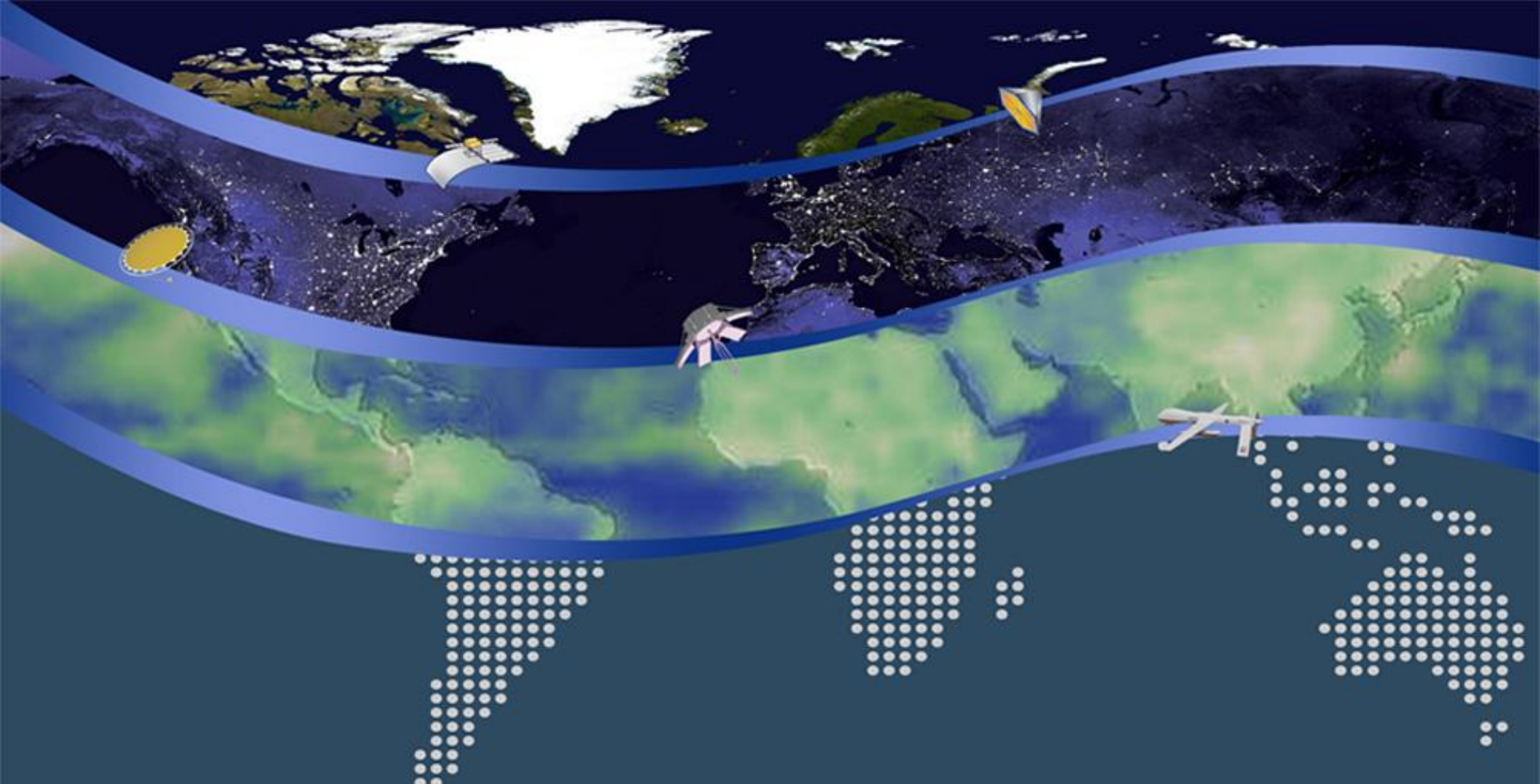


Geo-CAPE Technology Investment Overview

September, 2009

Karen Moe
NASA Earth Science Technology Office

Technology Investments / Risk Mitigation

- Earth Science Technology Overview
- Geo-CAPE Technology Portfolio
- Key Technical Challenges from the Science Data Systems in the Decadal Survey Era Workshop (June 2009)
- NASA ROSES Technology Opportunities for Data Systems

NASA Earth Science Technology

- Advances in Earth science are often enabled by advances in technology
- In many cases, fundamentally new tools and techniques are needed before a measurement can be made or significantly improved
- NASA's Earth Science organization places a high priority on developing new technologies to meet present and future scientific challenges
- The Earth Science Technology Office (ESTO) was formed to address these technology challenges

Approach to Technology Development

Science driven, *competed*, *actively managed*, *dynamically communicated*

Competitive, peer-reviewed proposals enable selection of best-of-class technology investments

Risks are retired before major dollars are invested: a *cost-effective approach* to technology development and validation

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: science campaigns, instruments, ground systems and missions
  - infusion is by competitive selection by science investigators or mission managers, not the technology program

Technology Product Lines

Advanced Component Technology (ACT) Program - development of component and subsystem technologies for instruments and platforms

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

Advanced Information Systems Technologies (AIST) - 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.

GEO-CAPE

Technology Investments

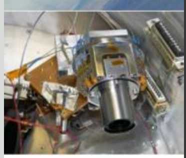
Earth Science Technology Office

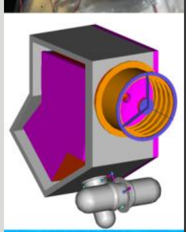
ESTO Technology Development in Support of

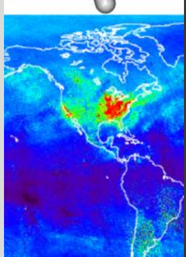
Sentinel Multispectral Atmospheric Composition Measurements

Infrared

Update 6-11-08







Missions Supported: ACE, GACM , GEO-CAPE

Measurement Approach

An infrared spectrometer that accurately measures ozone from LEO and GEO

Earth Science Technology Office (ESTO) Investments

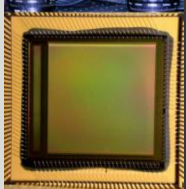
- Completed 2nd instrument technology advancement of SIRAS-G, a WFOV, multi-grating/channel IR spectral imager concept designed for LEO or GEO. Lab demonstrated fully functional imaging MWIR spectrometer (3.35-4.8 micron) operating at cryogenic temperatures. (T. Kampe- IIP2 & IIP3)
- Developing TIMS, a miniaturized InfraRed Grating Mapping Spectrometer for space-based global mapping of carbon monoxide (CO) profiles in the troposphere (Kumer – IIP4)
- Development and demonstration of multi-disciplinary frameworks and observation simulations of an adaptive measurement strategy on a sensor web for rapid air quality assessment. (Lee/JPL - AIST05)
- Development of the Adaptive Sky Cloud Science Sensor Web simulation for global atmospheric cloud monitoring. (Burl/JPL - AIST05)
- Developed and ground-demonstrated a multispectral imaging airborne Fabry-Perot interferometer (FPI) system designed for geostationary observations. The concept observes a narrow interval within the 9.6 micron ozone infrared band with a spectral resolution ~ 0.07 cm-1, and also has applicability toward measurement of other trace species (A. Larar-IIP1)
- Characterization of lab prototype of the SWIR (2.3 um) subsystem of an infrared gas filter correlation radiometer for GEO CO measurements (Neil/LaRC-IIP07)
- Development and demonstration of high-speed, high-dynamic range CMOS hybrid focal plane arrays (FPAs), and parallel, co-aligned optical trains for UV/V/NIR, and mid-IR bands of (PanFTS) instrument (Sander/JPL-IIP07)

Future Technology Investment Areas

- Further development of SIRAS-G subsystem technologies (focal plane arrays, scan mirror, and calibration subsystems) prior to integration into prototype
- Complete 4-channel SIRAS–G system EM and fully characterize the performance of the instrument in airborne demonstrations SIRAS-G instrument prototype
- SIRAS-G IR Grating Spectrometer EM build and field demonstration
- TIMS field demonstration and airborne demonstration
- Modify and demonstrate TIMS components operation @ 9.6 and 3.57 mm, and in the NO2 and aerosol sensing regions of the visible
- Demonstrate a 2-channel TIMS
- Build an expanded TIMS EM utilizing multi-channel mapping spectrometers with measurement capabilities @ 9.6 um (tropospheric O_3 profiles), @ 3.57 um (near surface O_3 and HCHO), @ 2.3 and 4.65 um (CO) and in VIS regions suitable for NO_2 and aerosol
- Knowledge management (capture, representation, categorization and use of Earth science knowledge)
- Goal-directed science data management (e.g., automatically task sensor web components to reconfigure for on-demand event or model predictions)
- Fabry-Perot Interferometer EM build and field demonstration (i.e., mountain top and/or aircraft deployment); system enhancements/optimizations to improve radiometric, spatial, and spectral fidelity; continued laboratory characterization testing
- Detectors, SCS optics, image stabilization and knowledge system
- CO Detector - Radiation hard high performance electronics (ADC, FPGAs,solid state storage, etc) – Enhancing
- Bring CMOS detectors to TRL 5/6 for TROPI
- CO Detector - Light weight thermal control and structural materials – Enhancing

ESTO Technology Development in Support of

Global Ocean Carbon, Ecosystems, & Coastal Process Measurements



Update 6-11-08

Missions Supported: ACE, GEO-CAPE

Measurement Approach

- LEO UV-VIS spectrometer
- GEO high resolution hyperspectral imager

Earth Science Technology Office (ESTO) Investments

- Developed and partially demonstrated a multi-spectral imager for oceanographic imaging applications. The concept is based on implementing a surface plasmon tunable filter (SPTF) with a CMOS imager (B. Pain - ATIP-99)
- Demonstrated a full-scale breadboard dual spectrograph with sensitivities in the UV/VIS (310-481 nm) and the VIS/NIR (500-900 nm) for geostationary observations (S. Janz - IIP-02)
- Development of a tele-supervised adaptive ocean sensor fleet for improved in-situ study of harmful algal blooms, coastal pollutants, oil spills, and hurricane factors (Dolan - AIST-05)
- Development and installation of a prototype gateway between the Digital Oceanographic Data System (DODS) and Web Mapping Servers (WMS) to enable access to Earth science data (P. Cornillon - AIST-QRS-01)
- Development and demonstration of a low cost, reusable, autonomous ocean surface platform to collect ocean-atmosphere data and distribute it in real-time as part of a sensor web (T. Ames - AIST-QRS-01)
- Development and implementation of on-board data reduction and cloud detection methodologies to reduce communication bandwidth requirements (J. LeMoigne - AIST-02)
- Development of a spatiotemporal data mining system for tracking and modeling ocean object movement (Y. Cai - AIST-QRS-04)
- Design and development of an integrated satellite, underwater and ocean surface sensor network for ocean observation and modeling (P. Arabshahi – AIST-05)
- Development and integration of model-based control tools for mobile and stationary sensors in the New York Harbor Observation and Prediction System sensor web (A. Talukder - AIST-QRS-06)

Future Technology Investment Areas

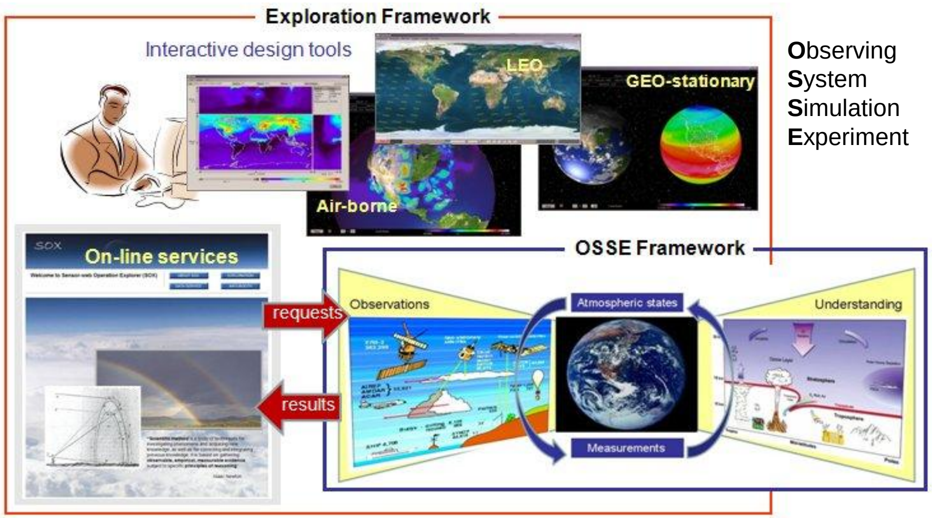
- Develop an SPTF & low-power high sensitivity broadband CMOS imager with accurate wavelength control over entire spectral region.
- Integrate and test multi-spectral device with appropriate optics
- Optimize stray light performance and detector performance of GeoSpec,
- investigate long term stability/performance
- GeoSpec aircraft demo will require some repackaging
- Autonomous in-situ data collection and management, especially for GEO applications
- Image Stabilization and knowledge system
- Aspheric Single Crystal Silicon fabrication and test to advance to TRL 6 for GEO-CAPE
- System modeling and design for GEO-CAPE steering mirror control feedback
- Improving read noise on detector subsystem and detector optimization for specific full-well requirements
- Demonstration with subset of channels with a simple telescope in an aircraft demonstration

Sensor-Web Operations Explorer (SOX)

PI: MeeMong Lee, JPL

Objective

- Enable adaptive measurement strategy exploration on a sensor web for rapid air quality assessment.
- Provide a comprehensive sensor-web system simulation with multiple sensors and multiple platforms.
- Provide a quantitative science return metric that can identify where and when specific measurements have the greatest impact.
- Provide a collaborative campaign planning process among distributed users.



Approach

- Develop multi-disciplinary frameworks and link observation simulations, reference models, science retrieval and analysis algorithms, data assimilation software, forecasting code, and assessment code.
- Develop scalable system modules with asynchronous interface protocols and create a "system of systems" providing flexible system configuration and operation.

Co-Is/Partners

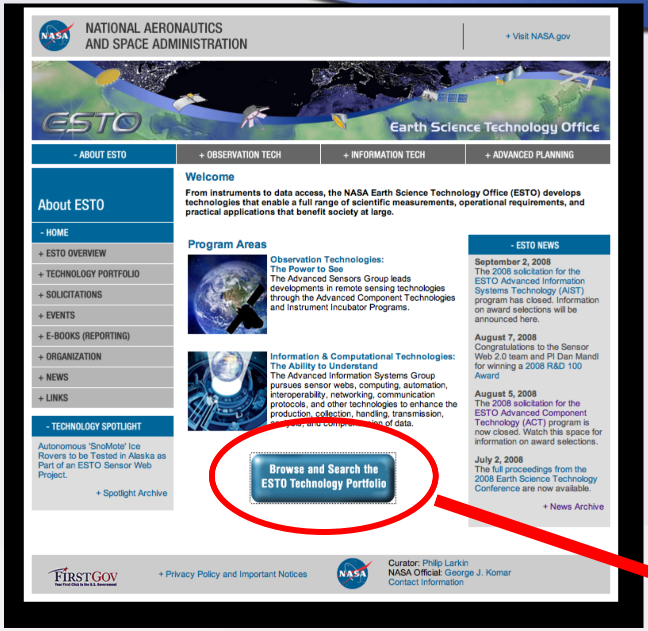
Charles Miller, Kevin Bowman, Richard Weidner, JPL; Adrian Sandu, Virginia Tech

Key Milestones

• Software architecture design	03/06
• Interface definitions	02/07
• Single-platform SOX system deployment	09/07
• Air-borne sensor-web simulation	03/08
• Dual-platform campaign planner	06/08
• Dual-platform SOX service deployment	11/08
• In-situ sensor-web configuration	03/09
• Multi-platform campaign planner	06/09
• Multi-platform SOX system deployment	09/09

TRL_{in} = 2 $TRL_{current}$ = 4

How Do I Learn More?



ESTO Web Site

(esto.nasa.gov)

Key Technical Challenges for Science Data Systems

- Lineage issues due to mobility of data products
- Integration of multiple data sources
- Near real-time need for data products
- Managing huge volumes of data from the user's perspective

Source:

Science Data Systems in the Decadal Survey Era Workshop

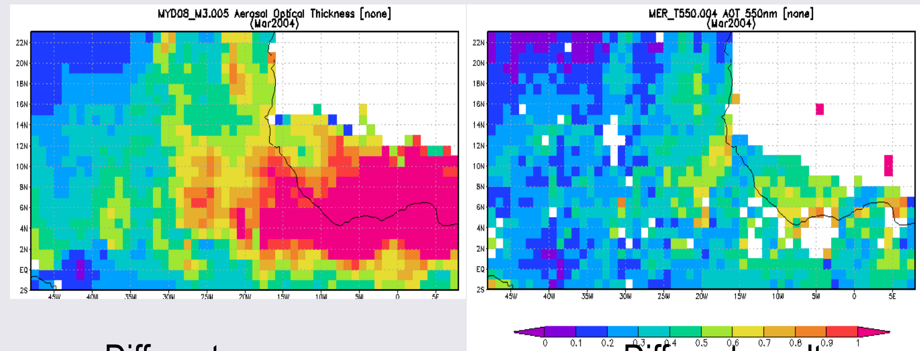
June, 2009

Lineage Issues Due to Mobility of Data Products

- Data instances may not be exact replicas
  - Source, lineage, documentation may be disconnected from data Web services such as OPeNDAP, WCS may alter format and metadata
  - Data may be intrinsically tied to service, for which metadata may be incomplete
- Version control
  - Multiple clearinghouses may offer conflicting “latest version”
  - Reprocessed data is common, but versioning not always explicit once filename is altered
- Multiple purposes of metadata may not be preserved
  - Discovery, access, use, understanding
  - Virtual products created on-the-fly may not contain complete processing history
- No standards to distinguish “most authentic” of many possible replicas

Same parameter

Same space & time

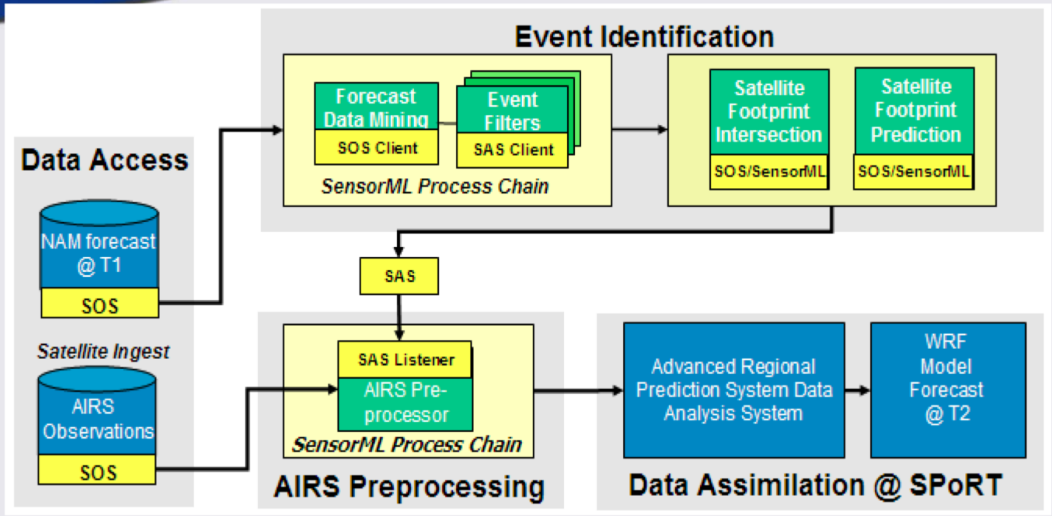


Different provenance

Different result

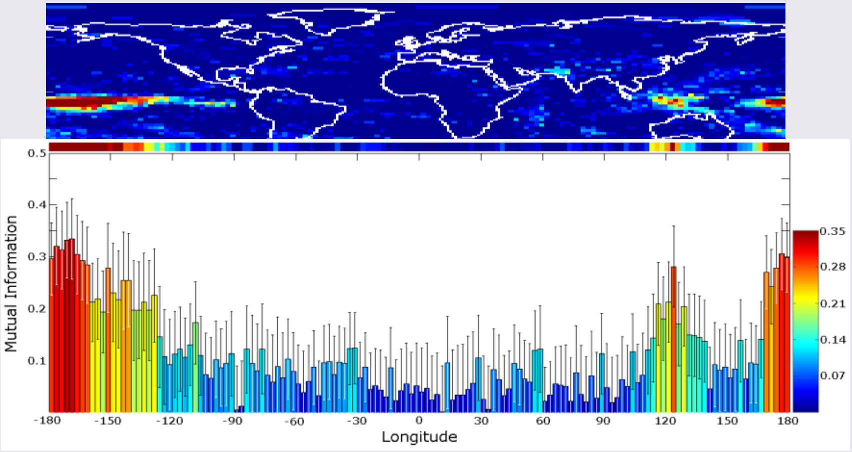
Integration of Multiple Data Sources

- Earth science instruments produce data with different sampling characteristics, geometries, retrieval methods, etc.
- Difficult for individual scientists to find and acquire the data they need
  - Datasets may exist only in a virtual sense
  - Large volumes
  - Requires searching, subsetting, and transforming variables in thousands of files with different characteristics.
- Different scientists would want to perform these searches, queries, and transformations in different ways.
- It is simply not feasible to create static datasets in every configuration needed by the science community.



Integration of Multiple Data Sources Cont.

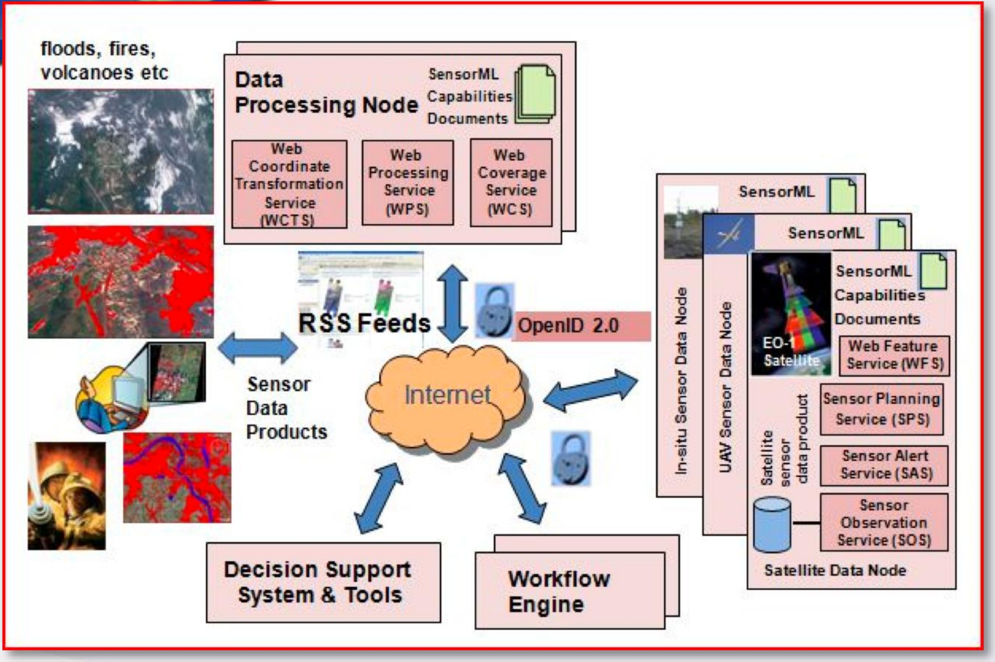
- Representation and propagation of uncertainties presents challenges:
  - No uniform standard for reporting uncertainties in Earth science datasets.
  - Mission specific validation analysis uses its own methodology.



(Top) A Mutual Information (MI) map of Cloud Cover vs. Eastern Equatorial Pacific CTI, which indexes ENSO.
(Bottom) An improved map showing error bars in the MI estimates.

  - Hard to propagate uncertainties through subsequent science calculations, or to pursue inferential questions.
  - Hard to determine the underlying physical processes that generated the data.
  - Hard to determine a fidelity of model predictions from observational statistics especially when combining data from different sources.
  - Need to provide an optimal inference about an unknown quantity (with uncertainties attached), given all available measurements. (data fusion)

Near Real-time Data Analysis

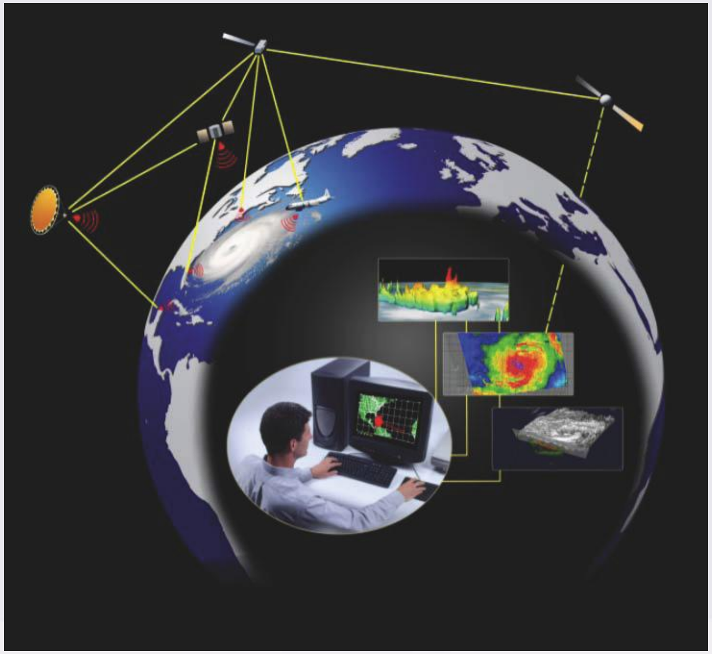


- Increasingly high data volumes and rates present computing challenges:
  - Inferring high level values and products
  - Event-driven data acquisition
  - Decision support with 3 hour turn-around
  - Data validation with end-users
- Need to maximize science return and societal benefit over limited downlink bandwidth
  - Making sure that the most informative observations are identified demands either
    - on-board processing or
    - multi-instrument networks in which low data rate instruments inform downlink decisions for high data rate instruments.

Managing Huge Volumes of Data from the User's Perspective

NASA anticipates generating petabytes of data over the lifetime of the decadal survey missions. Challenges associated with this scale of data include

- Highly distributed storage management
- Distributed, orchestrated processing

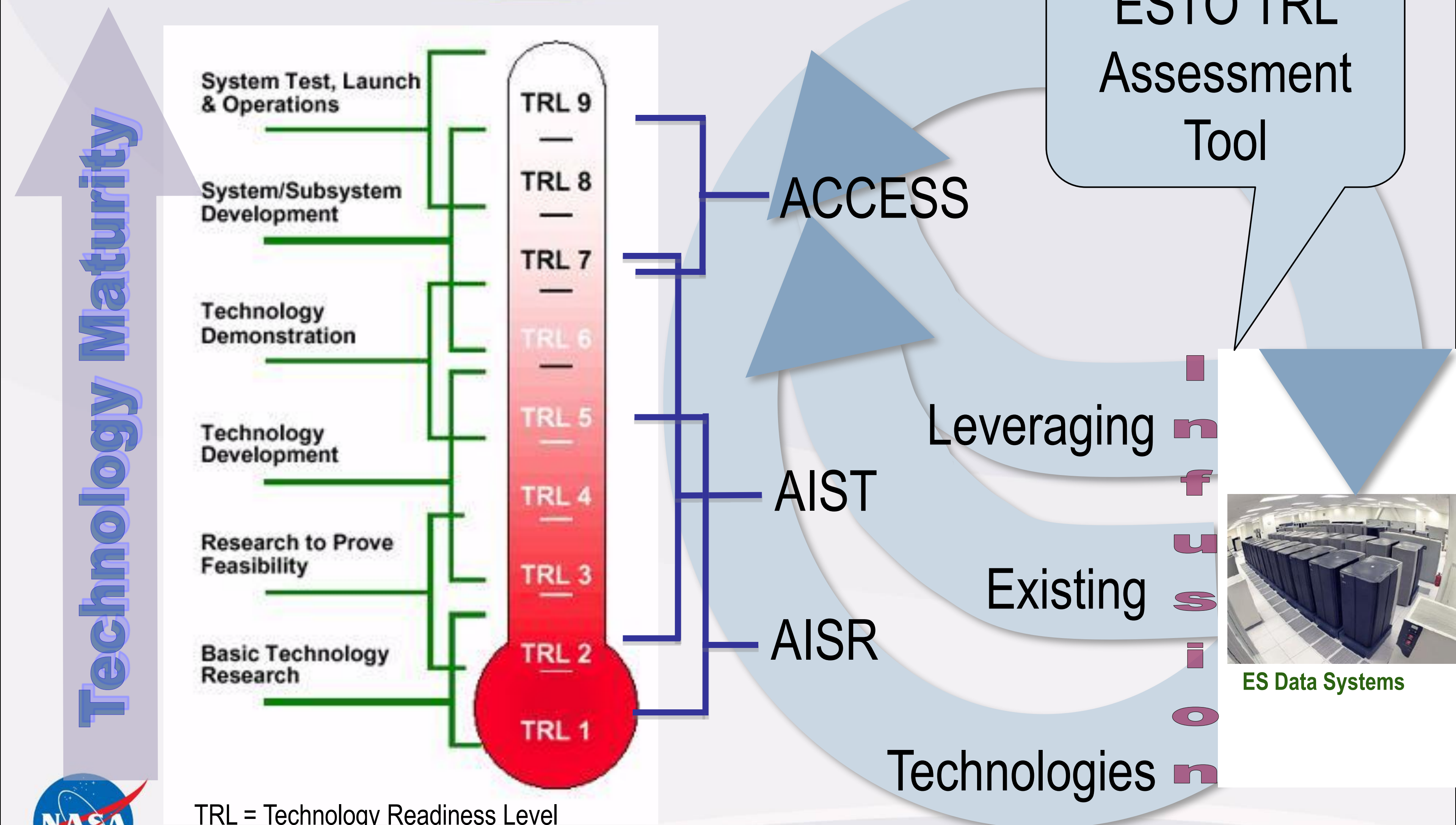


- Movement and distribution of large scale data products
- Search and retrieval of relevant information (data summarization and trend analysis)
- Event detection in near-real time and knowledge discovery
- On demand services (mining, distribution, subsetting) of large data stores

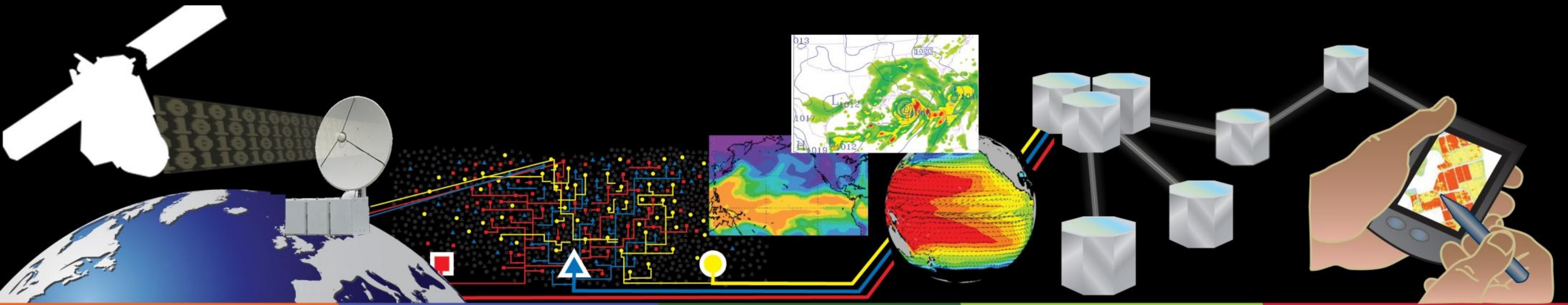
NASA ROSES Programs for Data Systems Research

- NASA's Earth Science approach for continually evolving data systems is through a competitive NASA Research Announcement (NRA) entitled "Research Opportunities in Space and Earth Science (ROSES)"
- ROSES contains many program elements, but technology infusion into Earth science data systems generally involves the leveraging existing technologies and methodologies and maturing them through one or more these elements (depending upon the starting TRL):
  - Applied Information Systems Research (AISR)
  - Advanced Information Systems Technology (AIST)
  - Advancing Collaborative Connections for Earth System Science (ACCESS)
- These programs are centered on technologies and methodologies that serve the Earth science research and applied science communities.

Role of NASA Programs in Technology Infusion



AIST Program Scope



Data Collection & Handling	Transmission & Dissemination	Data & Information Production	System Management	Search, Access, Analysis & Display

AIST technologies are providing increased access to, and improved interrogation of, Earth science data through services designed for a wide range of users.

AIST technologies are managing remote sensing resources and data in order to create fully interoperable systems and provide feedback loops for new, improved observations.

AIST technologies are creating new ways to improve, visualize, combine, extract and understand complex and ever-expanding Earth science data returns.

AIST technologies are ensuring rapid, robust, error-free data transfer and exchange across and among disparate space- and ground-based systems.

AIST technologies are helping make observations more useful, more autonomous, more timely, and more efficient while also preserving the lifetimes (cost) of valuable instruments and sensors.

Advanced Information Systems Technology (AIST)

Since 1999, AIST has released and funded 5 solicitations:

ROSES Solicitation	Project Period (FY)	Focus Areas
AIST-99	2000 - 2003	On-board and space-based systems
AIST-02	2003 - 2007	Flight information systems, space-ground communications, systems management, and model interoperability
AIST-04	2004 - present	Remote sensing data mining and data thinning strategies for model use
AIST-05	2006 – present	Sensor Web technologies – smart sensing, sensor Web communications, and model interactions
AIST-08	2009 – 2011	Sensor system support, advanced data processing, and data services management supporting Decadal Survey measurement goals

Technology Portfolio available at http://esto.nasa.gov/

Advancing Collaborative Connections for Earth System Science (ACCESS)

Since 2005, ACCESS has released and funded 4 solicitations:

ROSES Solicitation	Project Period (FY)	Focus Areas
ACCESS-05	2006 – 2007	Community-based science processing systems and portals that emphasize greater interoperability of distributed data and processing assets
ACCESS-06	2007 – 2008	EOS ClearingHouse (ECHO) clients and other middleware technologies
ACCESS-07	2008 – 2009	Interoperability to facilitate transparent access and manipulation of heterogeneous and distributed data and deployment of existing tools through service oriented architectures (SOA) to enhance reuse
ACCESS-09	2010 – 2012	Improving access to Web services and service registries, and knowledge of data quality and production legacy

Recommendations Forward

- ***Identify Geo-CAPE technology gaps and provide to ESTO***
  - ***IIP, ACT Flight components***
  - ***AIST, ACCESS Data components***
- ***Look at current Air and Ocean data needs to project Geo-CAPE technology gaps, provide to ESTO***
- ***Include Data Utilization and Operations Concepts in early deliberation***

Back-up

Summary of Solicitations,

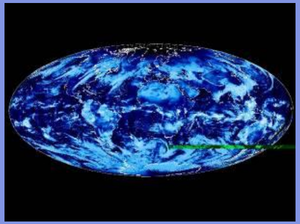
ESTO Awards Mapped to Decadal Survey Missions

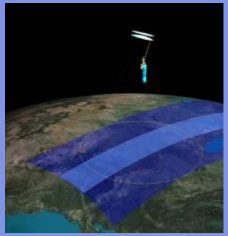
Competititively Selected Earth Science Technologies

NRA Solicitations	Awards	Budget-$M	Focus
IIP Round 1 (Instruments) '98	27	39	Open, unconstrained solicitation; covering active and passive optical and active and passive microwave instruments
IIP Round 2 (Instruments) '01	11	30	Microwave radiometry, radar, laser/lidar instruments
IIP Round 3 (Instruments) '02	10	22	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	60	Atmospheric aerosols and trace gases, ice topographic mapping, and tropospheric winds
IIP Round 5 (Instruments) '07	21	64	Instrument and instrument subsystems that will enable NRC decadal survey mission science measurements and visionary concepts
ATI Component Technology (ACT Round 1) '99	23	17	Core instrument technology; covering active and passive optical, and active and passive microwave instrument components
ACT Round 2 (Components) '02	14	15	Antenna, electronics, detectors, and optics components
ACT Round 3 (Components) '05	14	22	Active and passive microwave components
ACT Round 4 (Components) '08	17	16	Laser transmitters, optical detectors, high speed ranging and digitizing electronics, stray light control and detectors, electronically steerable Ku- and X-band antenna technologies, RF hybrid chips, lo-power wave receivers,
AIST Round 1 (Info Systems) '99	30	26	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	23	Space/ground-based, computational technology
Mini-AIST (Info Systems) '04	6	2	Ocean Biology and Biogeochemistry Data Mining Data Mining for Climate and Weather Models
AIST Round 3 (Info Systems) '05	28	31	Smart sensing, sensor web communications and enabling model interactions in sensor webs.
AIST Round 4 (Info Systems) '08	20	25	Sensor system support, advanced data processing, and data services management that contribute to Earth science information and mission operations systems recommended by the decadal survey.

NASA Earth Science Decadal Survey Missions

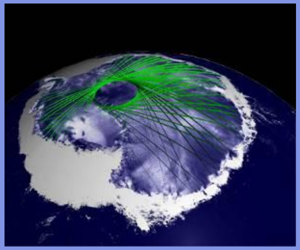
Climate Absolute Radiance and Refractivity Observatory **(CLARREO)**





Soil Moisture Active Passive **(SMAP)**

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

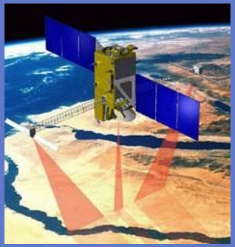


Deformation, Ecosystem Structure and Dynamics of Ice **(DESDynI)**

Tier I

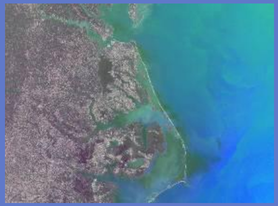
Hyperspectral Infrared Imager **(HYSPIRI)**

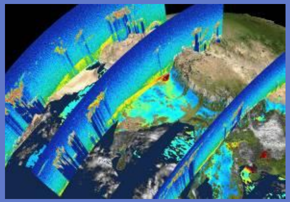
Active Sensing of CO2 Emissions **(ASCENDS)**



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

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

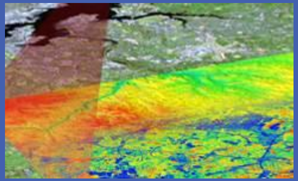




Aerosol - Cloud - Ecosystems **(ACE)**

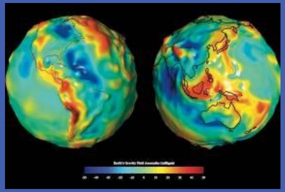
Tier II

LIDAR Surface Topography **(LIST)**



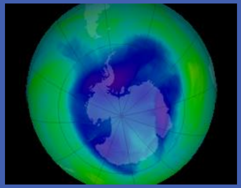
Precipitation and All-Weather Temperature and Humidity **(PATH)**

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



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

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



Global Atmospheric Composition Mission **(GACM)**

Tier III

Instrument Awards vs. DS Missions

2007 Instrument Incubator Awards versus Decadal Survey Missions	CLARREO	SMAP	ICESat-II	DESDynI	HyspIRI	ASCENDS	SWOT	GEO-CAPE	ACE	LIST	PATH	GRACE-II	SCLP	GACM	3D-WINDS	CLARREO-NOAA	GPSRO	XOVWM
Abshire/GSFC - column CO2, 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 CO2, 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	■																	
Neil/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														■				
Weimer/Ball - vegetation canopy, steerable lidar				■														
Yu/GSFC - topography and vegetation structure, swath-mapping lidar										■								

■ IIP07 Awards

Component Awards vs. DS Missions

2008 Advanced Component Technology Awards versus Decadal Survey Mission	CLARREO	SMAP	ICESat-II	DESDynI	HyspIRI	ASCENDS	SWOT	GEO-CAPE	ACE	LIST	PATH	GRACE-II	SCLP	GACM	3D-WINDS	CLARREO-NOAA	GPSRO	XOVWM
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							■											

■ ACT08 Awards

Information Systems Awards vs. DS Missions

2008 Advanced Information Systems Technology Awards versus Decadal Survey Mission	CLARREO	SMAP	ICESat-II	DESDynI	HyspIRI	ASCENDS	SWOT	GEO-CAPE	ACE	LIST	PATH	GRACE-II	SCLP	GACM	3D-WINDS	CLARREO-NOAA	GPSRO	XOVWM	Broad App.
Bock/Scripps, UCSD – Solid Earth – Data fusion				■															
Braverman/JPL – Carbon/eco – Data fusion						■													
Donnellan/JPL – Solid Earth – Cloud computing				■															
Flatley/GSFC – Broad app. – On-board data/signal processing									■										
French/USC/ISI – Broad app. – On-board data & signal processing		■																	
Goodman/MSFC – Climate – Data manipulation								■											
Ivancic/GRC – Atm. comp. – Sensor web enablement																			■
Leptoukh/GSFC – Atm. Comp. - Ontology								■											
Lou/JPL – Solid Earth – On-board data & signal processing				■															
Mandl/GSFC – Carbon/eco – Data manipulation					■														
Moghaddam/U. Mich – Water/energy – Mission simulation & design		■																	
Nemani/ARC – Carbon/eco – Mission management		■																	
Norton/JPL – Climate – On-board data & signal processing									■										
Peters-Lidard/GSFC – Water/energy – Algorithms & modeling		■																	
Rosen/JPL – Climate – Algorithms & modeling				■															
Schneider/U. Florida – Weather – Data manipulation															■				
Seablom/GSFC – Climate – Mission management															■				
Shen/UMBC – Weather – High-performance computing	■																		
Tanelli/JPL – Climate – Mission/system simulation & design									■										
Von Allmen/JPL – Solid Earth – Algorithms & modeling				■															

■ AIST08 Awards