GEO-CAPE

Technology Investments

ESTO
Earth Science Technology Office

Mission and Payload:

GEO-CAPE consists of three instruments in geosynchronous Earth orbit near 80°W longitude: a **UV-visible-near-IR wide-area imaging spectrometer** (7-km nadir pixel) capable of mapping North and South America from 45°S to 50°N at about hourly intervals, a **steerable high-spatial-resolution (250 m) event-imaging spectrometer** with a 300-km field of view, and an **IR correlation radiometer** for CO mapping over a field consistent with the wide-area spectrometer. The solar backscatter data from the UV to the near-IR will provide aerosol optical depth information for assimilation into aerosol models and downscaling to surface concentrations. The same data will provide high-quality information on NO2 and formaldehyde tropospheric columns from which emissions of NO*x* and volatile organic compounds, precursors of both O3 and aerosols, can be characterized. Combination of the near-IR and thermal-IR data will describe vertical CO, an excellent tracer of long-range transport of pollution. The high-resolution event imager would serve as a multidisciplinary programmable scientific observatory and an immediate-response sensor for possible disaster mitigation. The data from the high-resolution event-imaging spectrometer would be coupled to the data generated by the wide-area spectrometer through on-board processing to target specific events (such as forest fires, releases of pollutants, and industrial accidents) where high-spatial-resolution analysis would provide benefits. A substantial fraction of its time would be made available for direct support of selected aircraft and ground-based campaigns or special observing opportunities.

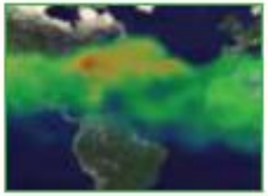
Mission Overview

- Mission Description:
  - Atmospheric gas columns for air quality forecasts;
  - ocean color for coastal ecosystem health and climate emissions

- Instruments:
  - High-spatial-resolution hyperspectral spectrometer
  - Low-spatial-resolution imaging spectrometer
  - IR correlation radiometer

GEOSTATIONARY COASTAL AND AIR POLLUTION EVENTS (GEO-CAPE)

Launch: 2013-2016   Mission Size: Medium



Identification of human versus natural sources of aerosols and ozone precursors

Dynamics of coastal ecosystems, river plumes, and tidal fronts

Observation of air pollution transport in North, Central, and South America

Prediction of track of oil spills, fires, and releases from natural disasters

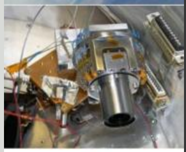
Detection and tracking of waterborne hazardous materials

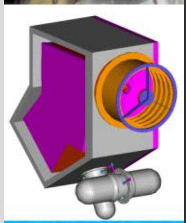
Coastal health

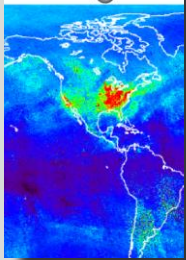
Forecasts of air quality

Update 6-11-08

ESTO Technology Development in Support of
Sentinel Multispectral Atmospheric Composition Measurements
Infrared







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

Update 6-11-08

ESTO Technology Development in Support of

Global Ocean Carbon, Ecosystems, & Coastal Process Measurements

Missions Supported: ACE, GEO-CAPE

Measurement Approach

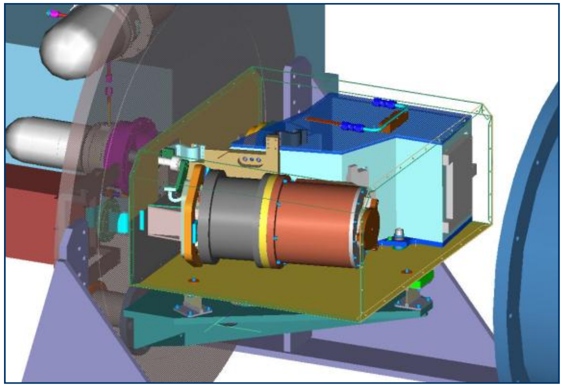
- LEO UV-VIS spectrometer
- GEO high resolution hyperspectral imager

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)

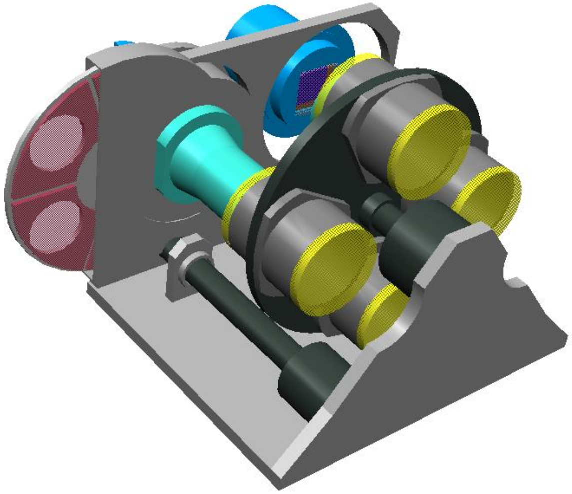
Future Technology Investment Areas

- 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



Instrument Technologies

(Current and Completed ESTO Investments)

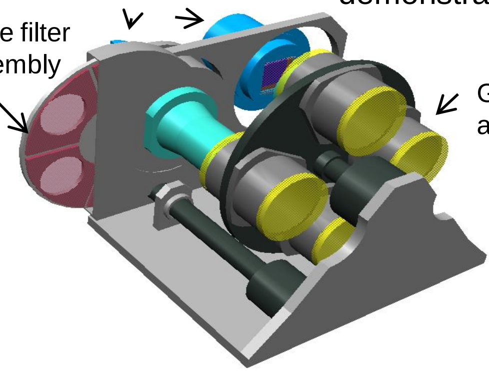


Infrared Correlation Radiometer for GEO-CAPE

PI: Doreen Neil, NASA LaRC

Objective

- Develop Gas Filter Correlation Radiometer technology to demonstrate the 2.3 um performance needed for the GEO-CAPE DS Mission.
  - –Characterize the noise and spectral performance of a laboratory prototype of the SWIR (2.3 um) subsystem of an infrared gas filter correlation radiometer for geostationary carbon monoxide (CO) measurements.
  - –Verify the instrument model to guide evolving GEO-CAPE mission implementation decisions.



Infrared Correlation Radiometer for GEO-CAPE

Measurements at both 2.3 µm and 4.6 µm are required to obtain boundary layer CO.

Approach

•Fabricate the 2.3 um subsystem of an infrared gas filter correlation radiometer specifically designed for geostationary measurements.

•Characterize performance to quantify instrument response functions (spectral , spatial, radiometric, and polarization), and explicitly, an end-to-end noise performance characterization.

•Incorporate these characterizations into the CO measurement modeling system for use in GEO-CAPE mission formulation and payload system engineering.

Co-Is/Partners: Jack Fishman, William Luck NASA LaRC, David Edwards NCAR, Lackson Marufu UMd

Key Milestones

- System Requirements Review 06/09
- Critical Design review 08/09
- Test Plan Review 03/10
- Breadboard Assembly complete 03/10
- Characterizations complete 09/10
- Instrument Performance Model complete 01/11

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

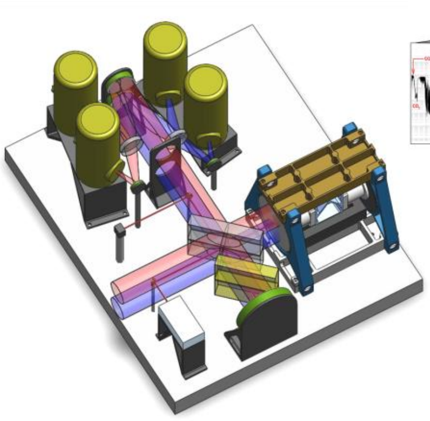
Panchromatic Fourier Transform Spectrometer (PanFTS) Instrument for the GEO-CAPE Mission

PI: Stanley P. Sander, JPL

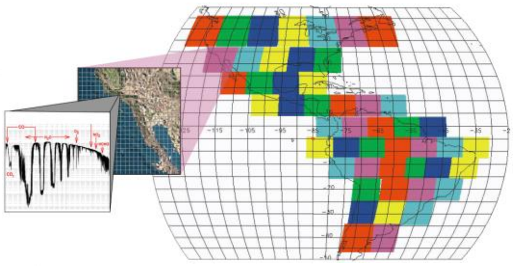
Objective

- Develop detailed instrument requirement set for the imaging Fourier Transform Spectroscopy (FTS) with broad spectral (0.25 – 15 um) range to support the Decadal GEO-CAPE mission.
- Develop a lab PanFTS instrument which demonstrates two key enabling technologies: high-speed, high-dynamic range CMOS hybrid focal plane arrays (FPAs), and parallel, co-aligned optical trains for the ultraviolet-Visible-Near-infrared (UV-Vis-NIR), and mid-IR bands.
- Verify the performance of PanFTS by acquiring and analyzing atmospheric spectra from JPL's California Laboratory of Atmospheric Remote Sensing (CLARS).

PanFTS Instrument Architecture



PanFTS Observational Approach



The geostationary orbiting PanFTS will sequentially imaging ~50 patches for ~1 minute each with an 900km X 900km IFOV using a 128 X 128 pixel array to provide 7-km pixel resolution and 0.06 cm^{-1} spectral resolution

Approach

- Develop detailed instrument design specifications on FPAs, FTS scan mechanism and interferometer optics
- Issue Request for Information to industry for FPA detectors and electronics
- Verify scan mechanism by life testing
- Procure key components, build/test lab instrument
- Field deployment/test at CLARS Facility

Key Milestones

- Complete instrument requirements definition 12/08
- Complete instrument design 06/09
- Deliver Scan Mechanism 12/09
- Deliver UV FPA 03/10
- Deliver IR FPA 07/10
- Complete instrument assembly 09/10
- Complete field testing at CLARS Facility 08/11

Co-Is/Partners:

R. Beer, J-F Blavier, K. Bowman, A. Eldering, R. Key, D. Rider, G. Toon, W. Traub, J. Worden, JPL

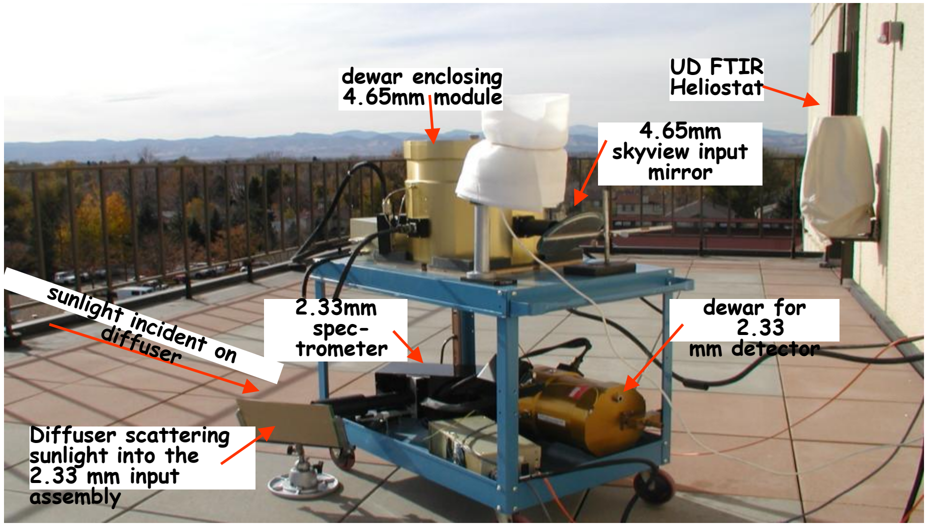
TRL_{in} = 3 $TRL_{current}$ = 3

Tropospheric Infrared Mapping Spectrometers (TIMS) for CO

PI: John Kumer, Lockheed Martin Adv. Tech. Center

Objective

- Develop a miniaturized version of an infrared Grating Mapping Spectrometer (GMS) prototype for mapping tropospheric CO profiles.
- Validate operational performance in a field demonstration campaign.
- Based on validation results, generate a design recommendation for a flight instrument version.



TIMS and FTIR data acquisition at UD, Nov. 2007

Accomplishments

- Developed VSWIR and MWIR portable brassboard spectrometers with required spectral resolution and sensitivity; achieved
  - Noise equivalent radiance NEdN = 2.74E-10 & 1.28E-10 W/(cm2srcm-1) for VSWIR & MWIR, respectively, better than threshold values 8E-10 & 2E-10 as stated in the original proposal
  - Spectral resolution .25 & .53 cm-1 as compared to goals 0.13 and 0.2 cm-1, however these actuals are far better than achieved by previous spectrometers such as SCIAMACHY or AIRS, and coupled with the low noise have facilitated excellent CO retrieval
- Demonstrated ability to acquire high quality atmospheric spectra in ground-based tests
- Validated retrieval of CO profiles from these spectra through comparison with Denver University FTS measurements
- Measurement concept has been demonstrated through ground measurements campaigns
- Developed concepts for flight instrument design, operation, and data production – focus has been on GEO-CAPE Mission

Co-Is/Partners: AE Roche, R. Rairden, JL Mergenthaler, Lockheed; F. Murcray, Denver University; L. Straw, UMBC; R. Chatfield, NASA ARC

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

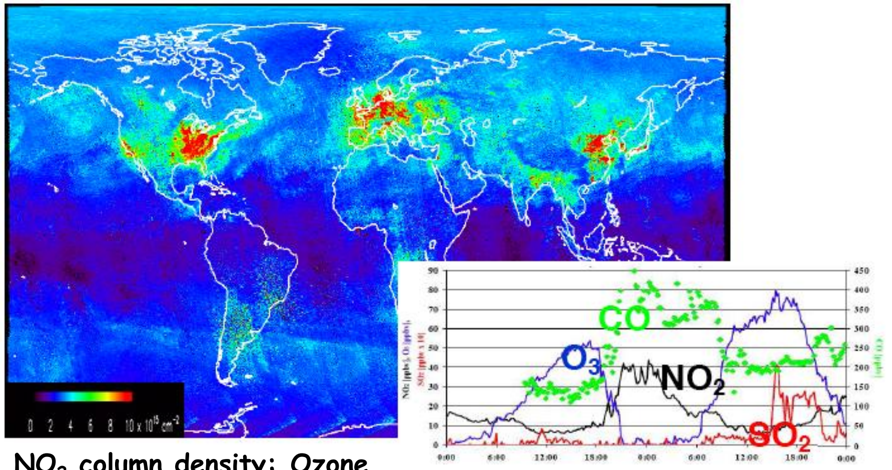
ESTO Earth Science Technology Office

Geostationary Spectrograph (GeoSpec) for Earth and Atmospheric Science Applications

PI: Dr. 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

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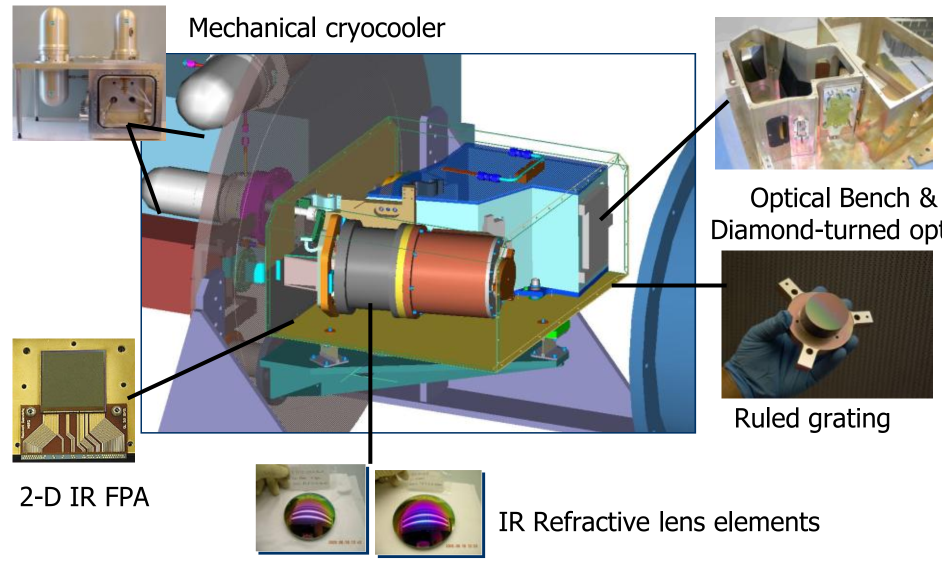
SIRAS-G, the Spaceborne Infrared Atmospheric Sounder for GEO

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



Accomplishments

- 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)

Partners

Bill Folkner/Jet Propulsion Laboratory

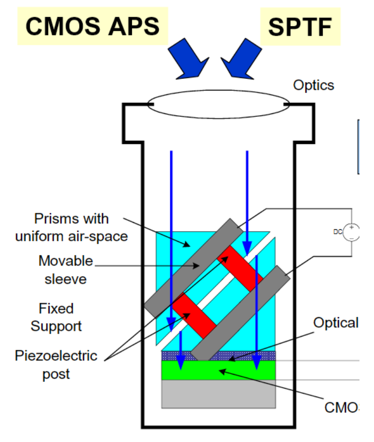
TRLin= 2 TRLout= 4

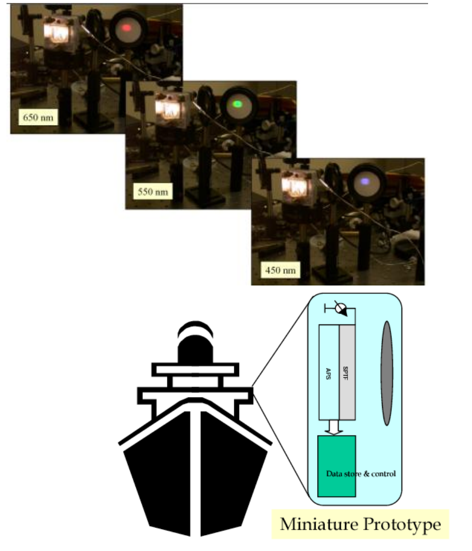
Multi-Spectral Staring CMOS Focal-plane Array for Oceanographic Imaging Applications

PI: Mithu Pain, JPL

Objectives

Develop an advanced, low-cost, compact, high-resolution, staring multi-spectral digital focal-plane array (FPA) based on demonstrated CMOS Active Pixel Sensor (APS) and Surface-Plasmon-Tunable-Filter (SPTF) technologies. The instrument component will find use in Oceanography and Meteorology, atmospheric chemistry, cloud studies, aerosol studies, studies relating to vegetation recovery, volcanic ash characteristics, flood characterization, and land-cover usage and changes.





Accomplishments

Developed a new multi-spectral imager by integrating a Surface-Plasmon-Tunable-Filter (SPTF) with a CMOS imager.

- Unlike other spectral devices, this unit operates in a spectral-sequential manner, providing output at one wavelength over the entire field-of-view.
- The center-frequency (or wavelength) can be changed across the entire visible band and is tunable on-the-fly by changing the applied voltages on the SPTF.
- The instrument is small and compact (<100 g, < 16 cm^3) and is low-power (<100 mW) due to the use of a CMOS imager and due to the absence of any d.c. current draw by the SPTF.

Developed a megapixel imager with superior performance compared to previous generation in terms of cross-talk, noise, linearity, and signal handling capacity.

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

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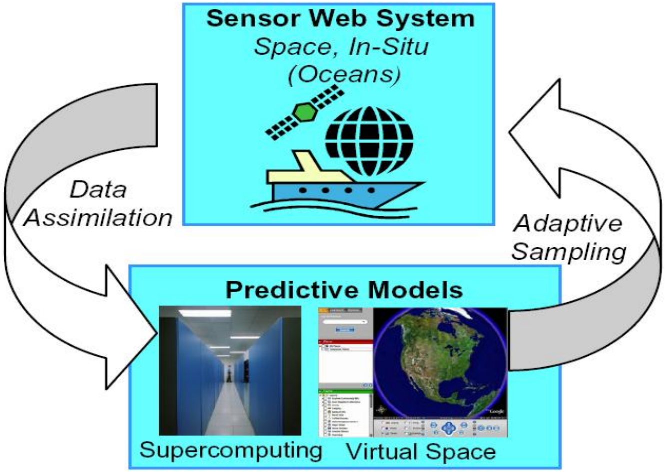
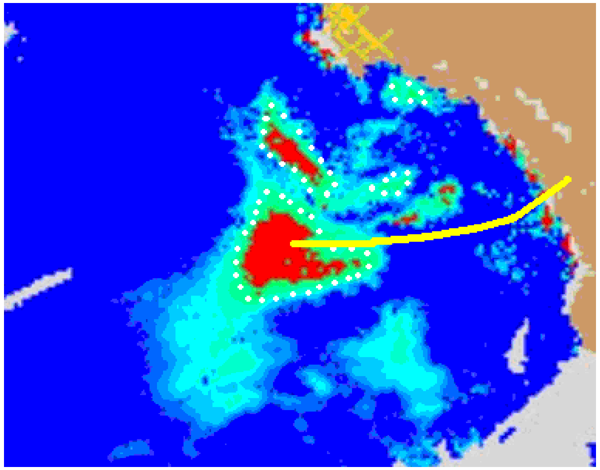


Information Systems Technologies

(Current and Completed ESTO Investments)

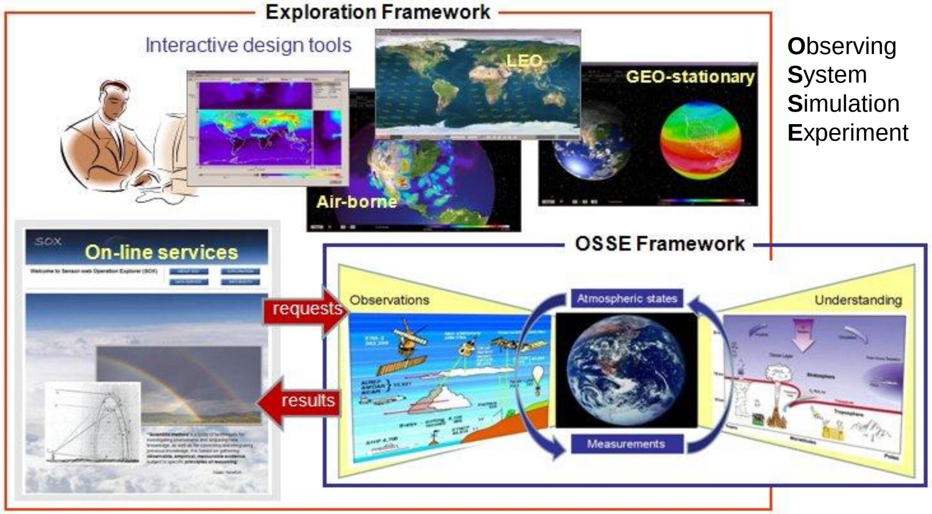


Sensor-Web Operations Explorer (SOX)

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.



Observing System Simulation Experiment

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

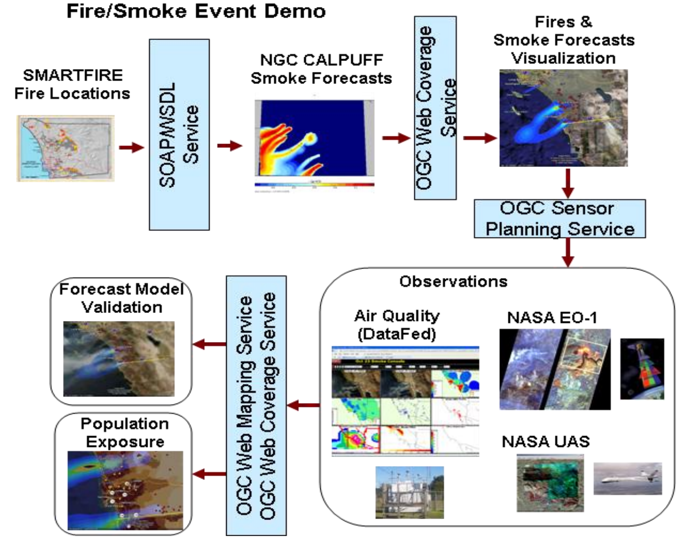
Sensor-Analysis-Model Interoperability Technology Suite

PI: Stefan Falke, Northrop Grumman IS

Objective

The Sensor-Analysis-Model Interoperability Technology Suite (SAMITS) fosters two-way data & control flow between active sensors & data analysis/modeling tools.

- Develop SAMITS package:
  - Standards,
  - Technologies,
  - Methods,
  - Use cases,
  - Guidance for implementing networked interaction between sensor webs and models.
- Test SAMITS through use case applications tying together atmospheric, air quality, & fire sensors with weather & smoke forecasting models.



SAMITS Fire/Smoke Event Demo

Approach

- Use & extend geospatial interoperability & emerging sensor web standards, e.g. Open Geospatial Consortium (OGC) Sensor Web Enablement specifications, to bridge the gap between sensors & models.
- Test framework through multi-project, multi-organization testbeds & pilots, such as OGC, GEOSS & Empire Challenge.

Co-Is/Partners

- Don Sullivan/NASA ARC
- Rudolf Husar/Washington Univ. in St. Louis
- Mike Botts/Univ. of Alabama in Huntsville

Key Milestones

• Initial web service access to sensor observations	11/2006
• Use SensorML/SOS to encode sensors/obs.	2/2007
• Integrate ARC Sensor Planning Service	10/2007
• Extend sensor standards for sensor/model interop.	12/2007
• Demonstrate sensor-model interaction	3/2008
• End-to-end workflow with services & models	7/2008
• Define sensor-model implementation profile	5/2009
• Test catalog & services within applications	5/2009
• Complete SAMITS documentation & package	7/2009
• OGC-based catalog extended to SOS/SPS	9/2009

TRL_{in} = 4, $TRL_{current}$ = 6

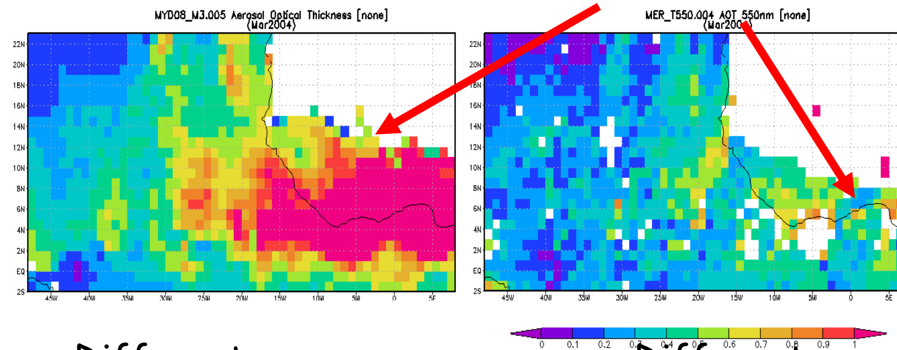
Multi-Sensor Data Synergy Advisor (MDSA)

PI: Gregory Leptoukh, NASA GSFC

Objective

- Augment Giovanni, the Goddard online tool for data access, visualization and analysis, with semantic web technologies and ontologies to support data inter-comparisons from different sensors or models.
- Data provenance (i.e., the essential data parameter details, quality, and production caveats) will be added to enable researchers to make valid data comparisons and draw quantitative conclusions on specific analysis (e.g., ocean fertilization due to acid rain).
- The resulting Giovanni framework enables encoding the dataset variable characteristics and related quality so that inter-comparison rules can be derived. Giovanni will support GeoCAPE data analysis, as well as ACE and GACM.

Same parameter — Same space & time



Different provenance → Different result

Figure illustrates that the lack of provenance data can produce very different results with the same data.

Approach

- Capture scientist knowledge (rulesets) of the science & data quality characteristics
- Encode this knowledge so a computer can retrieve it
- Present only the safe comparisons, or the caveats for speculative comparisons
- Provide user-tunable quality screening
- Generate the Giovanni workflow and record the associated provenance

Co-Is/Partners:
Chris Lynnes, NASA GSFC; Peter Fox, RPI; Ana Prados, UMBC; Suhung Shen, GMU

Key Milestones

• Use Cases Formulation	09/09
• Ontology and Ruleset Development	03/10
• Ontology Tool Prototype Deployment	09/10
• User Interface Proof of Concept	03/11
• Advisor Service Integration	09/11
• Use Case Implementation and Validation	03/12

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

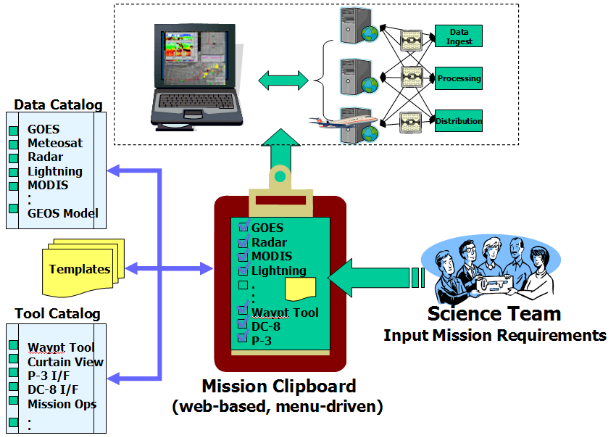
Technology Infusion for the Real Time Mission Monitor

PI: Michael Goodman, NASA MSFC

Objective

- Develop a science decision-making tool, built upon a service oriented architecture that seamlessly integrates multiple applications for facilitating the monitoring and management of airborne assets in NASA Earth science ground validation and field campaigns
- Redesign, implement, and operate the Real Time Mission Monitor (RTMM) from a web portal utilizing applications on a common framework for science data visualization and airborne mission management

Auto Configuration Approach



Schematic flow diagram depicting the basic inputs and resource catalogs used by the Mission Clipboard to auto-configure the RTMM system for a specific mission

Approach

- Define and design a service oriented, architecture based, decision support system utilizing sensor web-enabled data access & services
- Design and build a Mission Clipboard (an interactive web-based tool that will allow mission managers and/or science team members to build a mission-specific RTMM applications)
- Conduct integrated system field demonstration

Co-Is/Partners:

R. Blakeslee, P. Meyer, NASA MSFC; D. Hardin, M. He, J. Hall, Y. Lu, and K. Regner, UA Huntsville

Key Milestones

- Prototype Mission Clipboard sys defined & designed 10/09
- Initial prototype Mission Clipboard system demo 04/10
- Initial data sources for system catalogs selected 06/10
- Prototype Mission Clipboard used in field experiment 09/10
- System requirements from field experiences revised 12/10
- System upgrades per science team advice completed 05/11
- Upgraded Mission Clipboard demo in field experiment 07/11
- System requirements from field experiences revised 10/11
- Final system upgrades and documentation completed 03/12

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

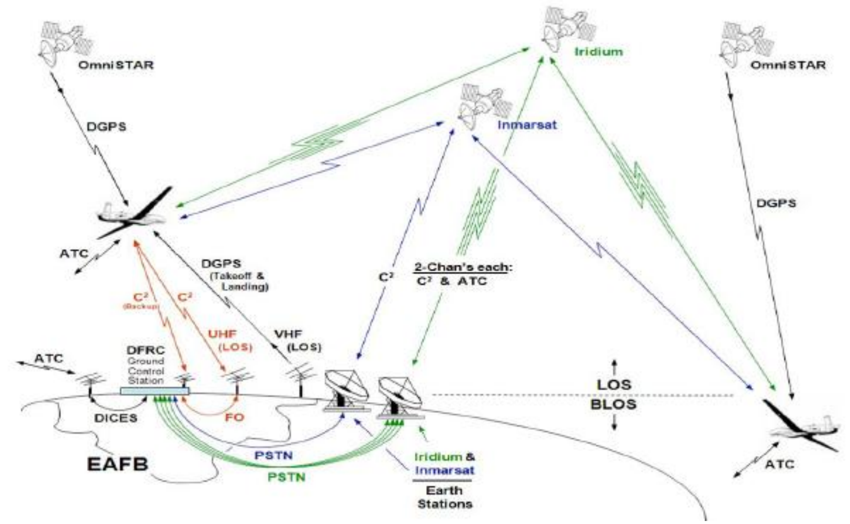
ESTO Earth Science Technology Office

Real-Time and Store-and-Forward Delivery of Unmanned Airborne Vehicle Sensor Data

PI: Will Ivancic, NASA GRC

Objective

- Develop and deploy a mobile communication architecture based on Internet technologies
- Improve the data throughput by developing and deploying technologies that enable the efficient use of the available communications links. Such technologies may include:
  - Delay/Disruption Tolerant Networking (DTN)
  - Improvements to the Saratoga transport protocol (implementing a rate-based feature and congestion control)
  - Development of a protocol that advertises link properties from modem to router



Flight Control & Air Traffic Control Communications Architecture

Approach

- Collaborate with ARC and their satellite service providers to develop and deploy mobile networking technologies to meet ARC's needs and address all of the satellite service provider requirements
- Collaborate with Cisco Systems & appropriate radio manufacturers to develop a rate-based implementation of Saratoga and a modem link-property advertisement protocol
- Conduct integrated tests of the architecture and protocols using flight sensor data in a relevant environment

Co-Is/Partners: Don Sullivan, NASA ARC

Key Milestones

• Mobile communications architecture developed	09/09
• Rate-based transport protocol developed	03/11
• Store-and-forward protocol developed	06/11
• Radio-to-router Layer-2 trigger protocol developed	03/12
• Integrated demonstration	09/12

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

Earth Science Technology Office

Telesupervised Adaptive Ocean Sensor Fleet

PI: John M. Dolan, Carnegie Mellon University (CMU)

Objective

- Improve in-situ study of Harmful Algal Blooms (HAB), coastal pollutants, oil spills, and hurricane factors
- Expand data-gathering effectiveness and science return of existing NOAA OASIS (Ocean Atmosphere Sensor Integration System) surface vehicles
- Establish sensor web capability combining ocean-deployed and space sensors
- Provide manageable demands on scientists for tasking, control, and monitoring

Telesupervised Adaptive Ocean Sensor Fleet investigating a Harmful Algal Bloom (simulated with water-tracing dye).

Approach

- Telesupervise a networked fleet of NOAA surface autonomous vehicles (OASIS)
- Adaptively reposition sensor assets based on environmental sensor inputs (e.g., concentration gradients)
- Integrate complementary established and emergent technologies (System Supervision Architecture, Inference Grids, Adaptive Sensor Fleet, Instrument Remote Control, and OASIS)
- Conduct thorough, realistic, step-by-step testing in relevant environments

Co-Is/Partners:
Jeffrey Hosler, John Moisan, Tiffany Moisan, GSFC; Alberto Elfes, JPL; Gregg Podnar, CMU; John Higinbotham, Emergent Space Technologies

Key Milestones

• Interface Definition Document	02/07
• Test components on one platform in water	05/07
• Autonomous multi-platform mapping of dye	07/07
• Science requirements for Inference Grid	02/08
• Multi-platform concentration search simulation	05/08
• HAB search in estuary for high concentration	07/08
• Moving water test plan & identify location	02/09
• Simulate test using in-situ and MODIS data	05/09
• Use MODIS data to target and reassign fleet	07/09

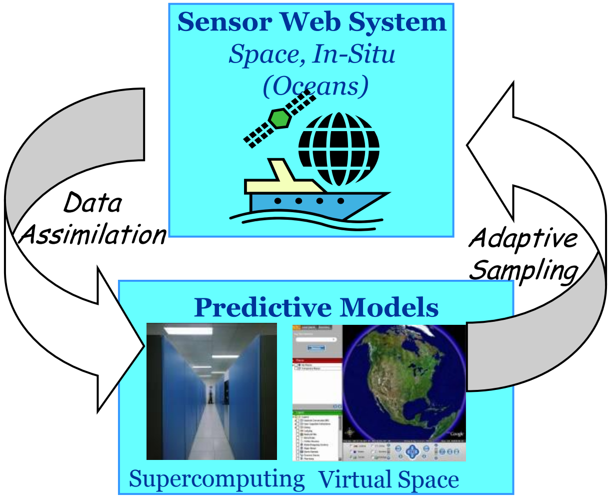
$TRL_{in} = 4$ $TRL_{current} = 6$

A Smart Sensor Web for Ocean Observation: System Design, Modeling, and Optimization

PI: Payman Arabshahi, University of Washington (UW)

Objective

- Design, develop, and test an integrated satellite and underwater acoustic communications and navigation sensor network infrastructure and a semi-closed loop dynamic sensor network for ocean observation and modeling. Key features include
    - reconfiguration of sensor assets
    - adaptive sampling, targeted observations
    - autonomous event detection,
    - built-in navigation on mobile nodes (Seagliders),
    - high-bandwidth, high-power observation on cabled seafloor and stationary nodes.
- Perform science experiments in Puget Sound or Monterey Bay, enabled by such a network, and evolve them to growing levels of sophistication over 3 years.



Semi-closed loop dynamic smart ocean sensor web architecture

Approach

- Develop a comprehensive acoustic sensor network architecture, engineering model, and telecom protocols, including features and evaluation performance metrics.
- Develop a full and accurate software simulation environment, incorporating network element models, and the developed protocols.
- Perform laboratory tests and ocean sensor web data collection experiments.
- Develop the interface between the ocean smart sensor web and the Regional Ocean Modeling System (ROMS) predictive model, operate it in near real-time, assimilating acoustic measurements.

Co-Is/Partners:

Andrew Gray, AGCI Inc; Yi Chao, JPL/UCLA;
Sumit Roy, UW; Bruce Howe, University of Hawaii

Key Milestones

- Prepare satellite sensor data for Monterey Bay 03/07
- Software demonstration of 2-element network 09/07
- Architecture description document 09/07
- Test and refine the ROMS prediction 03/08
- Develop MAC and network layer protocols 05/08
- Full-scale software demonstration, modeling of network elements, and a 4-element network 07/08
- Ocean sensor web experiments at Monterey Bay 01/09
- Demonstration of first prototype of integrated satellite/acoustic sensor network 01/09
- Complete data analysis from field demonstration 08/09

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

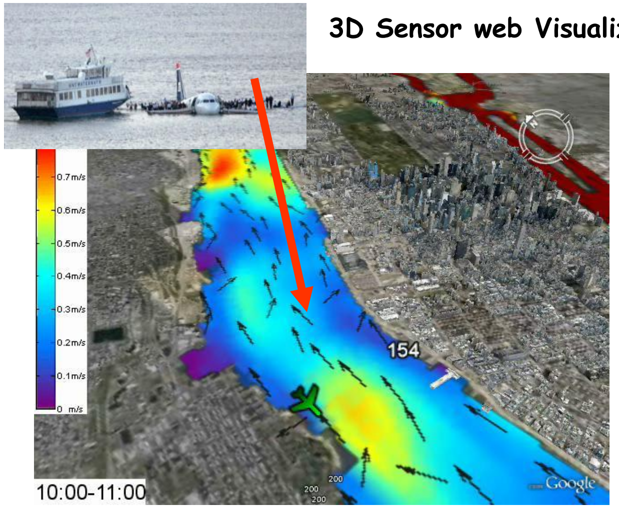
Autonomous In-situ Control and Resource Management in Distributed Heterogeneous Sensor Webs (CARDS Follow-On)

PI: Ashit Talukder, Jet Propulsion Laboratory

Objective

- Design and develop advanced visualization tools for Coastal New York Harbor Observation and Prediction (NYHOPS) Sensor Web
- Deploy automated visualization toolkit on the world wide web for use by general public and customers of the NYHOPS system
- Enable better understanding of coastal and maritime conditions in New York/New Jersey area using advanced visualization capabilities
- Allow visualization of adaptive CARDS sensor web control of NYHOPS mobile/static resources

3D Sensor web Visualization and Dissemination



Original 2D system used in real-time to assess deployment of rescue boats to USAir 1549 crash.

New 3D CARDS system (shown) validated against original 2D system and adopted for current and future use.

Accomplishments

- Added division of model region into multiple sub-regions at different resolutions to trade-off between image size and resolution
- Implemented display of vector data by overlaying two layers
- Rendered same data with different colormaps to improve visualization
- Developed code to provide Google Earth files for different datasets & formats
- Optimized image generation code to significantly reduce generation time
- Integrated visualization code on Steven's Institute of Technology servers
- Designed and deployed supporting documentation for 3D web-page
- Demonstrated practical use of visualization following USAir 1549 crash
    - 2D visualizations of water current direction, and magnitude predictions, helped decide on deployment of rescue boats (3D tools validated offline)

Co-Is/Partners: A. Blumberg & N. Georgas, Steven's Institute of Technology; A. Panangadan, JPL

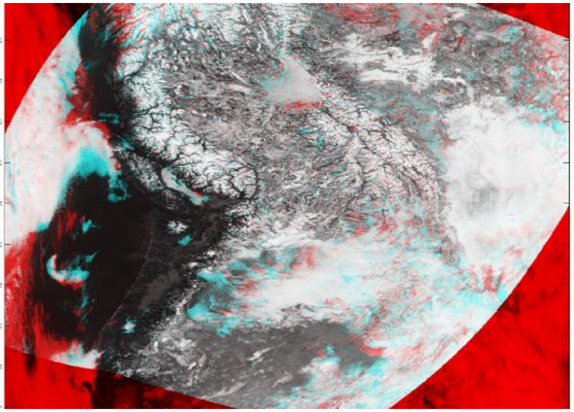
TRL_{in} = 4 TRL_{out} = 8

Adaptive Sky

PI: Michael Burl, (JPL)

Objective

- Enable observations from multiple sensing assets (satellites, in-situ sensors, etc.) to be dynamically combined into "sensor webs".
- Develop an efficient, trusted C-language feature correspondence toolbox that serves the sensor web community as LINPACK (LINear algebra PACKage) has served the numerical computing community.
- Demonstrate fusion of multi-instrument observations into novel data products of high scientific value.



Automatic registration between images taken 100 minutes apart with the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on Aqua (cyan) and the twin MODIS instrument on Terra (red).

Accomplishments

- Detailed scientific use scenarios – Earth Observing System (EOS) match-ups, combining satellite and ground-based cloud imagery, volcanic plume and ash cloud monitoring, Southern California Fires, etc.
- Developed a toolbox that other sensor web projects can use to compare data
- Successful application of techniques to real data:
    - Detection and tracking of clouds in ground imagery using Maximally-stable Extremal Region (MSER) features.
    - Identification and automatic registration of A-Train and Terra coincidences.
    - Automatic stabilization of Geostationary Operational Environmental Satellite (GOES) image sequences.
- Demonstration of multi-instrument fusion within Google Earth – lidar observation of volcanic ash cloud.

CoI: Michael J. Garay (Raytheon)

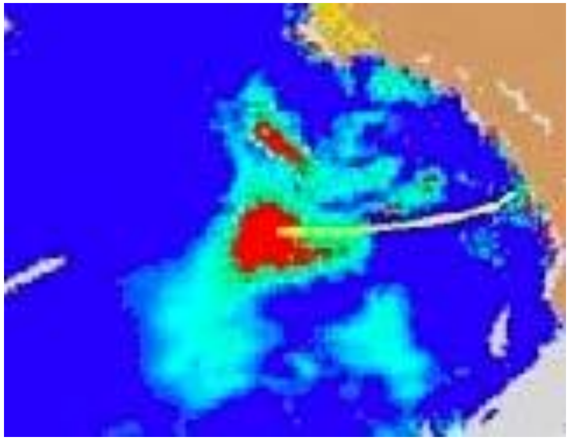
TRL_{in} = 3; TRL_{out} = 4

Spatiotemporal Data Mining System for Tracking and Modeling Ocean Object Movement

PI: Yang Cai, Carnegie Mellon University

Objectives

- This project enables more efficient and less time consuming analysis of oceanographic objects, e.g. river plumes and harmful algal blooms, etc.
- To track the movement of ocean objects that have been identified
- To predict the movement of identified objects.



Tracking and prediction of harmful algae

Accomplishments

- Completed case studies for tracking the harmful algal blooms and river plumes, using SeaWiFS satellite images
- Completed the prototypes of the spatiotemporal data mining toolbox in MATLAB that can easily be used by field researchers and monitoring institutes
- Developed prototype software for object tracking that can help to monitor the harmful algae across regions and is able to automate the visual oceanography process
- Developed the prediction models that combine images and numerical data sources. Results show that the computer model can process more samples (over 2,384) than human manual process (188) with better accuracy in positive detection and positive accuracy

Co-I/Partner: Co-I, Richard Stumpf, NOAA

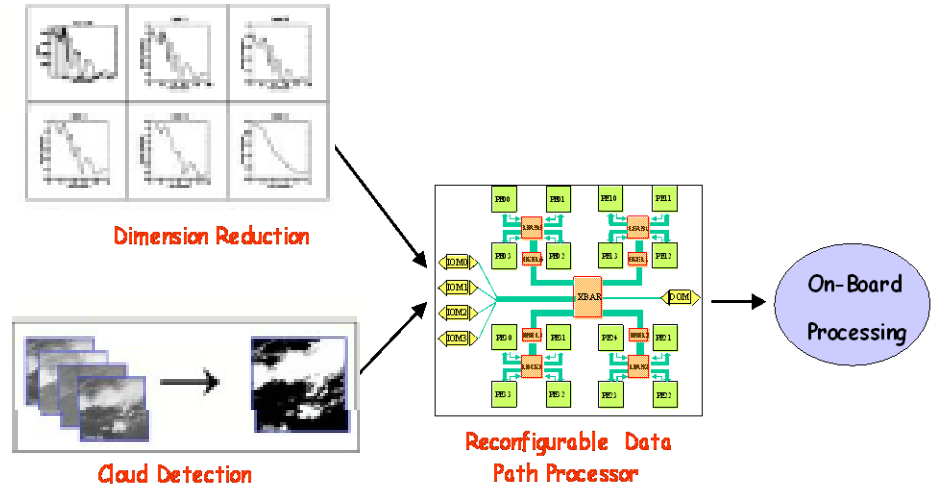
TRL_{in} = 4; TRL_{out} = 6

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

PI: Jacqueline Le Moigne, GSFC

Objective

- Investigate the use of reconfigurable computing for on-board automatic processing of remote sensing data.
- Use Reconfigurable Data Path Processor/Field Programmable Path Array (RDPP/FPPA), a radiation tolerant alternative to Field Programmable Gate Arrays, developed at NASA/Goddard and U. of Idaho as the computation engine of our study.



Reconfigurable Data Processing

Accomplishments

- Performed Algorithms Tradeoff Studies
- Applied and Validated Dimension Reduction to Hyperspectral AIRS Data
- Designed a Flexible FPPA Reconfigurable Processing Testbed ; Designed FPPA Graphical Design Environment
- Performed Algorithm implementation study
- Developed New FPPA Technology Advances/Method &Pilot Software for Accurate Mathematical Computing on Integer Hardware
- Implemented Wavelet-Based Hyperspectral Dimension Reduction on SRC-6: 32X Speedup
- Implemented Automatic Cloud Cover Assessment (ACCA) on SRC-6: 28X Speedup and less than 1% Error Over Water
- Implemented Automatic Image Registration in SRC-6: 4X Speedup

CoIs: P.S. Yeh, J. Joiner, *GSFC.* W. Xia, *GS&T*
G. Donohoe & Team, *U. Idaho,* T. El-Ghazawi & Team, *GWU*

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

Earth Science Technology Office