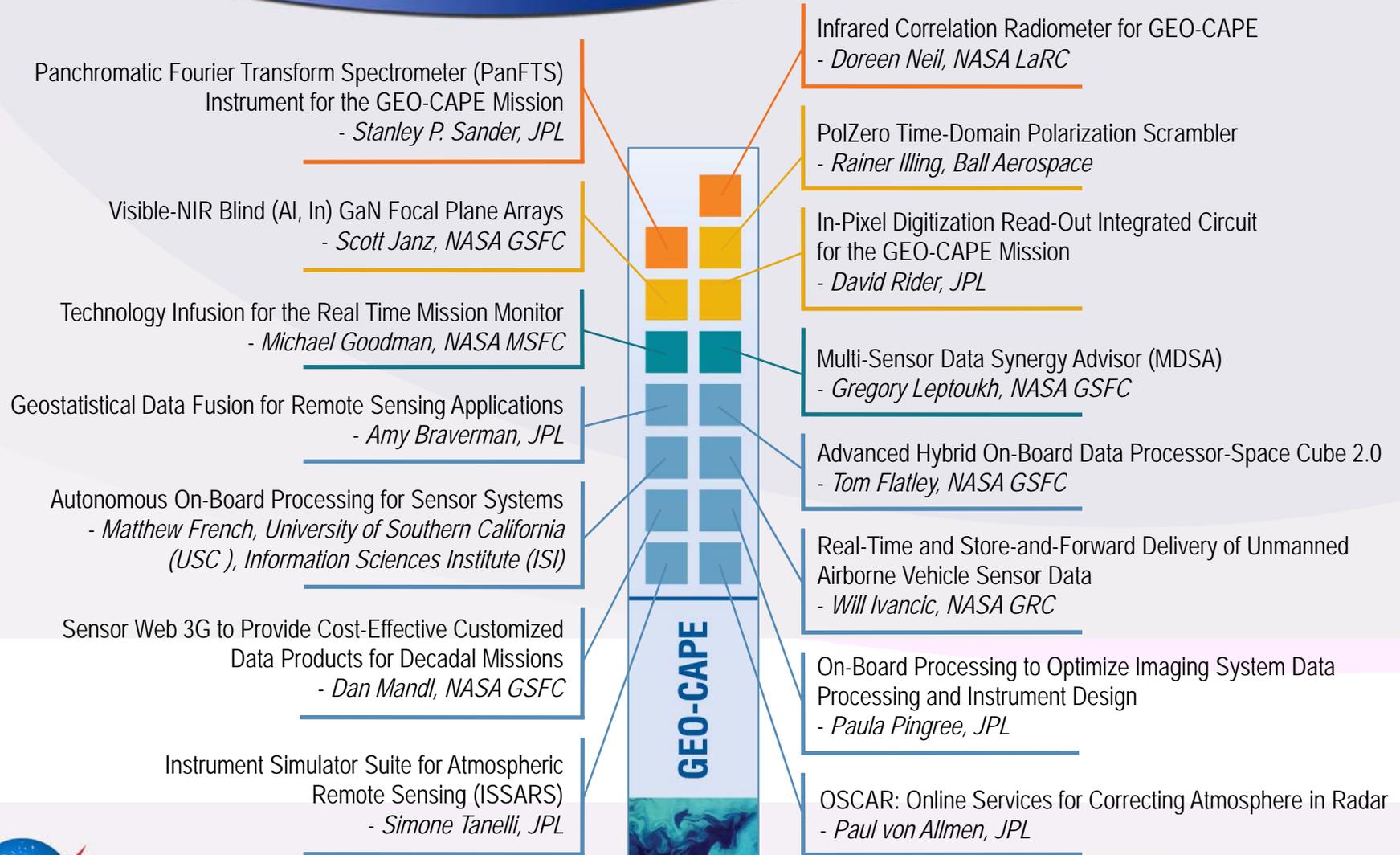
 Instruments

 Components

 Information Systems



# Current ESTO Investments: Enabling GEO-CAPE



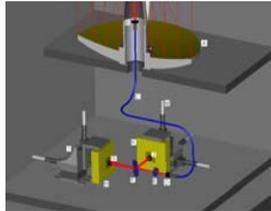
■ Instruments     
 ■ Components     
 ■ ■ Information Systems

# ESTO Decadal Survey Technologies: Column CO<sub>2</sub>

**Laser Absorption Spectrometer for Profiling of CO<sub>2</sub>**  
IIP-01: Menzies



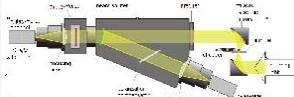
**Development of 2μ Differential Absorption Lidar for CO<sub>2</sub>**; IIP-04: Ismail



**CO<sub>2</sub> Laser Sounder for ASCENDS Mission**  
IIP-07: Abshire



**Novel laser Approach for Precision Column CO<sub>2</sub> Measurement**  
IIP-07: Heaps



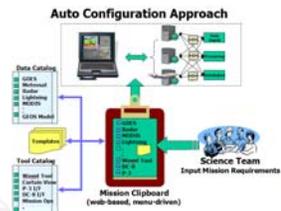
**Laser Sensing of O<sub>2</sub> for Determination of CO<sub>2</sub> Mixing Ratios**  
ACT-08: Dobbler



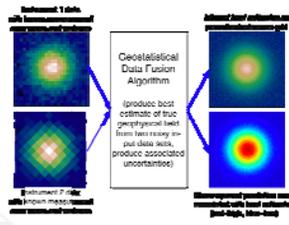
## ASCENDS Mission



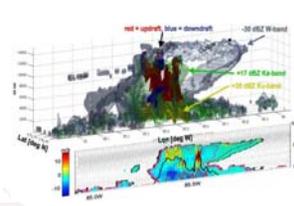
**Real time Monitor for Science Validation**  
AIST-08: Goodman



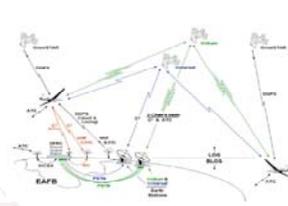
**Data Fusion for Remote Sensing**  
AIST-08: Braverman



**Instr. Simulator for Remote Sensing**  
AIST-08: Tanelli

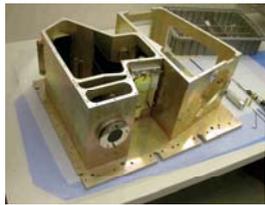


**Real-time Store & Forward Delivery of UAV Sensor Data**  
AIST-08: Ivancic

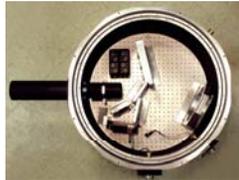


# ESTO Decadal Survey Technologies

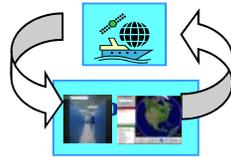
Spaceborne Infrared Atmosphere sounder  
IIP-03: Thomas Kampe



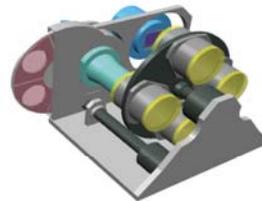
Optics hardware for Tropospheric Infrared Mapping Spectrometer (TIMS)  
IIP-04: John Kumer



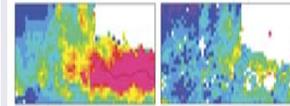
Integrated asset Sensor Web for Ocean Observation  
AIST-05: Payman Arabshahi



Infrared Correlation Radiometer fabrication and characterization  
IIP-07: Doreen Neil



Multi-Sensor Data Synergy Advisor (MDSA) for provenance and utility of data  
AIST-08: Greg Leptoukh



## GEO-CAPE Mission

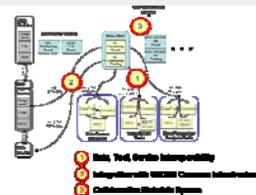
Tier II Mission



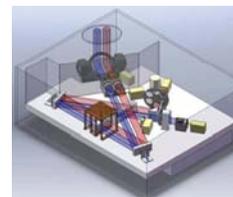
Hyperspectral UV/VIS/NIR instrumentation  
IIP-03: Scott Janz



Sensor-Web Operations Explorer (SOX) adaptive measurement strategies  
AIST-05: Meemong Lee



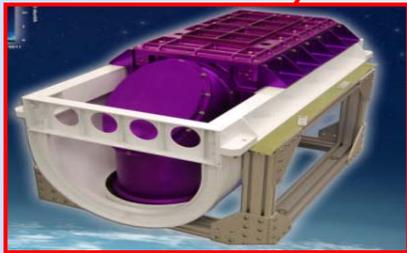
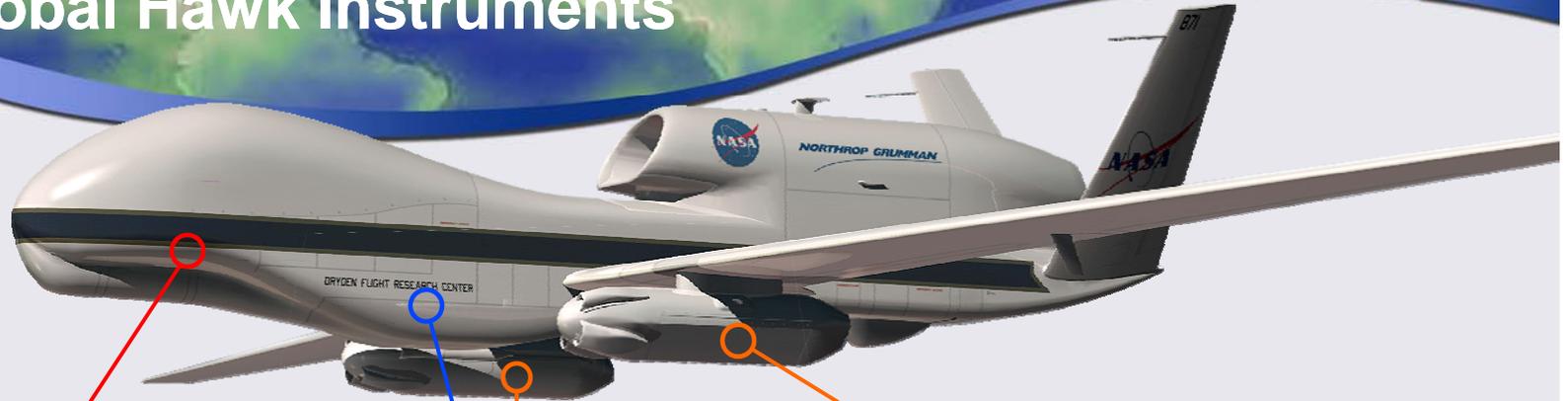
Sensor Analysis Model Interoperability Technology Suite  
AIST-05: Stefan Falke



Panchromatic Fourier Transform Spectrometer (PanFTS)  
IIP-07: Stanley Sander



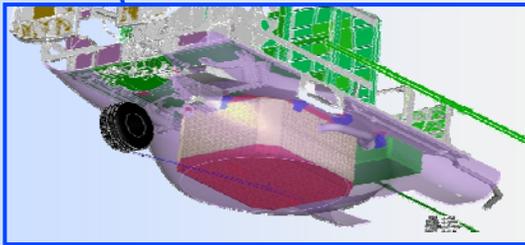
# Stimulus-Funded Technology Development Global Hawk Instruments



## Land, Vegetation, & Ice Sensor (LVIS)

This task will integrate the LVIS capability onto the Global Hawk and provide an automated, reliable package for high altitude measurements.

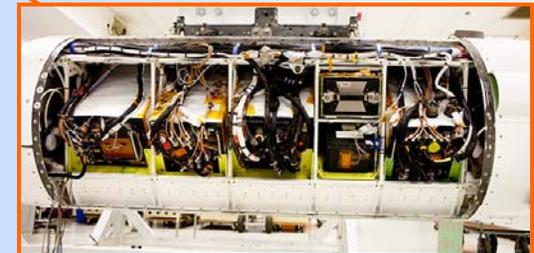
\$1.6M



## Global Ozone Lidar Demonstrator (GOLD)

GOLD will enable, for the first time, Ozone LIDAR measurements from a high-altitude aircraft that support global atmospheric composition and climate change investigations.

\$1.5M



## UAVSAR

The Uninhabited Aerial Vehicle – Synthetic Aperture Radar (UAVSAR) project will install two existing UAVSAR pods on a UAV for the first time. On Global Hawk, UAVSAR will generate precise topographic maps and single-pass polarimetric interferograms of ice and vegetation.

\$4.4M

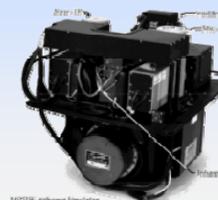


# Stimulus-Funded Development: Facility Class Instruments

## Enhanced MODIS Airborne Simulator (eMAS)

This task will replace major subsystems on the MAS to extend its service life, increase reliability and improve data. The task will also increase spectral coverage, resolution, and calibration accuracy. The upgraded MAS will fly on the NASA ER-2.

\$3.0M



## Portable Remote Imaging Spectrometer (PRISM)

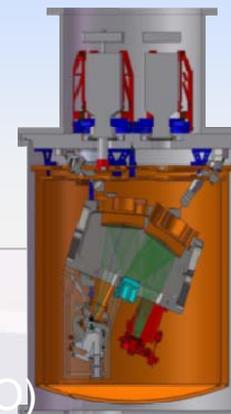
PRISM will be a UV-NIR (350 to 1050 nm) spectrometer capable of airborne measurements from a variety of platforms. PRISM will be particularly optimized for coastal ocean measurements, with unprecedented sensitivity across the large range of coastal reflectance. PRISM will be test flown on the DHC-6 Twin Otter.

\$2.5M

## Next Generation Airborne Visible InfraRed Imaging Spectrometer (AVIRISng)

This next generation AVIRIS-class imaging spectrometer will help continue measurements of upwelling spectral radiance and support the HypSPIRI Decadal Survey mission. Several new subsystems will help AVIRISng to achieve a factor of two improvement in SNR and spectral resolution relative to AVIRIS, as well as significant reductions in mass and volume for future flights on the DHC-6 Twin Otter.

\$5M





# Conclusions

Over the past decade, many ESTO investments have supported key Earth Science measurements.

Several current investments are specifically targeted toward Decadal Survey mission concepts.

ESTO will continue to support this discipline of Earth science with new investments and evolving state-of-the-art alternatives.





**Technology Enables our Future**



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Backup Slides

# Instrument Incubator Program 2007 Awards vs. Decadal Survey Missions

<b>2007 Instrument Incubator Awards versus Decadal Survey Missions</b>	CLARREO	SMAP	ICESat-II	DESDynI	HypIRI	ASCENDS	SWOT	GEO-CAPE	ACE	LIST	PATH	GRACE-II	SCLIP	GACM	3D-Winds	CLARREO-NOAA	GPSRO	XOVM
Abshire/GSFC - column CO <sub>2</sub> , lidar						✱												
Diner/JPL - aerosols and clouds, polarimetric imager									✱									
Durden/JPL - clouds and precipitation, profiling radar																		
Folkner/JPL - time-varying gravity, laser frequency stabilization																		
Fu/JPL - surface water and ocean topography, interferometric SAR																		
Grund/Ball - tropospheric winds, Doppler lidar																		✱
Hackwell/Aerospace - mineral and gas, TIR spectrometer					✱													
Heaps/GSFC - column CO <sub>2</sub> , lidar						✱												
Hook/JPL - mineral/water resources, hyperspectral TIR spectrometer																		
Kavaya/LaRC - tropospheric winds, Doppler lidar																		✱
Kopp/CU - radiation balance, UV-SWIR hyperspectral imager																		
Lambrigtsen/JPL - T, water vapor, precipitation; microwave sounder																		
McClain/GSFC - ocean color, UV-SWIR radiometer																		
Mlynczak/LaRC - radiation balance far-IR spectrometer																		
Nell/LaRC - boundary laser CO, gas correlation radiometer																		
Papapolymerou/GT - snow-water equivalent, X-band phased array																		
Revercomb/UWM - radiation balance, SI-traceable IR calibration																		
Sander/JPL - air pollution and coastal imaging, panchromatic FTS																		
Stek/JPL - atmospheric composition, microwave limb sounder																		✱
Welmer/Ball - vegetation canopy, steerable lidar					✱													
Yu/GSFC - topography and vegetation structure, swath-mapping lidar										✱								



- IIP-07 Award Linkage
- ✱ IIP-07 Award Linkage with Airborne Testing Planned

# Advanced Component Technology Program 2008 Awards vs. Decadal Survey Missions

2008 Advanced Component Technology Awards versus Decadal Survey Mission	CLARREO	SMAP	ICESat-II	DESDymI	HypIRI	ASCENDS	SWOT	GEO-CAPE	ACE	LIST	PATH	GRACE-II	SCLP	GACM	3D-WINDS	CLARREO-NOAA	GPSRO	XOVWMI
Dobbs/ITT - corrugated mirror telescope array for lidar			■	■		■			■	■				■	■			
Fang/JPL - large deployable reflector for Ka- and W-band									■	■								
Hoffman/JPL - thermal packaging for RF hybrids, radar				■			■							■				
Illing/Ball - polarization scrambler, spectroscopy					■			■	■									
Janz/GSFC - visible NIR blind GaN focal plane array, hyperspectral								■										
Krainak/GSFC - NIR optical receiver, lidar			■	■		■			■	■					■			
Marx/GSFC - hybrid doppler wind lidar transceiver															■			
McGill/GSFC - detector technology for cloud aerosol lidar									■						■			
Meehan/JPL - RF ASIC for digital beamforming, GNSS															■		■	
Mlynczak/LaRC - FIR detectors for Earth radiation	■																	
Phillips/LockMart - CO2 laser absorption spectroscopy						■												
Reising/Colo. St. Univ.- radiometer for wet-tropospheric correction							■											
Rider/JPL - analog to digital converter from UV to mid-IR					■			■	■					■				
Siqueira/Univ. Mass. - low power, high BW receiver, Ka-band							■											
Taylor/Composite Tech. Dev. - large aperture, deployable reflector		■					■				■		■					■
Thomson/JPL - deployable Ka-band reflect array							■											

■ ACT-08 Award Linkage



# Advanced Information Systems Technology 2008 Awards vs. Decadal Survey Missions

2008 Advanced Information Systems Technology Awards versus Decadal Survey Missions	CLARREO	SMAP	ICESat-II	DISDYM	HYPER	ASCENDS	SWOT	GEO-CAPRE	ACE	LIST	PATH	GRACE-II	SCLP	GAUGE	3D-WINDS	CLARREO-NOAA	OPSWC	20VWIS	Broad App.
BochWarpp, UIUC - Solid Earth - Data fusion				■															
Barberan/JPL, Berkeley - Data fusion	■					■													
Donnellan/JPL - Solid Earth - Cloud computing				■															
Hildebrand/JPL - Broad app. - On-board data/signal processing										■									
Fornari/UCR/UMI - Broad app. - On-board data & signal processing				■	■														
Goodman/NSF/JPL - Climate - Data manipulation								■											
Hansen/NSF - Atm. cons. - Sensor web evaluation																			■
Lautman/NSF/JPL - Atm. cons. - On-board								■											
Leu/JPL - Solid Earth - On-board data & signal processing				■															
Mandrus/JPL - Carbonace - Data manipulation					■														
Maschhoff/UMI, Wash - Water resources - Mission simulation & design		■																	
Naranjo/NSF - Carbonace - Mission management		■																	
Peters-Lidard/NSF/JPL - Water resources - Algorithms & modeling		■																	
Pingree/JPL - Climate - On-board data & signal processing									■										
Rosen/JPL - Climate - Algorithms & modeling				■															
Schneider/UMI Florida - Weather - Data manipulation															■				
Seabloom/NSF/JPL - Climate - Mission management												■							
Shen/NSF - Weather - High-performance computing	■																		
Tanelli/JPL - Climate - Mission simulation & design									■										
Van Almen/JPL - Solid Earth - Algorithms & modeling				■															



■ AIST-08 Award Primary Linkage  
 □ AIST-08 Award Secondary Linkage