HyspIRI Technology Investment Overview

October 22, 2008

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Earth Science Technology Office

Future Directions for NASA Earth Science and 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

Earth Science Technology: A Flexible, Science-Driven Approach

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

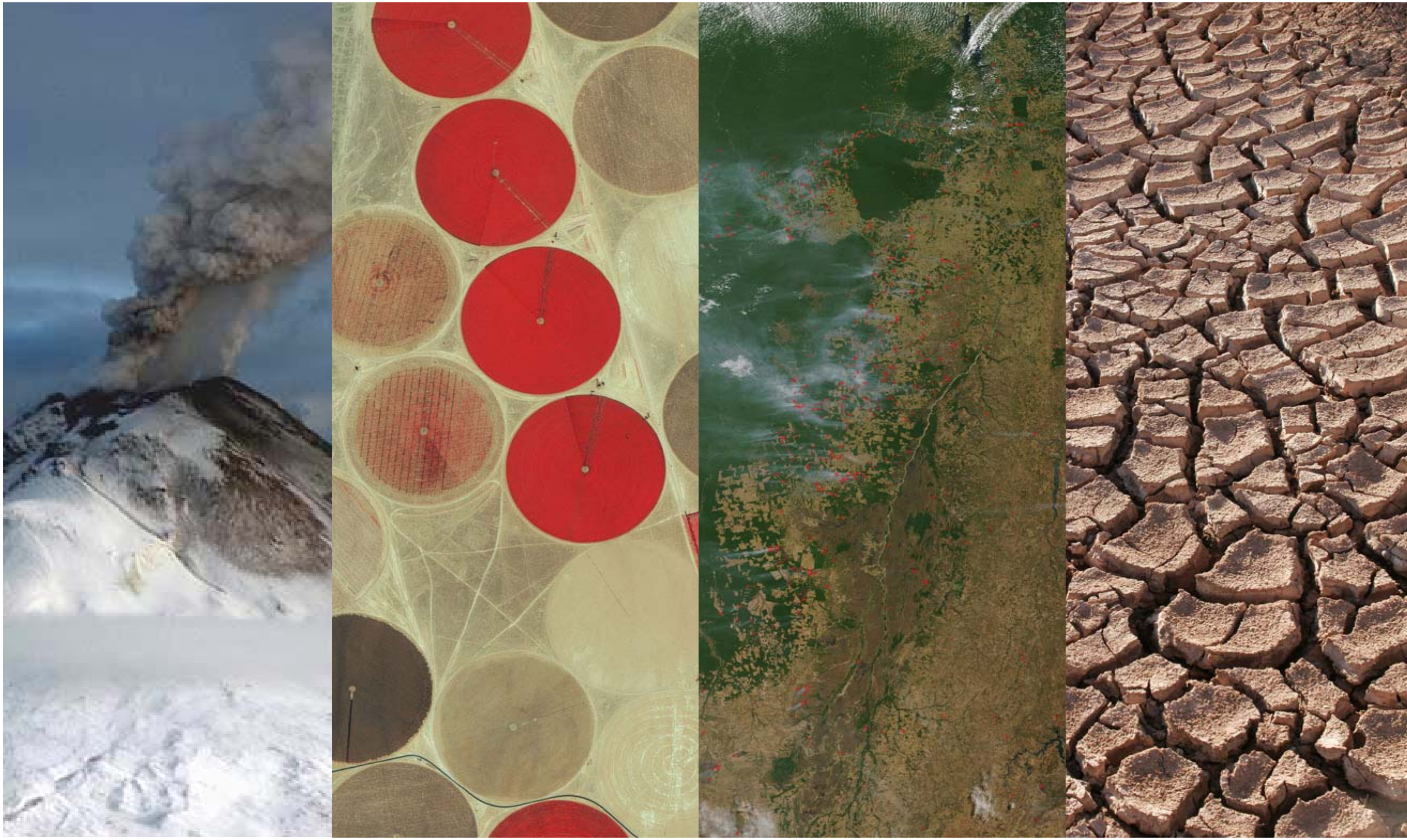
Instrument Incubator Program (IIP) - new instrument and measurement techniques, including laboratory development and airborne validation

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. Includes data manipulation, and visualization of very large, highly distributed remotely sensed data sets consistent with modeling needs

Presentation Outline

- Outline
  - Mission description and payload highlights
  - Observation technologies
  - Information system technologies
- Most tasks initiated before Decadal Survey was released!
- Some tasks have broad mission relevancy
- Some tasks have relevancy to the application of the science to societal benefits

HyspIRI - Technology Investments

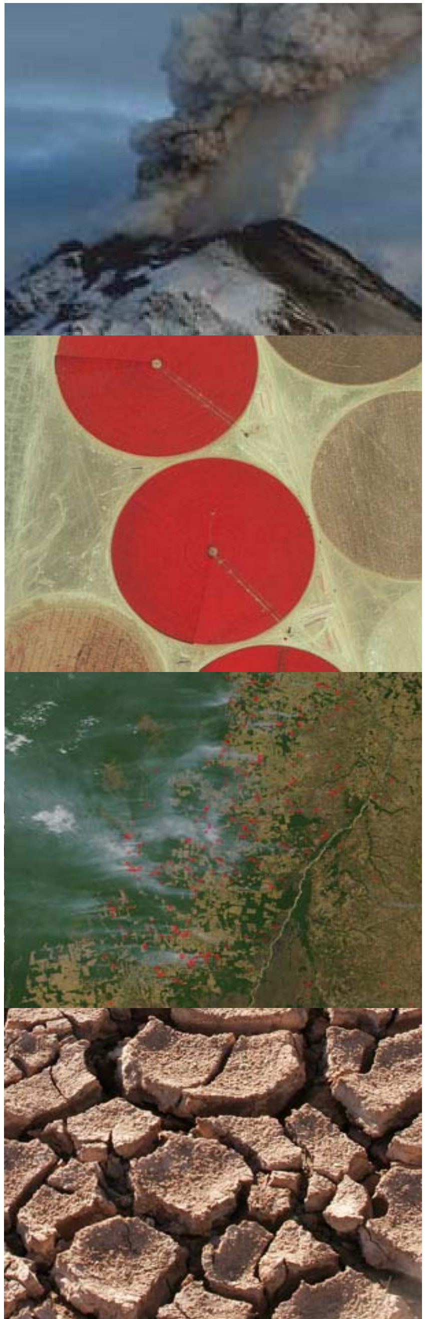


Mission and Payload

The HyspIRI mission uses imaging spectroscopy (optical hyperspectral imaging at 400-2500 nm and multispectral IR at 8-12 μm) of the global land and coastal surface. The mission would obtain global coverage from LEO with a repeat frequency of 30 days at 45-m spatial resolution. A pointing capability is required for frequent and high-resolution imaging of critical events, such as volcanoes, wildfires, and droughts.

The payload consists of a hyperspectral imager with a thermal multispectral scanner, both on the same platform and both pointable. Given recent advances in detectors, optics, and electronics, it is now feasible to acquire pushbroom images with 620 pixels cross-track and 210 spectral bands in the 400- to 2,500-nm region. If three spectrometers are used with the same telescope, a 90-km swath results when Earth's curvature is taken into account. A multispectral imager similar to ASTER is required in the thermal IR region. For the thermal channels (five bands in the 8- to 12-μm region), the requirements for volcano-eruption prediction are high thermal sensitivity of about 0.1 K and a pixel size of less than 90 m. An optomechanical scanner, as opposed to a pushbroom scanner, would provide a wide swath of as much as 400 km at the required sensitivity and pixel size. The HyspIRI mission has its heritage in the imaging spectrometer Hyperion on EO-1 launched in 2000 and in ASTER, the Japanese multispectral SWIR and thermal IR instrument flown on Terra. The hyperspectral imager's design is the same as the design used by JPL for the Moon Mineralogy Mapper (M3) instrument on the Indian Moon-orbiting mission, Chandrayaan-1, and so will be a proven technology.

From Decadal Survey



Mission Overview

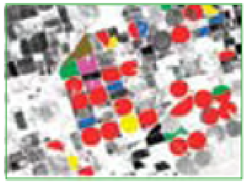
- Mission Description:
  - This mission provides the surface temperature and emissivity from LEO at high spatial resolution (45m) and high temporal resolution (monthly) for studies at the local, regional and global scale.
- Instruments:
  - Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer
    - Push broom images with 620 pixels cross-track and 210 spectral bands in the 400 to 2,500-nm region
  - Thermal InfraRed (TIR) Multispectral Scanner
    - Five bands in the 8-12 um region

From Decadal Survey

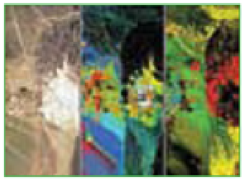
HYPERSPECTRAL INFRARED IMAGER (HYSPIRI)

Launch: 2013-2016   Mission Size: Medium

Processes indicating volcanic eruption



Nutrients and water status of vegetation; soil type and health



Spectra to identify locations of natural resources

Changes in vegetation type and deforestation; drought early warning

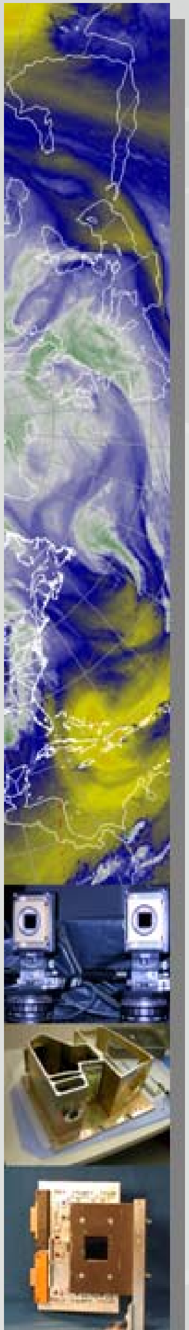
Improved exploration for natural resources

Forecasts of likelihood of volcanic eruptions and landslides

From Decadal Survey

ESTO Technology Development in Support of an

Advanced Remote-Sensing Imaging Emission Spectrometer



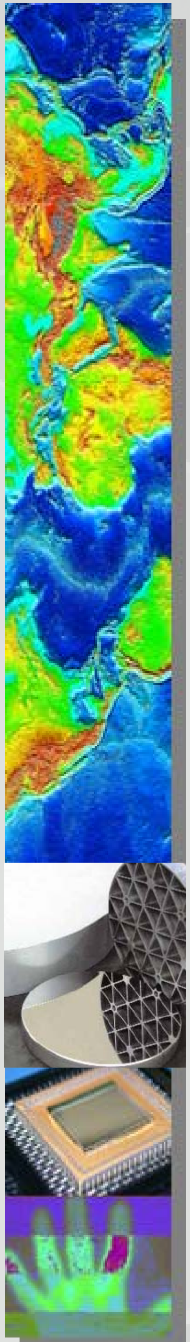
Missions Supported: HyspIRI

Measurement Approach

Hyperspectral, high-resolution imager sounder

Earth Science Technology Office (ESTO) Investments

- Development and airborne demonstration of a thermal infrared imaging spectrometer with high spatial and spectral resolution to support the HyspIRI mission (Hook/JPL-IIP07)
- Development and airborne demonstration of a high-performance thermal imager for HyspIRI-type measurement applications (Hall/The Aerospace Corp.-IIP-07)
- Completed second instrument technology advancement of SIRAS-G, a WFOV, multi-grating/channel IR spectral imager concept designed to accurately measure atmospheric temperature and water vapor from LEO or GEO. Lab demonstrated fully functional imaging MWIR spectrometer (3.35-4.8 µm) operating at cryogenic temperatures (Kampe/Ball Aerospace - IIP-02)
- Designed and lab demonstrated a proof-of concept Hyperspectral imager that is suitable for area coverage from GEO orbit. The instrument design concept is a dual spectrograph covering the UV/VIS wavelength region of 310-481 nm and the VIS/NIR wavelength region of 500-900nm. GeoSpec is designed to take space based measurements of environmentally important trace gases, coastal and oceanic pollution events, and measure the origin and evolution of aerosol plumes. (S. Janz/GSFC-IPP-02)
- Reconfigurable Computing Based Compression for Spaceborne Hyperspectral Imaging Processing (S. Hauck/U Washington- AIST-02)
- A Reconfigurable Computing Environment for On-Board Data reduction and Cloud Detection (J. LeMoigne/GSFC AIST-02)
- A tunable high performance compression scheme suitable for push-broom sensors for quick-look and direct broadcast applications. (P. Yeh/GSFC AIST-02)
- An Inter-operable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS (D. Mandl/GSFC AIST-05)



ESTO Technology Development in Support of

Land Surface Imaging

Missions Supported: HyspIRI

Measurement Approach

Spectrometers UV/VIS, near-IR, thermal IR

Earth Science Technology Office (ESTO) Investments

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- Designed, fabricated, hybridized and fully characterized a 1,024 x 1,024 (1K x 1K) GaAs Quantum Welled Infrared Photodetector (QWIP) array sensitive to the 8-14 µm infrared spectral region. (M. Jhabvala/GSFC -ATIP-99 and ACT-02)
- Land Information System (C. Peters-Lidard/GSFC AIST-02) and Land Information Sensor Web (P. Houser/IGES AIST-05)
- Data Mining for Understanding the Dynamic Evolution of Land-Surface Variables (P. Kumar/U Illinois AIST-05)
- Science Model Driven Autonomous Sensor Web (A. Davies/JPL AIST-QRS-07)
- Optimized Autonomous Space – In-situ Sensorweb (W. Song/Washington State AIST-05)

ESTO Technology Development in Support of

Physiology & Functional Group Measurements

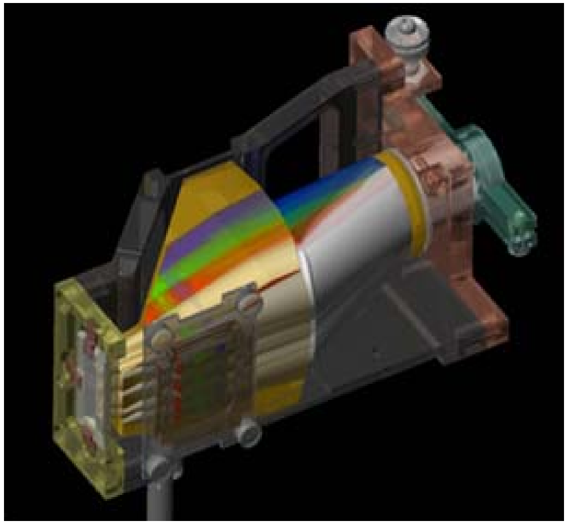
Missions Supported: ACE**, HyspIRI**

Measurement Approach

Polar-orbiting imaging spectrometer(s) (~350-2500 nm); **Multi-Spectral imager in the Thermal IR**; High spectral resolution aerosol lidar (SP) for atmospheric correction over oceans

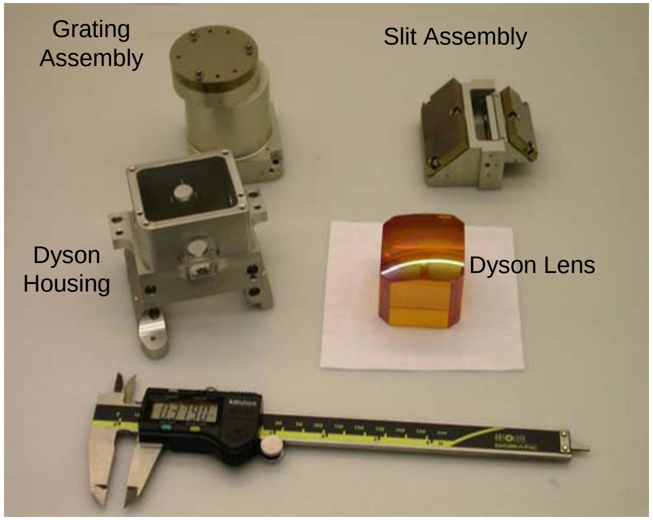
Earth Science Technology Office (ESTO) Investments

- Developed a large format (256X256) array VIS-NIR bland Aluminum Gallium Nitride (AlGaN) UV imager designed for 310-365 nm operation (Mott/GSFC-ACT-02)
- **Developed ultra-narrow UV and visible interference filters that demonstrated a 100%improvement in transmission over previously available filters (Potter/Barr Associates – ACT 02)**
- **Demonstrated a full-scale dual spectrograph breadboard instrument capable of the required sensitivity to enable future geostationary instrumentation. The instrument design concept is a dual spectrograph covering the UV/VIS wavelength region of 310-481 nm and the VIS/NIR wavelength region of 500-900 nm (S. Janz - IIP-02)**
- Developing an autonomous diode-pumped UV laser system for High Spectral Resolution (HSRL) Aerosol Lidar measurements. Proposed flight demonstration of autonomous joint Ozone and aerosol performance. (Hostetler/LaRC – IIP 04)
- **Developed an on-board data compression tool for scientist to maximize science return despite scarce downlink resources (S. Dolinar/JPL AIST-02)**
- **MATLAB-BASED Adaptive Comuting for NASA Image Processing Applications (S. Hauck/U Washington AIST-02)**



Instrument Technologies

(Current and Completed ESTO Investments)

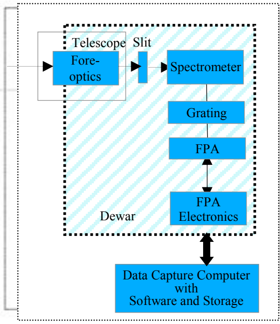


HyTES: Hyperspectral Thermal Emission Spectrometer for HyspIRI-TIR Science

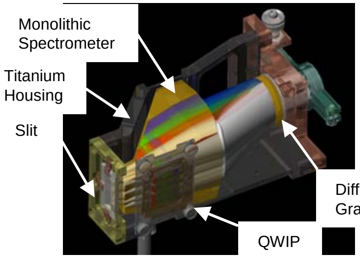
PI: Simon Hook, JPL

Objectives:

- Develop a thermal infrared imaging spectrometer with high spatial and spectral resolution to support the HyspIRI mission. This mission will address key science questions related to the Solid Earth and Carbon Cycle and Ecosystems focus areas .
  - The instrument will use at its base a cooled Dyson spectrometer that acquires 256 spectral channels of image data between 8 and 12 μm when used in conjunction with a Quantum Well Infrared Photodetector (QWIP) array
- Verify the performance in the laboratory as well as on an airborne platform.

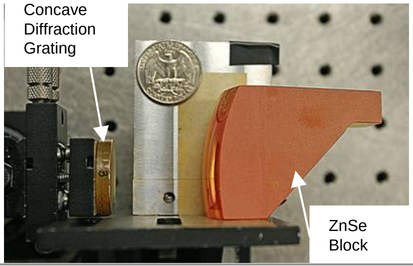


1) Block Diagram Concept



2) Graphical Concept

3) Concave Diffraction Grating



4) Dyson Spectrometer

Approach:

- Develop opto-thermo-mechanical system design requirements.
- Develop analytical system model and design for a cryocooler dyson spectrometer.
- Fabricate/procure spectrometer system (QWIP, grating, optics, thermal and mechanical components, test equipment).
- Integrate and test in the laboratory and on an airborne platform to verify performance.

Co-Is (JPL):

- Bjorn T. Eng, Sarath D. Gunapala, Cory J. Hill, William R. Johnson, Pantazis Mouroulis, Vincent J. Realmuto, Daniel W. Wilson.

Key Milestones:

• Complete science & prelim. instrument design requirement	10/08
• Complete Preliminary Design Review (PDR)	03/09
• Complete Critical Design Review (CDR)	06/09
• Complete procurement of critical components	12/09
• Complete fabrication	06/10
• Complete static, dynamic and force tests	12/10
• Complete calibration I&T	12/10
• Complete performance & science verification	05/11

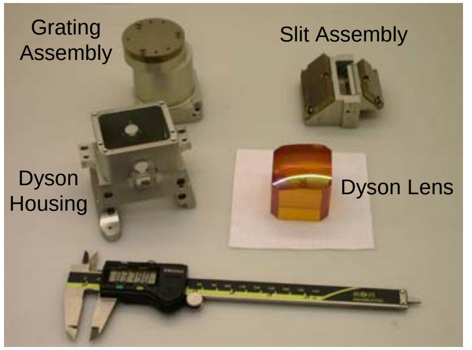
$TRL_{in} = 4$

Mineral and Gas Identification Using a High-Performance Thermal Infrared Imaging Spectrometer

PI: Jeffrey Hall, The Aerospace Corp.

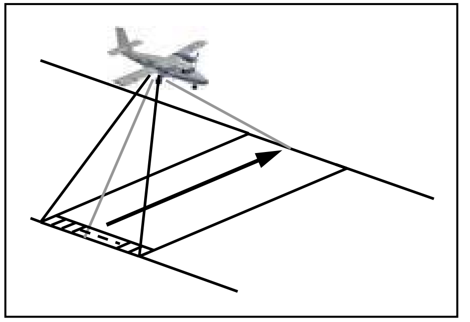
Objective

- Design and build an airborne demonstrator version of a high-performance thermal imager for HyspIRI-type measurement applications
- Demonstrate the feasibility of a two-detector-module design for increased swath width
- Demonstrate the new sensor's performance thru airborne field trials
- Develop LEO implementation concept



Dyson Spectrometer Components

Whiskbroom Scanning



Approach:

- Examine trade-offs between spectral resolution, spectral range, area coverage rate, and sensitivity for a satellite version of the airborne instrument
- Incorporate a cooled, optically-fast Dyson spectrometer mated to a high-frame-rate 2D focal plane array
- Use Fiber Support Technology (FiST) for thermal isolation of components

CoIs: Jeffrey Hall, David Tratt, David Warren, Stephen Young / The Aerospace Corp.
Michael Ramsey / Univ. of Pittsburgh

Key Milestones

• Conceptual Design Completion	1/09
• Preliminary Design Completion	7/09
• Critical Design Completion	1/10
• System Fabrication & Integration	7/10
• System Test - Laboratory	1/11
• System Test – Aircraft Flights	7/11

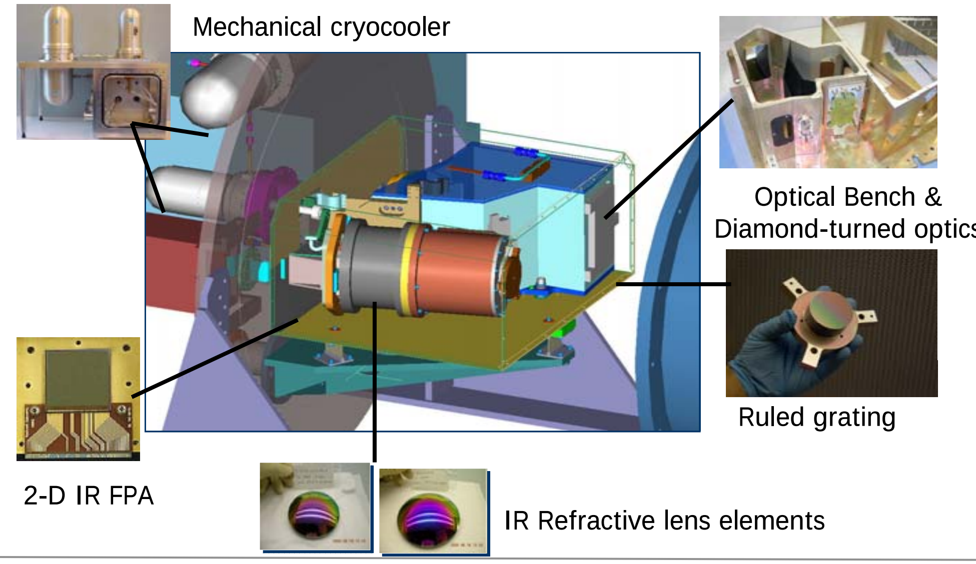
$TRL_{in} = 3$

SIRAS-G, the Spaceborne Infrared Atmospheric Sounder for GEO

PI: Thomas Kampe, Ball Aerospace & Technologies Corp. (BATC)

Objective

- Develop instrument technology for IR atmospheric sounding from GEO and LEO
- Validate operational performance in a laboratory demonstration
- Generate a design recommendation for space flight instrument



Accomplishment

- Developed single-channel MWIR lab demo that integrates flight-like spectrometer, active cooling, flight-like IR Focal Plane Arrays and electronics
- Spectrometer design developed for low distortion (spectral smile & keystone) & excellent image quality. Design form is extendable to multi-leg configuration (3-15 μm spectral coverage)
- Advanced technology multi-stage warm shield concept demonstrated
- Tested demo instrument in cryogenic environment using test methodology and apparatus developed at BATC (keystone distortion, smile, MTF, SRF, dispersion)

Technology Development Partners

Bill Folkner/Jet Propulsion Laboratory

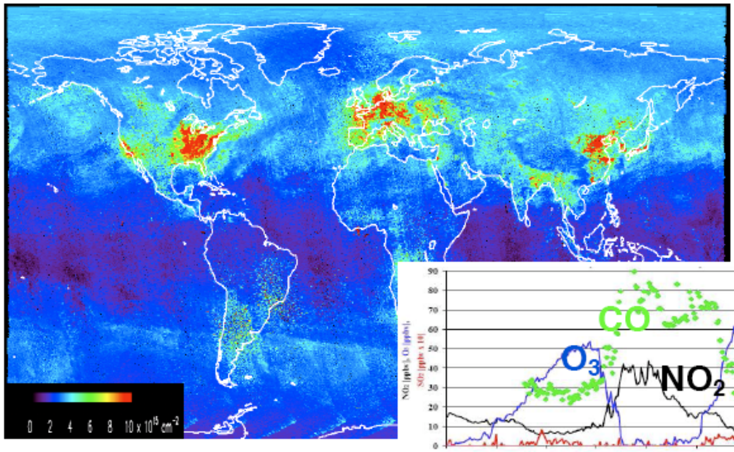
TRLin= 2 TRL current= 4

Geostationary Spectrograph (GeoSpec) for Earth and Atmospheric Science Applications

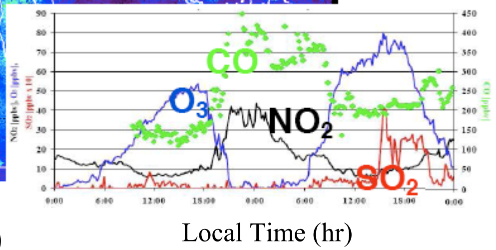
PI: Scott Janz, GSFC

Objective

- Demonstrate the feasibility of future Geostationary Earth Science missions using hyperspectral UV/VIS/NIR instrumentation.
- Geostationary orbit allows the measurement of the diurnal evolution of physical processes.
- Breadboard demonstration of a dual spectrograph instrument with UV/VIS and VIS/NIR channels using hybrid PIN/CMOS detectors.
- Target Earth Science Products: Coastal and ocean pollution events, tidal effects, origin and evolution of aerosol plumes, and trace gas measurements of O3, NO2, CH20, and SO2.



NO_2 column density: Ozone Monitoring Instrument (OMI)



Accomplishments:

- Completed GeoSpec instrument design and system performance studies including polarization sensitivity, spectral sampling/sensitivity trades, image quality, and detector packaging/thermal control.
- Completed design, testing, fabrication and coating of all system optics including convex holographic gratings and new technology single crystal silicon (SCS) mirrors.
- Completed design and fabrication of optical bench mechanical structure.
- Completed optical alignment and end-to-end testing of breadboard including atmospheric retrievals.
- Completed both ISAL and IMDC studies of flight instrument concept.

CoIs:

- Pennsylvania State University
- Washington State University
- Research Support Instruments/Ball Aerospace

$TRL_{in} = 3$ $TRL_{out} = 4$

Development of a 1K x 1K GaAs QWIP Far Infrared Detector Array

PI: Murzy Jhabvala, GSFC

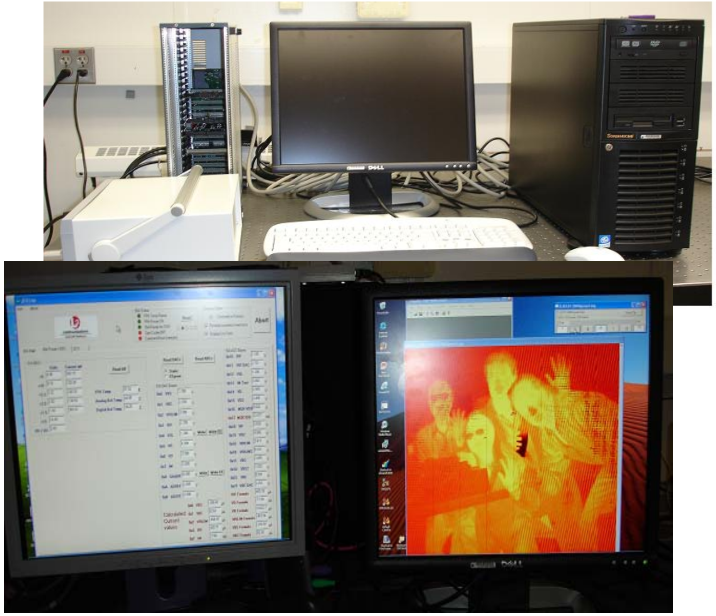
Objective

Design and fabricate a broadband 8-14 um infrared 1Kx1K, GaAs Quantum Well Infrared Photodetector (QWIP) imaging array.

Develop the readout integrated circuit (ROIC)

Design/build the electronics and camera system to perform imaging

Perform Earth observing airborne experiments



QWIP Camera And Electronics System

Accomplishments

Designed QWIP Array
Successfully completed QWIP array fabrication
Developed Rockwell based hybrid camera
First demonstration of 1Kx1K, 8-12 micron array
Tested and characterized QWIP camera and completed Final Report
Flight demonstrated 4-band QWIP on airborne experiment in Thailand (Biomass-burning Aerosol in South East Asia: Smoke Impact Assessment)

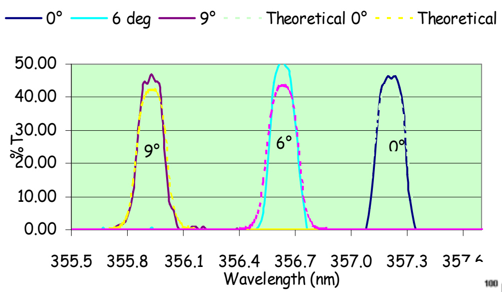
CoIs: Si-Chee Tsay, Dennis Reuter-NASA/GSFC,
Sarath Gunapala-NASA/JPL, K.K. Choi/Army Research Lab

TRL_{in}= 2 TRL_{out}= 6

Earth Science Technology Office

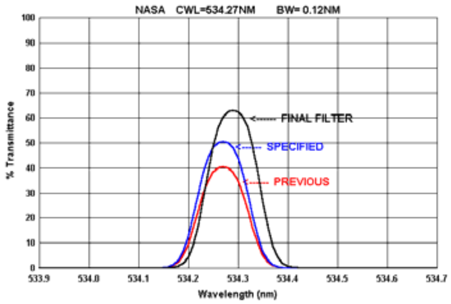
Advanced UV and Visible Ultra-narrow Interference Filter Technology Development

PI:John Potter, Barr Associates Inc.



Tuning performance

Transmission



Description and Objectives

- 3 year effort to conduct research to build interference filters with up to twice the transmission of current filters while maintaining other specifications in the UV. Technology can also be applied to Vis and UV areas of the spectrum.
- Demonstrate filter performance using a Raman LIDAR.
- Transfer research result to space optics.

Co-I's: David Whiteman (NASA –Goddard SFC), Igor Veselovskii/UMBC, Ms. Rebecca Tola, Barr Associates Inc. , Martin Cardirola / Ecotronics

Accomplishments

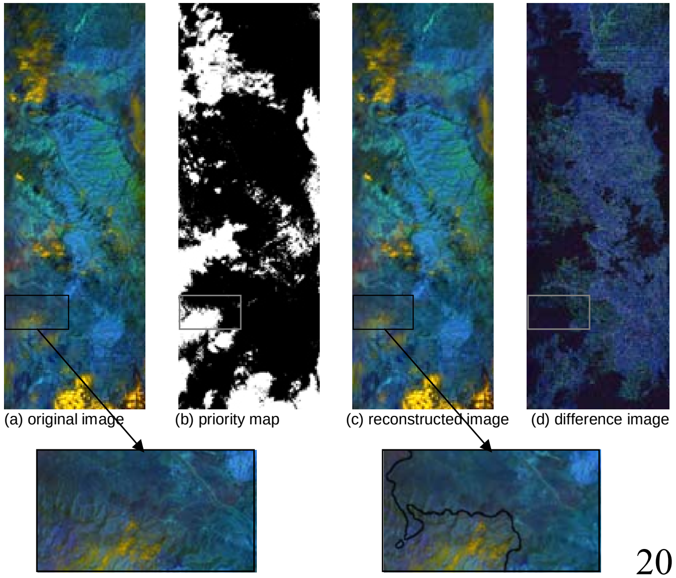
- **UV Band-pass filter fabrication and testing:** More than a factor of 2 improvement in transmission versus previous capability. Manufactured Angle tunable Ultra-Narrow band filter.(0-9°)
- **Impact:** Techniques and filters developed here have been used to improve upper tropospheric measurements of water vapor for Aqua satellite validation.
- **Enables:** Improvements in the transmission of these filters while maintaining other required specifications such as blocking permits higher sensitivity measurements of water vapor, temperature, ozone, etc. than is currently being accomplished by these systems with no increase in size, weight or power consumption. Only the interference filter in use would need to be changed.

TRL_{in} =3
TRL_{out} =5

Earth Science Technology Office

Information Systems Technologies

(Current and Completed ESTO Investments)

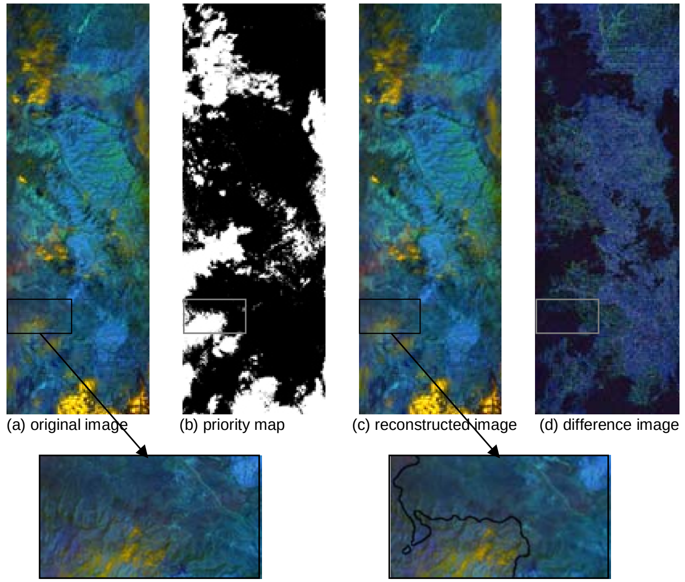


Region-of-Interest Data Compression with Prioritized Buffer Management

PI: Sam Dolinar at JPL

Objectives

- Create an onboard priority-oriented data compression tool for scientists to maximize science return despite scarce downlink resources
- Obtain test images and multi-spectral datasets, and develop algorithms for assigning priorities
- Develop a Web-accessible testbed for active experimentation by scientists
- Measure the gain in science return versus the required processing speed, memory, and storage of onboard computer



Accomplishments

- Developed region-of-interest (ROI) compression algorithms and software (ROI-ICER)
- Developed prioritized buffer management algorithms and software (PBM)
- Developed classification/prioritization algorithms for specific realistic scenarios
- Developed Web-accessible testbed for the ROI-ICER & PBM software
- Performed doctoral-level research on further improvements to the algorithms for classification/prioritization, ROI compression, and prioritized buffer management, leading to four Ph.D. theses at USC
- Some "so whats" E.G.:
    - Enables efficient use of limited communication resources by allocating scarce bits to the most important sections of images (both within images and across images). See example of prioritized bit allocation in image above.

CoIs: *Matt Klimesh and Aaron Kiely at JPL, Antonio Ortega at USC, and Roberto Manduchi at UCSC*

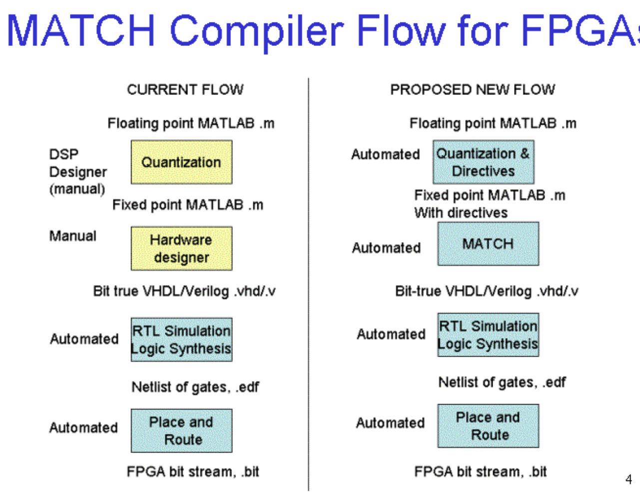
TRL_{in} = 1; TRL_{out} = 3

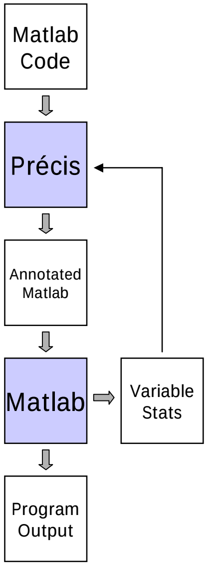
MATLAB-Based Adaptive Computing for NASA Image Processing Applications

PI: Scott Hauck, University of Washington

Objective

- Reduce code development times for adaptive applications from weeks to hours using compiler tools
- Produce efficient codes that optimize resources under performance constraints, or optimize performance under resource constraints
- Enable Adaptive (Field Programmable Gate Array (FPGA) based) Computing for NASA scientists via
  - MATLAB to FPGA Compiler (MATCH)
  - Automatic Variable Precision Support
  - Multi-spectral Image Classification Example





Accomplishments

- Reduced code development times for adaptive applications from weeks to hours using compiler tools
  - Developed compiler for automatic translation of MATLAB programs to Register Transfer Level (RTL) Very High Speed Integrated Circuit (VHSIC) Hardware Description \Language (VHDL) for mapping to FPGAs on reconfigurable hardware
  - Developed a set of variable precision tools to aid NASA developers in trading off quantization errors and fidelity for resources on an FPGA
  - Produced efficient codes that optimize resources under performance constraints, or optimize performance under resource constraints
- Transferred MATCH compiler technology to Accelchip, Inc. for commercialization
  - Developed an experimental prototype of the MATCH compiler on commercial FPGAs
  - Developed real-world applications to drive research on optimizations

CoIs: Prithviraj Banerjee, Northwestern University

$TRL_{in}=3$ $TRL_{out}=4$

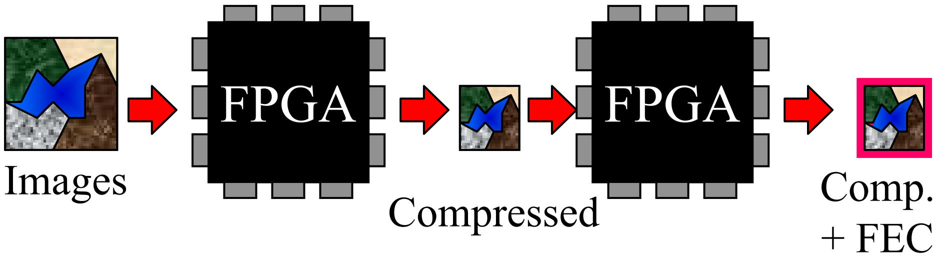
ESTO Earth Science Technology Office

Reconfig. Computing Based Compression for Hyperspectral Images

PI: Scott Hauck, University of Washington

Objective

- Enable fast, efficient compression of NASA hyperspectral data via:
    - Linear prediction
    - Set Partitioning in Hierarchical Trees (SPIHT) lossy image compression
    - Region-of-Interest-SPIHT based on cloud cover detection
    - Unequal loss protection/forward error Correction (FEC)
    - FPGA-based computation



Accomplishments

- Enabled fast, efficient compression of NASA hyperspectral data; a compression ratio of 3.11:1 was achieved for lossless data compression
- Optimized SPIHT for hyperspectral images & mapped algorithms to FPGA hardware
    - Significantly reduced bandwidth requirements while retaining important image data
    - Reduced the impact of transmission errors
    - Simplified predictive encoder for FPGA implementation

CoIs: Eve Riskin, Richard Ladner/Univ. of Washington

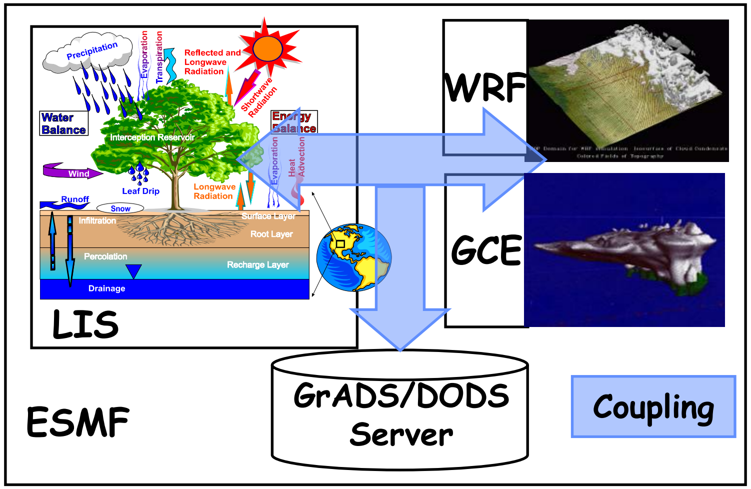
TRL_{in} = 2; TRL_{out} = 4

Coupling High-Resolution Earth System Models Using Advanced Computational Technologies

PI: Christa Peters-Lidard, GSFC

Objectives

- Apply advanced computational technologies to the problem of coupling high-resolution Earth system models
- Combine the emerging technologies of the Earth System Modeling Framework (ESMF), the Land Information System (LIS) and the Grid Analysis and Display System (GrADS)/Distributed Oceanographic Data System (DODS) and couple them to the Weather Research and Forecasting (WRF) model and the Goddard Cumulus Ensemble (GCE) model to enable high-resolution modeling



Accomplishments

- Successfully coupled LIS to GCE and WRF with ESMF
- Populated LIS GrADS/DODS Server (GDS) with data for the 2002 International H2O Project (IHOP) experiment
- Completed ESMF-compliant and non ESMF-compliant coupling of LIS and WRF and LIS and GCE
- Completed IHOP synthetic and real cases with WRF and GCE that show significant impact on radiation coupling timestep, length of spin-up, type of data used in spin-up, and horizontal heterogeneity

CoI: Wei-Kuo Tao, GSFC
Paul Houser, GMU/IGES

$TRL_{in} = 3$ $TRL_{out} = 5$

Land Information Sensor Web

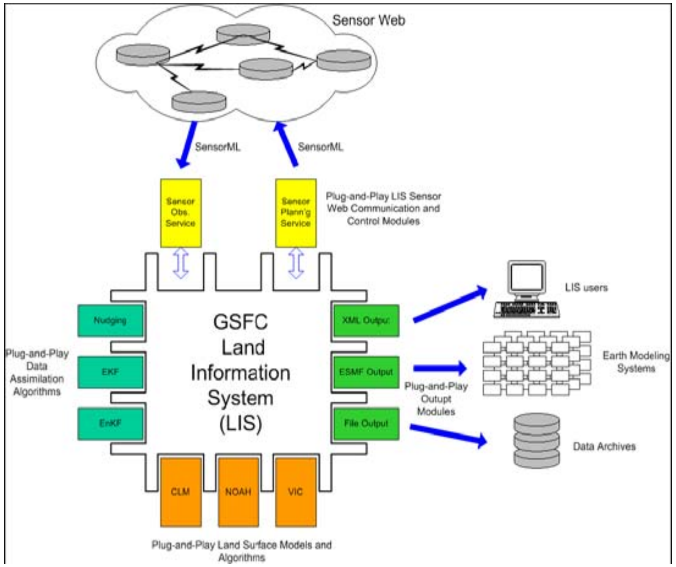
PI: Paul Houser, Institute of Global Environment and Society, Inc.

Objective

- Develop a prototype Land Information Sensor Web (LISW) by integrating the Land Information System (LIS) in a sensor web framework through continuous automatic calibration techniques and data assimilation methods

- LIS will enable on-the-fly sensor web reconfiguration to optimize the changing needs of science and solutions

- LISW will be based on a simulated interactive sensor web, which is then used to exercise and optimize the sensor web - modeling interfaces



Enabling LIS to interact with sensor webs with open protocols and web

Approach

This work will be performed in six steps:

- Establish a synthetic global land "truth"
- Establish a model of future land sensors
- Develop sensor web communication, reconfiguration and optimization
- Establish various land surface uncertainty, prediction and decision support metrics
- Exercise and evaluate the system using LISW experiments
- Design trade-offs for sensor web design

Co-Is/Partners

- James Geiger / NASA-GSFC
- Sujay Kumar, Yudong Tian / U. of Md. Baltimore Campus

Key Milestones

• Scenario development	03/2007
• Sensor simulation	09/2007
• Sensor web framework	02/2008
• Evaluation and optimization metrics	09/2008
• LISW experiments	03/2009
• Sensor web design implications	08/2009
• Collaboration, Communication & Dissemination	08/2009

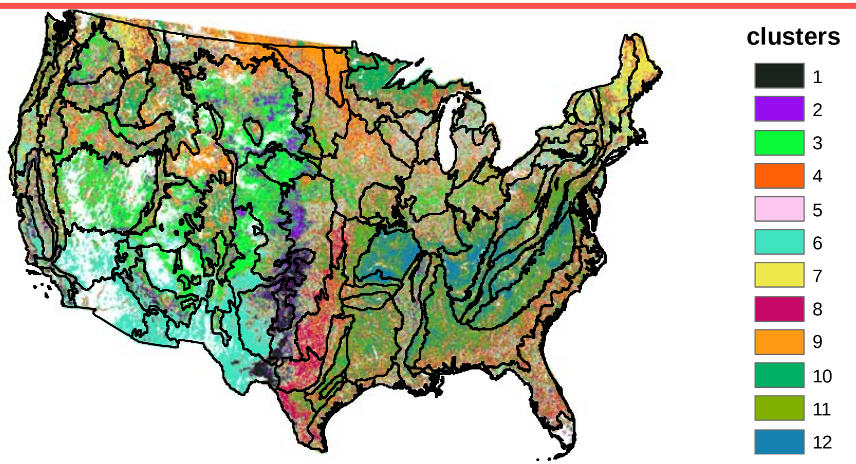
TRL_{in} = 4

Data Mining for Understanding the Dynamic Evolution of Land-Surface Variables: Technology Demonstration using the D2K Platform

PI: Praveen Kumar, University of Illinois

Objective

- Develop data mining techniques, using the Data to Knowledge (D2K) platform of NCSA, to facilitate analyses, visualization and modeling of terrestrial variables obtained from the TERRA and AQUA platforms, in support of scientific investigations for climate and weather applications.
  - MODIS terrestrial products to be supported include NDVI, EVI, LAI, FPAR, NPP, LST, and snow and ice cover.



Clustering analysis of MODIS Terrestrial data at 1km for May 2004. Clusters identified by different colors are overlaid with ecoregion boundaries.

Accomplishments

- Developed GeoLearn which supports processing, data mining, and visualization based on various data products
  - Terrestrial products (NDVI, EVI, LAI, FPAR, LST, Albedo, snow/ice cover (HDF-EOS files)
  - SRTM elevation
  - GIS coverage (vector and raster)
- GeoLearn provides data processing and mining support for very large data sizes (out of core processing capability)
- GeoLearn provides scientific analyses at regional and continental scales

CoI: Peter Bajcsy, NCSA, Univ. of Illinois

TRL_{in} = 4; TRL_{out} = 6

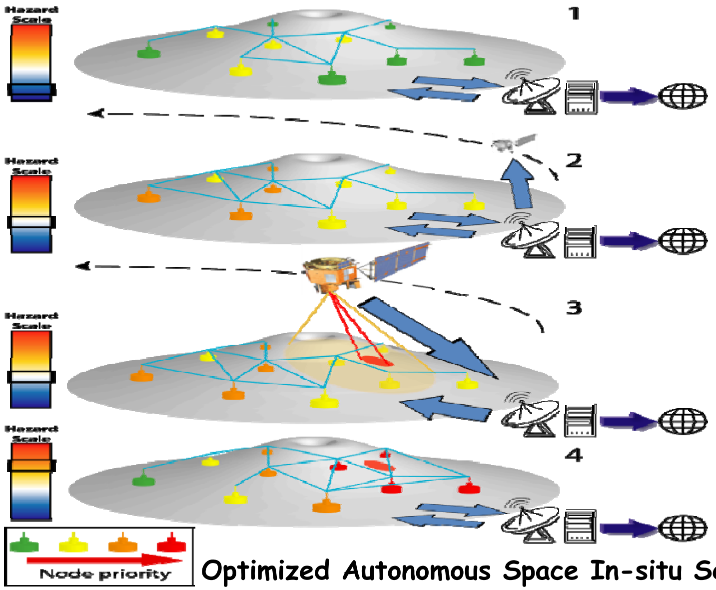
Optimized Autonomous Space - In-situ Sensorweb

PI: WenZhan Song, Washington State University

Objective

Develop a prototype real-time Optimized Autonomous Space - In-situ Sensor-web, with a focus on volcano hazard mitigation and with the goals of:

- Integrating complementary space and in-situ elements into an interactive, autonomous sensor-web.
- Advancing sensor-web power and communication resource management technology.
- Enabling scalability and seamless infusion of future space and in-situ assets into the sensor-web.



Optimized Autonomous Space In-situ Sensorweb

Approach

- Develop a test-bed in-situ array with smart sensor nodes
- Develop new self-organizing topology management and routing algorithms
- Develop new bandwidth allocation algorithms based on packet priorities
- Develop remote network management and reprogramming tools.
- Integrate the space and in-situ control
- Synthesize the sensor-web data ingestion and dissemination through the use of SensorML.
- Demonstrate end-to-end system performance with the in-situ test-bed at Mount St. Helens, and EO-1 platform.

Co-I's/Partners

- Frank Webb, Sharon Kedar, Steve Chien / JPL
- Richard LaHusen / USGS
- Behrooz Shirazi / Washington State University

04/08

Key Milestones

System Requirements	complete
System Design	complete
Testbed H/W Assembly	complete
System S/W Design	complete
Existing St. Helens Array Linked to EO-1	complete
SensorML Development	9/2008
S/W Implementation and Testing	6/2009
Field Demonstration	12/2009
Evaluations, Reports, Publications	12/2009

$TRL_{in} = 2$ $TRL_{current} = 3$

Earth Science Technology Office

Science Model Driven Autonomous Sensor Web

PI: Ashley Davies, JPL

Objective

- To maximize science data return and optimize asset and resource use of an existing sensor web by including volcanic process models in the control loop.
- We have modified an existing sensor web that has a simple trigger-reaction mode, to one that uses a volcanic process model to guide the reaction. For example: a ground sensor detects increasing activity, causing the sensor web to seek additional key data as input for a model of a volcanic process to determine volcano state.
- This effort integrated automated retasking and science process modeling to enable true science-driven sensor web operations.

Applications for Monitoring Volcanoes, Forest Fires, Snow/Ice Cover and Flooding

Accomplishments

- Volcano sensor web detected activity at Nyamulagira in the Democratic Republic of Congo and rescheduled satellite observations faster than the alternative system which incorporates human decision-making in the loop. Sensor Web-generated data and products were used to direct mitigation efforts around the town of Sake.
- Have defined and set up Web Services for the Model-based Sensor Web (a major step towards universal accessibility). Using web services automates complex coordination and analysis of data for multiple users. Data are automatically produced and disseminated to experts in the field.
- Volcano sensor web includes ground based sensors (tilt, seismic, acoustic, gas) and algorithms for sunlight removal, saturation detection, temperature fitting, and calculation of thermal emission and effusion rate.
- Developed a ground sensor package for two-way communication with satellites, allowing autonomous analysis-driven two-way triggering (spacecraft by ground sensor-derived trigger; ground sensor by spacecraft-derived trigger).
- Sensor web was expanded to sea ice and flood applications using other satellites and ground sensors.

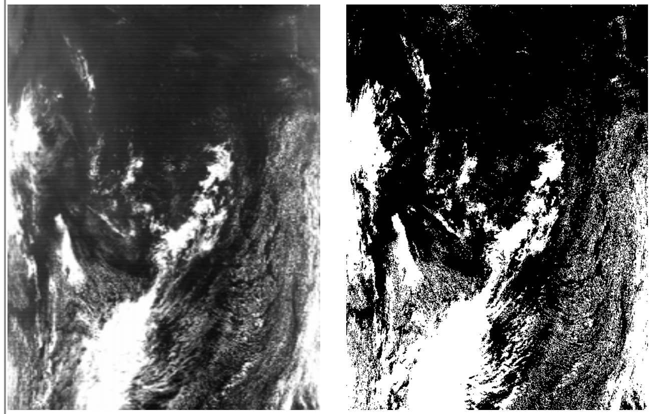
$TRL_{in} = 3$ $TRL_{out} = 5$

A Reconfigurable Computing Environment for On-Board Data Reduction and Cloud Detection

PI: Jacqueline LeMoigne, GSFC

Objective

- Investigate using reconfigurable computing for on-board automatic processing of remote sensing data
- Use the Field Programmable Processor Array (FPPA), a radiation tolerant alternative to Field Programmable Gate Arrays, as the computation engine
- Implement two basic methodologies that enable reduction in communication bandwidth on the FPPA: data reduction and cloud detection



1-bit cloud mask can be compressed to 0.4 bits per pixel

MODIS Original Image and Cloud Mask

Approach

- Simulate both Principal Components Analysis (PCA) and wavelet-based data reduction and Landsat-7 Automatic Cloud Cover Assessment (ACCA) cloud detection using the FPPA software environment
- Implement PCA data reduction and ACCA cloud detection methodologies in hardware
- Analyze results and optimize performances

Co-Is/Partners

Pen-Shu Yeh & Joanna Joiner, GSFC
Greg Donohoe, University of Idaho
Tarek El-Ghazawi, George Washington University
Richard Irish, SSAI

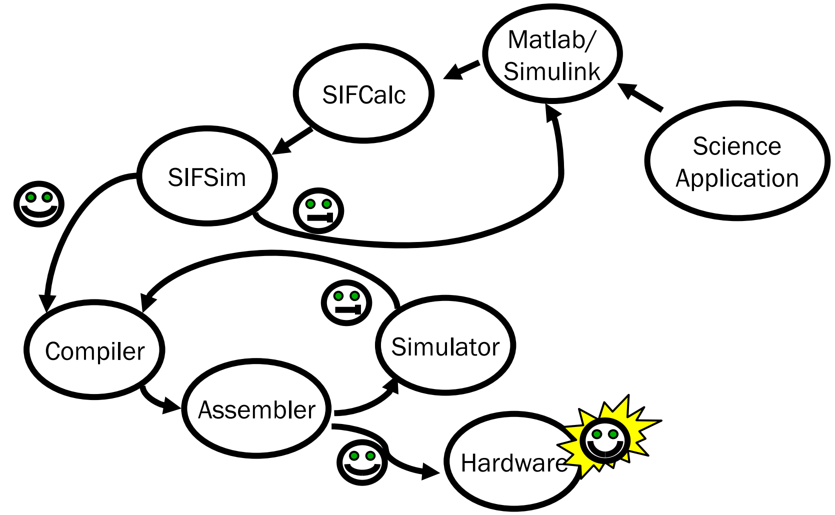
Key Milestones

• Complete Analysis of Algorithms for FPPA	11/03
• Complete design FPPA testbed architecture	05/04
• Complete necessary FPPA software modules	11/04
• Complete building architecture testbed	10/06
• Complete actual FPPA implementation of selected algorithms	02/07
• Complete performance analysis & publications	02/07

$TRL_{in}=3, TRL_{current}=5$

Onboard Instrument Data Processing on a Reconfigurable Processor

Pen-Shu Yeh, GSFC/Code 567



Hardware: RDPP with 16 Processing Elements in one chip with 500 MOPS/watt for onboard applications

Objective

- Develop software necessary to exploit the capabilities of a reconfigurable data path processor (RDPP) being developed under ATIP/ESTO to perform onboard sensor data processing.
- Develop support software (design entry tools, compiler, and basic function library).
- Implement several sensor data processing algorithms.
- Validate performance through instruction simulation.

Accomplishments

- Developed a toolset of software to include a simulator, compiler, and assembler
- Demonstrated the software on the RDPP

Schedule and Deliverables

- Task initiated June 2000; completed June 2003
- Completed software simulator-Dec. 2001
- Completed compiler –Dec. 2002
- Debugged software for test board- June 2003

Projected Infusion

- Interferometers
- Sensor readout correction
- Image enhancement
- Pre-modulation filtering
- Feature extraction
- SAR onboard processing
- Radiometric calibration

$TRL_{current}$=5

Science Theme

Atmospheric Composition — Climate
Water & Energy Cycle — Solid Earth

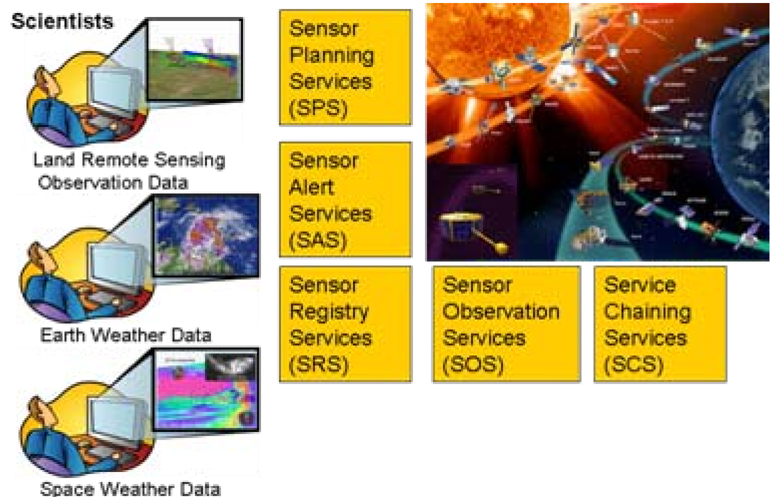
Information Systems: Data Collection and Handling

An Inter-operable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS

PI: Dan Mandl, GSFC

Objective

•Develop the capability to generically discover and task sensors configured in a modular Sensor Web architecture, in space and in-situ, via the Internet
• Assist future Earth science needs for integrating multiple observations without requiring the end-user to have intimate knowledge of the sensors being used
• Demonstrate and validate a path for rapid, low cost sensor integration, which is not tied to a particular system, and thus able to absorb new assets in an easily evolvable coordinated manner
• Facilitate the United States contribution to the Global Earth Observation System of Systems (GEOSS) by defining a common sensor interface protocol based upon emerging community standards



Vision for Space Sensor and Subsequent Science Data Access Via Generic Web Services to Form Sensor Web

Approach

This project will help improve data acquisitions by reducing response time and increasing data quantity and quality for the desired earth science data. This will be accomplished in the following ways:
• Provide an interoperability standard
• Enable instant discovery of available sensor resources
• Enable the ability to direct other sensors
• Enable the ability to specify how the available data should be delivered and combined

Co-Is/Partners

• Robert Sohlberg, Chris Justice, John Townshend /U. of Md. College Park
• Jeffrey Masek, Stuart Frye / GSFC
• Stephen Ungar, Troy Ames / GSFC
• Steve Chien / JPL

Key Milestones

• Development of relevant science & operations concepts and scenarios	06/07
• 1st demonstration EO-1 "discoverable"/taskable via Internet and the use of Sensor Model Language (SensorML) & EO-1 Autonomy SW	09/07
• Augment demonstration 1 with Goddard Mission Services Evolution Center (GMSEC) framework in testbed for 2nd demonstration	06/08
• Integration of SensorML, Instrument Remote Control, GMSEC, Core Flight Executive and Cosmic Hot Interstellar Plasma Spectrometer or testbed into 3rd demonstration	03/09
• Full capabilities demonstration, 4th demo	09/09

$TRL_{in} = 3$ $TRL_{current} = 4$

For more information on these and other Earth Science technologies, go to :

http://esto.nasa.gov

Or contact :

Janice L. Buckner
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