Aerosol-Cloud-Ecosystems (ACE)

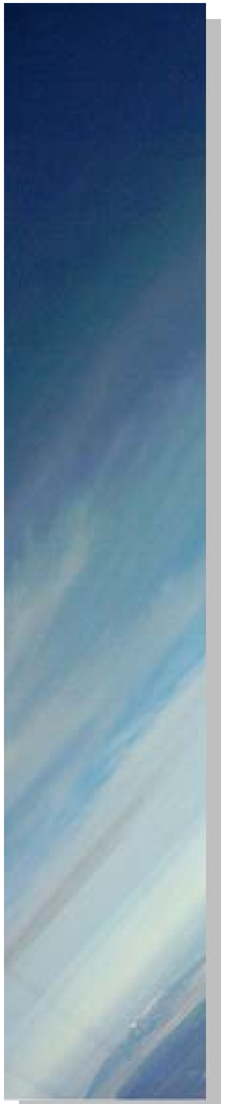
Technology Investments

ESTO
Earth Science Technology Office

Mission and Payload

The primary goal of the Aerosol-Cloud-Ecosystems (ACE) mission is to reduce uncertainty about climate forcing in aerosol-cloud interactions and ocean ecosystem carbon dioxide (CO_2) uptake. Aerosol-cloud interaction is the largest uncertainty in current climate models. Aerosols can make clouds brighter and affect their formation. Aerosols can also affect cloud precipitation and have been linked to decreased rainfall in the Mediterranean. Results from the ACE mission would narrow the uncertainty in climate predictions and improve the capability of models to provide more precise predictions of local climate change, including changes in rainfall. ACE aerosol measurements could also be assimilated into air-quality models to improve air-quality forecasts. Ocean ecosystem measurements would provide information on uptake of CO_2 by phytoplankton and improve estimates of the ocean CO_2 sink. As CO_2 increases, the oceans will acidify, and this will affect the whole food chain, including coral-reef formation. The ACE mission could assess changes in the productivity of pelagic fishing zones and provide for early detection of harmful algal blooms. Benefits of the mission would include enabling the development of strategies for adaptation to climate change, evaluation of the consequences of increases in greenhouse gases, enabling of improved public health through early warning of pollution events, and evaluation of effects of climate change on ocean ecosystems and food production.

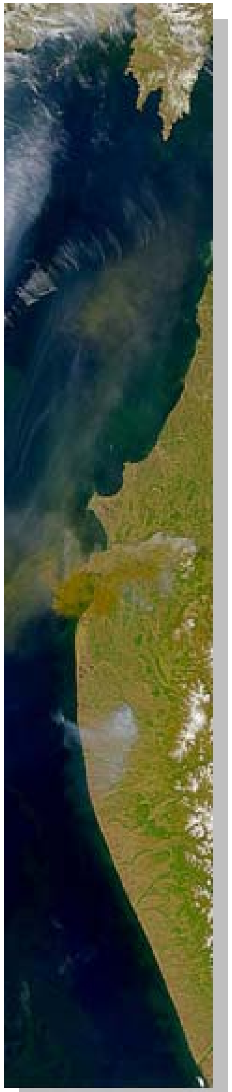
Ref: "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," National Academies Press, 2007



Mission Overview

- **Mission Description**
  - Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry

- **Key Instruments**
  - Multi-beam cross-track dual wavelength lidar
  - Cross-track scanning cloud radar (Ka/W band)
  - Multiangle, multi-wavelength polarimeter
  - Multiband, cross-track visible-UV spectrometer



Ref: “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,” National Academies Press, 2007

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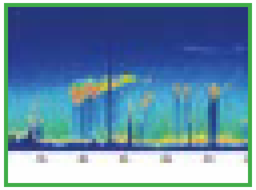
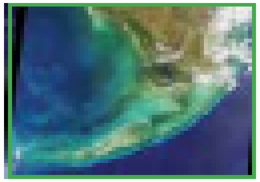
AEROSOL-CLOUD-ECOSYSTEMS (ACE)

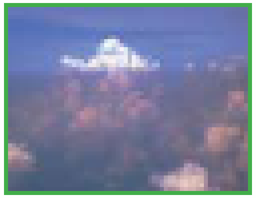
Launch: 2013-2016   Mission Size: Large



Cloud and aerosol height



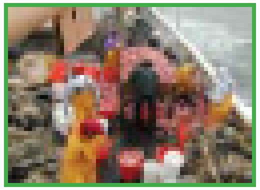
Organic material in surface ocean layers



Aerosol and cloud types and properties

Improved climate models

Prediction of local climate change



Ocean productivity

Ocean health

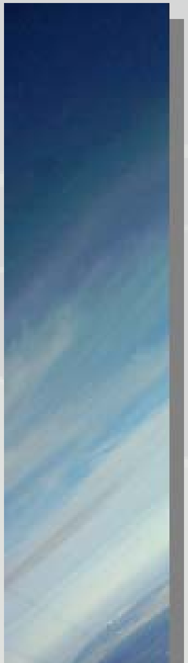
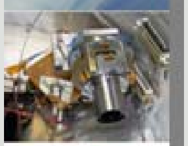
Air-quality models and forecasts

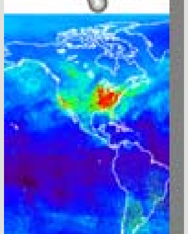
Ref: “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,” National Academies Press, 2007

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

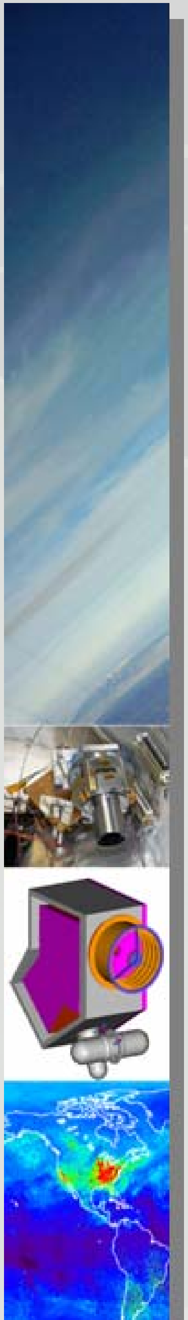
- Completed 2nd instrument technology advancement of SIRAS-G, a WFOV, multi-grating/channel IR spectral imager concept designed for LEO or GEO. Lab demonstrated fully functional imaging MWIR spectrometer (3.35-4.8 micron) operating at cryogenic temperatures. (T. Kampe- IIP2 & IIP3)
- Developing TIMS, 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)

ESTO Technology Development in Support of

Sentinel Multispectral Atmospheric Composition Measurements

UV/VIS/NIR

Update 6-11-08



Missions Supported: ACE, GACM , GEO-CAPE

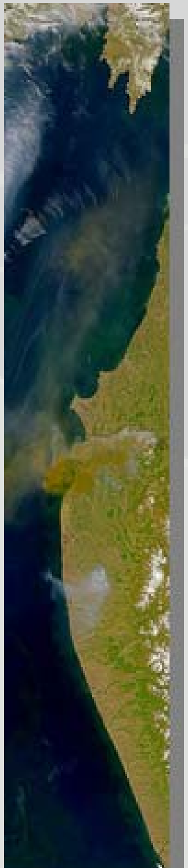
Measurement Approach

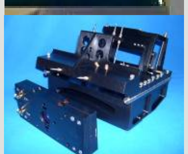
A multispectral spectrometer (UV/VIS/NIR) that accurately measures atmospheric composition profiles from LEO and GEO

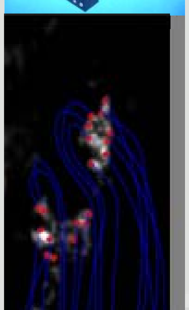
Earth Science Technology Office (ESTO) Investments

- **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)**
- **Developed an engineering model Wide Field-of-View imaging spectrometer, hyperspectral imaging system providing continuous wavelength coverage from the UV to NIR with better than 1-nm spectral resolution and an instantaneous field-of-view of 1 km x 1 km at a 705-km circular orbit (R. Pollock IIP-98)**
- **Development and demonstration of the 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)**
- 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)
- **Retirement of technology risk associated with the multi-angle, high-accuracy polarimetric spectrometer for the ACE mission for detailed measurements of atmospheric clouds and aerosol (Diner/JPL-IIP07)**

Next Generation Aerosol Measurements







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Missions Supported: ACE

Measurement Approach

A payload suite that includes a multi-angle multi-spectral imaging polarimeter, a Ka/W-band dual-frequency Doppler radar, a multi-wavelength high spectral resolution backscatter and extinction lidar

Earth Science Technology Office (ESTO) Investments

- Development and Demonstration of an Optical Autocovariance Direct Detection Wind Lidar (Grund/Ball-IIP07)
- Full spectropolarimetric validation and performance enhancements for a hyperspectral polarimeter for aerosol retrievals (HYSPAR) (Jones/SBIR Phase III)
- Retirement of technology risk associated with the multi-angle, high-accuracy polarimetric spectrometer for the ACE mission for detailed measurements of atmospheric clouds and aerosol (Diner/JPL-IIP07)
- Development and characterization of an ocean radiometer to enable the measurement of the ocean phytoplankton species composition & uptake of CO_2 by measuring ocean color in support of ACE mission (McClain/GSFC-IIP07)
- Advancement and aircraft (UAV) demonstration of the high-energy pump laser technologies and UV conversion techniques for spaceborne ozone and aerosol lidar applications (Browell/LaRC-II P04)
- Develop transmitter and receiver technologies for a combined High Spectral Resolution Lidar (HSRL) and Differential Absorption Lidar (DIAL) instrument for aerosols and ozone measurements (Hostetler/LaRC-IIP 04)
- Development and airborne demonstration of a Ku/Ka-band dual frequency, Doppler, polarimetric, scanning precipitation and cloud radar for TRMM Follow-On missions (Im/JPL-IIP 98)
- Development and laboratory demonstration of dual-band (Ka & W) radar for cloud and precipitation measurements (Durden/JPL-IIP07)
- Lab demonstration of rad-tolerant FPGA-based 4-channel radar data processor (with EDAC) and controller for adaptive rain scene targeting. This technology enables 3X increase in swath coverage and 2X data reduction (Berkun/JPL - AIST99)
- Lab demonstration of a breadboard single-chip, FPGA-based real-time processor for computing full Doppler spectrum of precipitation (Durden/JPL – AIST01)
- Development and laboratory demonstration of a prototype model of a dual frequency, wide-angle beam-pointing, membrane antenna for spaceborne rainfall measurements (Im/JPL-IIP 01)
- Development of the Adaptive Sky Cloud Science Sensor Web simulation for global atmospheric cloud monitoring (Burl/JPL-AISTQRS)

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ESTO Technology Development in Support of

Global Ocean Carbon, Ecosystems, & Coastal Process Measurements

Missions Supported: ACE, GEO-CAPE

Measurement Approach

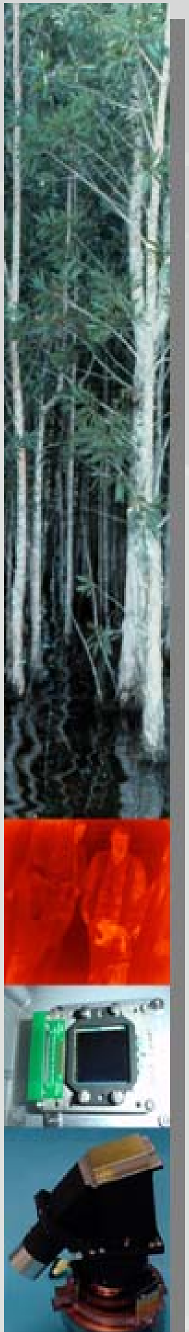
- **LEO UV-VIS spectrometer**
- GEO high resolution hyperspectral imager

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)**

ESTO Technology Development in Support of

Physiology & Functional Group Measurements



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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 (256 X 256) array VIS-NIR blind 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)**

Polarimeter
Instrument Technologies

(Current and Completed ESTO Investments)

SWIR Aerosol/Cloud Polarimetric Imager

PI: David Diner, JPL

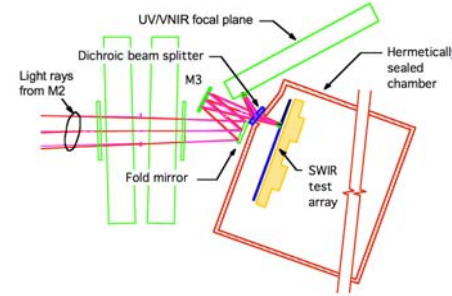
Objectives:

- Retire technology risk associated with the multi-angle, high-accuracy polarimetric spectrometer for the Aerosol-Cloud-Ecosystems (ACE) mission for detailed measurements of atmospheric clouds and aerosol
  - By extending the polarimetric imaging approach from the ultraviolet/visible/near-infrared (UV/V/NIR) band into the shortwave infrared (SWIR)

Technologies to be developed:

- Diattenuation-compensated dichroic beamsplitter.
- Miniature SWIR spectropolarimetric filters in the 1610 - 2130 nm range.

Brassboard camera with dual photoelastic modulator assembly in the foreground. (This multi-angle UV/V/NIR polarimetric spectrometer has been developed through ESTO IIP.)



Modified camera design incorporating a dichroic beamsplitter, UV/V/NIR, and SWIR focal planes.

Approach:

- Design, fabricate, and test (a) diattenuation-compensated dichroic beamsplitter, (b) quarter-waveplate (QWP) with visible-to-SWIR performance, (c) miniaturized filters and polarizers
- Rebalance the diattenuation compensation performance of the camera mirror coatings
- Incorporate commercial SWIR detector array
- Develop the cooling system for the laboratory SWIR focal plane and a conceptual thermal design for the satellite sensor
- Integrate and test the brassboard camera

Co-I:

- Russell Chipman, University of Arizona

Key Milestones:

- Upgrade laboratory Mueller Matrix Polarimeter 02/09
- Complete preparation on SWIR filter testing 04/09
- Complete beamsplitter and QWP design 05/09
- Develop lab cooling system for SWIR detector 10/09
- Complete calibrated SWIR detector 01/10
- Complete Beamsplitter and QWP testing 04/10
- Integrated focal plane subassembly 07/10
- Integrate camera 08/10
- Complete camera system test 01/11

TRL_{in} = 3

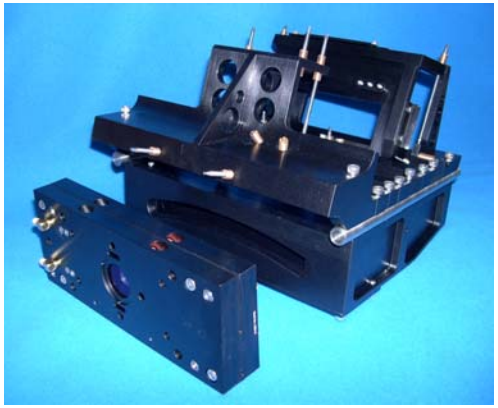
ESTO
Earth Science Technology Office

Aerosol Spectropolarimetric Camera

PI: David Diner, JPL

Objectives:

- Retire risk of key technologies for a new-generation spaceborne imager, integrating the unique strengths of multispectral, multiangle, and high-accuracy polarimetric approaches for atmospheric clouds and aerosol measurements.
  - This polarimetric spectrometer will be a primary instrument of the Aerosol-Cloud-Ecosystems (ACE) Mission
- Technologies include:
  - A ruggedized photoelastic modulator (PEM) to extract accurate linear polarization imagery
  - Robust optics preserving radiometric and polarimetric fidelity of the measurements
  - Miniature spectropolarimetric filters



Brassboard camera (back) and
dual-photoelastic modulator (PEM, front)

Approach:

- Upgrade a commercial PEM.
- Design, fabricate, and test a brassboard camera with reflective optics and an integrated half-FOV, 660-nm focal plane.
- Design, fabricate, and test components necessary to demonstrate upgradability of camera to 355-935 nm operation.
- Derive requirements for a space camera from studies of applications in ultraviolet, visible, near-infrared, and shortwave infrared

Co-Is:

- Jet Propulsion Laboratory
- University of Arizona
- Hampton University
- NASA-GISS

Key Milestones:

- Completed test of PEM in launch environments (Advance TRL from 3 to 5) 01/07
- Verify that Filters meeting performance goal 05/08
- Integrate 660-nm camera 05/08
- Test 660-nm camera in lab environment 08/08
- Test 660-nm camera in outdoor environment 09/08
- Test the components for multiwavelength camera in lab environment 09/08
- Complete specification and implementation plan for the nine-camera flight instrument 09/08

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

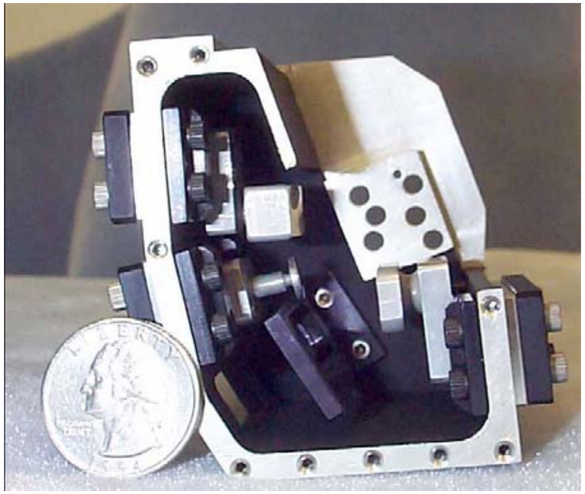
ESTO Earth Science Technology Office

Multi-angle Imaging SpectroRadiometer 2 (MISR-2)

PI: David Diner, JPL

Objectives:

- Develop several key technologies needed for the next generation multi-angle imaging spectroradiometer to measure aerosols, clouds heights, and distribution of land surface cover. Such technologies will demonstrate:
  - A significant size and mass reduction in the optical system
  - A >50% volume reduction of the camera electronics board
  - That filters can be cut and bonded to meet the more stringent packaging requirements of 80 μm center-to-center spacings (which is a 2x reduction from the MISR dimensions)



MISR-2 Camera

Accomplishments:

- Achieved all major goals of the MISR-2 activity
- Demonstrated that all-reflective camera has adequate performance
  - The all-reflective design opens new possibilities for MISR-2 cameras in terms of both spectral range and polarization
- Developed and demonstrated the MISR-2 electronics with capability for 6 signal chains
- Achieved the targeted size, mass, volume, and cable complexity reductions
- Developed the MISR-2 Electrical Ground Support Equipment
  - It can be used during any future MISR-2 development efforts with minimal modifications
- Demonstrated that significant reductions in filter size are possible

Partners: Barr Associates, SSG Inc.

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

Full Spectropolarimetric validation and performance enhancements for the Hyperspectral Polarimeter for Aerosol Retrievals (HySPAR)

PI: Stephen H. Jones, Aerodyne Research, Inc.

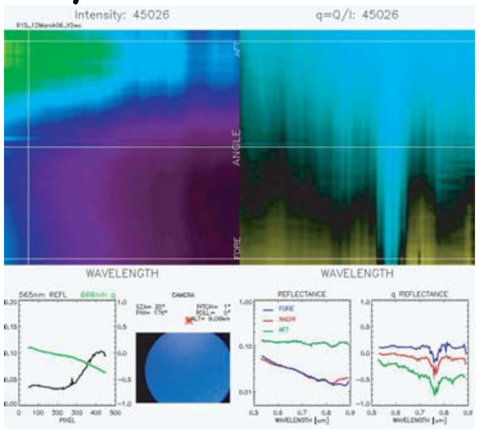
Objectives:

• Validate Level 1 data products – Stokes parameters using HyperSpectral Polarimeter for Aerosol Retrievals (HySPAR) designed and built under SBIR Phase II.

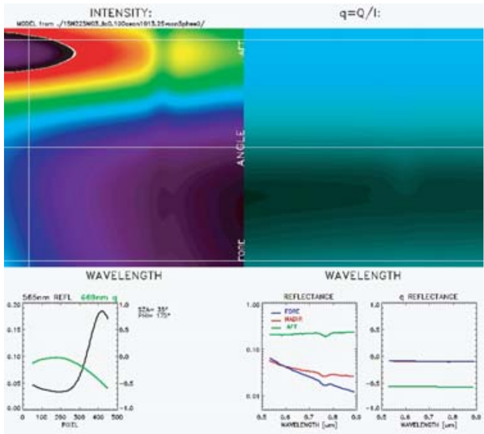
• Validate Level 2 data products – aerosol properties for uplook, downlook over water, and downlook over land.

• Demonstrate flightworthiness through a series of flights w/ LaRC's High Spectral Resolution Lidar (HSRL) and LaRC's A-band spectrometer (LAABS) sensors.

HySPAR Data Frame



Model Calculation



Accomplishments:

- Successful operation of HySPAR during all 15 Megacities Initiative: local & global research observations (MILAGRO) flights on an aircraft.
- Successful comparison of Level 1 data with the Research Scanning Polarimeter during coordinated flight.
- Learned that aircraft environment requires special algorithmic techniques to account for thermally induced sensor effects.
- Advanced the state-of-the-art in polarimetry including increased spectral resolution and addition of circular component of Stokes vector.
- Investigated successfully the combined active-passive retrieval techniques employing polarimetry and lidar.

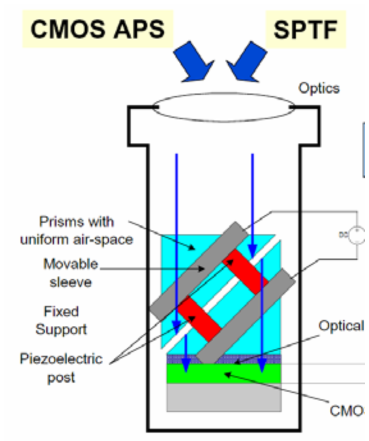
TRL_{in} = 4 TRL_{out} = 6

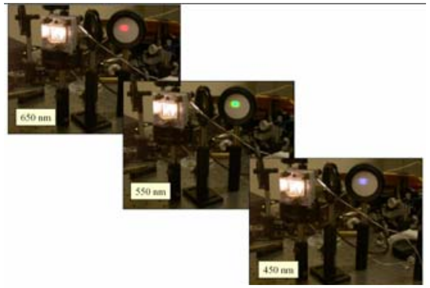
Multi-Spectral Staring CMOS Focal-plane Array for Oceanographic Imaging Applications

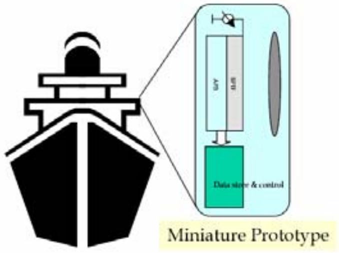
PI: Mithu Pain, JPL

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 gm, < 1inch^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

Spectrometer Instrument Technologies

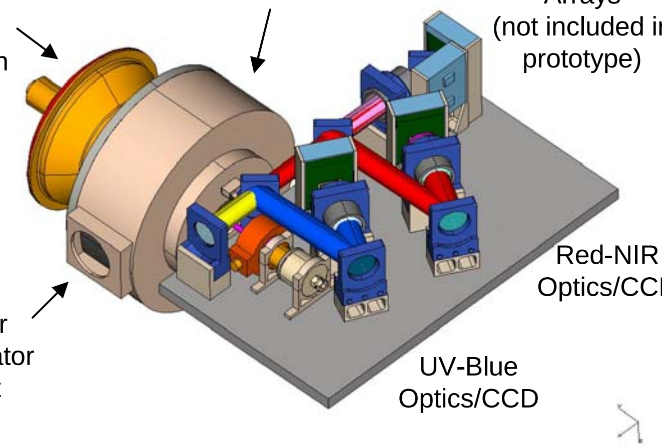
(Current and Completed ESTO Investments)

Ocean Radiometer for Carbon Assessment (ORCA) Prototype

PI: Charles McClain, GSFC

Objectives:

- Provide information on the ocean phytoplankton species composition & uptake of CO_2 by measuring ocean color in support of the Aerosol, Cloud, and Ecosystem (ACE) mission
- Build a working prototype of ORCA including the rotating telescope and CCD focal plane arrays spanning the UV-NIR (345 nm – 865 nm)
- Develop a comprehensive set of component and system level performance specifications.
- Define and test sensor calibration and characterization procedures and equipment required for the ORCA design.



Approach:

- Build a test bed version on an optical bench to refine optical layout and to test components and subsystems (e.g. polarization, point-spread functions, relative spectral response)
- Incorporate telescope scanning capability and package the system into a portable prototype
- Perform system level characterization at NIST

Key Milestones:

• Complete component testing & static optical bench configuration	Year 1
• Complete initial bench testing	Year 2
• Build & integrate rotating telescope assembly	Year 2
• Finalize prototype bench testing	Year 2
• Complete portable prototype packaging & deliver to NIST for system level testing	Year 3
• Complete system level calibration	Year 3

CoIs/Partners:

Jay Smith, Mark Wilson, Carl Kotecki, Jim Butler, and Ken Bluemenstock, GSFC; Mike Behrenfeld, Oregon State Univ.; Steve Brown, NIST; and Alan Holmes (consultant)

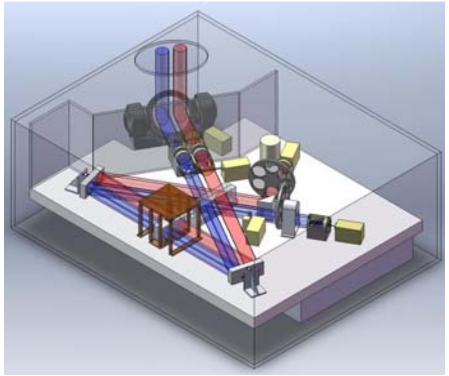
TRL_{in} = 3

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

PI: Stanley Sander, JPL

Objectives:

- Define a science plan for the GEO-CAPE mission which makes use of the enhanced vertical profiling capability of imaging Fourier Transform Spectroscopy (FTS) over the 0.25 – 15 μm spectral range.
- 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 Specs (for flight)	
Characteristic	Value
Size	130 x 100 x 50 cm
Mass	150 kg
Power	120 W
Data rate	150 MB/s
Field of view	±7.3 deg. off-nadir
Pointing required	~1 arcsec
Operational lifetime	5 years

PanFTS mechanical layout and flight instrument specs

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

Co-Is:

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

Key Milestones:

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

TRL_{in} = 3

04/08

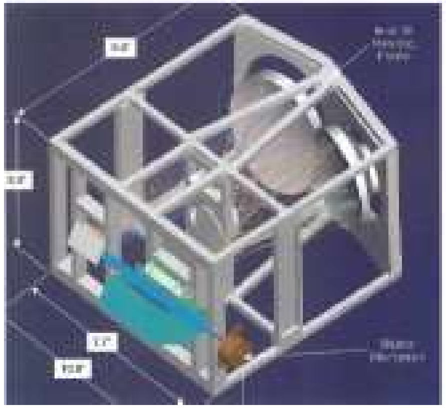
Wide Field Imaging Spectrometer (WFIS)

PI: Randy Pollock, Hamilton-Sundstrand

Objectives:

- Perform the final design iteration and test an engineering model of the WFIS to study atmospheric chemistry, clouds, and aerosols
- Build a hyperspectral instrument with limb-to-limb viewing and 1 km resolution
- Reduce size, weight, and power over similar current instruments
- Obtain airborne test data

Concept Design



Accomplishments:

- Demonstrated optomechanical portions of WFIS in a laboratory environment.
- Completed optomechanical design to near flight standards.
  -Met materials requirement for vacuum pressure and vibration (weight ~6.8Kg, size (22x18x33cms),
- Measurements of the geometric distortion of the optical system look promising.
- Simple modifications to the present work indicate that all the performance requirements for atmospheric chemistry and clouds/aerosol science can be demonstrated with the WFIS EM.

Co-Is: Warren Wiscombe, Yoram Kaufman, Pawan Bhartia, GSFC

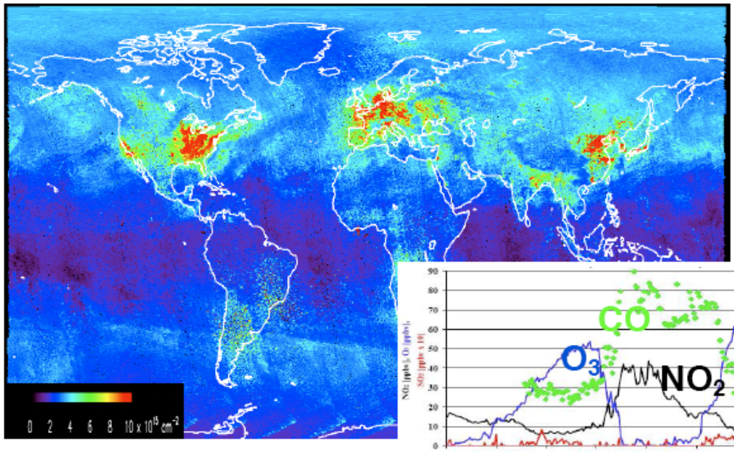
TRL_{in} = 3 TRL_{out} = 5

Geostationary Spectrograph (GeoSpec) for Earth and Atmospheric Science Applications

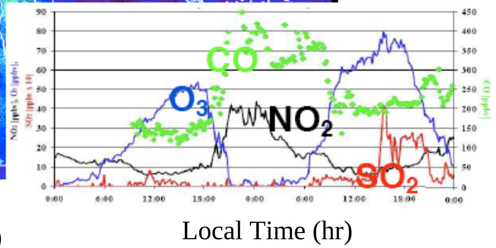
PI: Scott Janz, GSFC

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.

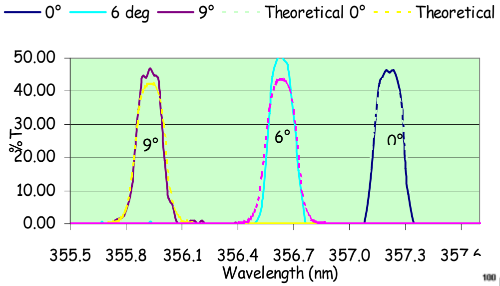
CoIs:

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

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

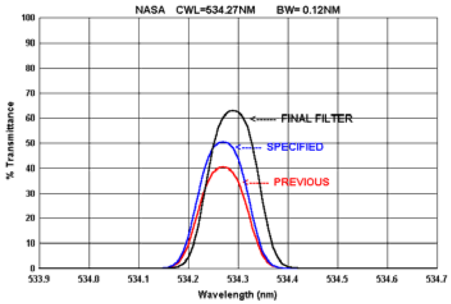
Advanced UV and Visible Ultra-narrow Interference Filter Technology Development

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**

ESTO Earth Science Technology Office

Radar
Instrument Technologies

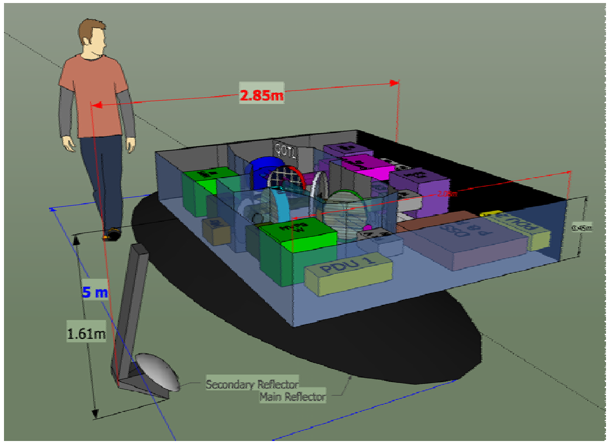
(Current and Completed ESTO Investments)

A Multi-Parameter Atmospheric Profiling Radar for ACE (ACERAD)

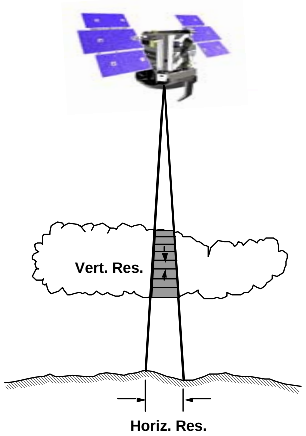
PI: Stephen L. Durden, JPL

Objectives:

- Design a dual-frequency (35/94 GHz) radar system for cloud and precipitation measurements.
  - The proposed radar would be a key element of the Aerosol-Cloud-Ecosystems (ACE) mission.
- Develop a detailed design of the antenna and radar front end for this radar.
- Verify the performance of a scaled antenna and prototype quasi-optical front end through laboratory testing.
- Study feasibility, performance, and utility of an Extremely High Frequency (EHF) channel above 200 GHz.



ACERAD radar configuration concept



ACERAD cloud measurement concept

Approach:

- Develop ACERAD requirements and perform a system level design; perform more detailed RF design and identify long-lead parts. Develop simulation of radar to verify performance.
- Design and test antenna and quasi-optical (low-loss) radar front end.
- Design and test EHF channel

Co-Is:

- Simone Tanelli, Daniel Esteban Fernandez, Lorene Samoska, Raul Perez, JPL
- Aluizio Prata, JPL and USC

Key Milestones:

• Complete system requirements	02/09
• Complete preliminary system design	09/09
• Complete Antenna/Transmission Line sesign	11/09
• Complete Deployment study	02/10
• Complete detailed Instrument design	10/10
• Complete Antenna/Transmission Line development	12/10
• Complete Scanning Mechanism study	01/11
• Complete RF subsystem design	05/11
• Complete Antenna/Transmission Line testing	06/11
• Complete EHF channel design and test	06/11

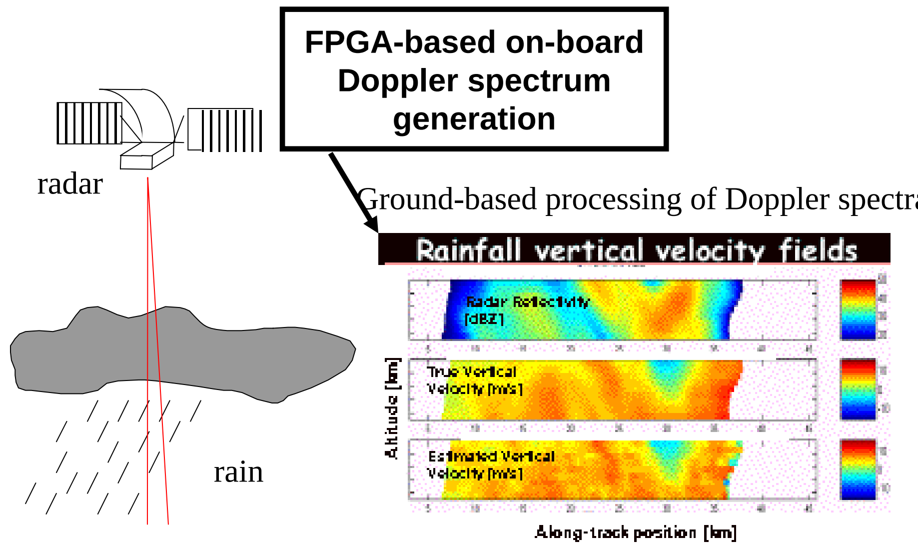
TRL_{in} = 3

An On-Board Processor for a Spaceborne Doppler Precipitation Radar

Stephen L. Durden, JPL

Objective:

- The objective of this work is to develop an on-board data processor that computes the Doppler spectrum of precipitation radar echoes.
- Justification: To improve latent heating measurements in future space-borne precipitation radars, we need to measure the vertical motion V of the atmosphere.
  - Accurate measurement of V from a moving satellite requires the full Doppler spectrum
  - On board FPGA-based processing substantially reduces the data volume for downlinking



Accomplishments:

- Completed high-level radar design
- Completed processor requirements
- Completed processing algorithm design; implemented bit-true FFT algorithm for simulations
- Completed Verilog coding of processor
- Generated test data using archived airborne radar data
- Lab hardware setup demonstrated for processing one coherent processing interval CPI (one block of data)
- Processor performance demonstrated using multiple CPIs of airborne radar data and 230 CPIs from model output

Co-Is: Mark Fischman (JPL), Andrew Berkun (JPL) **TRL_{out} = 5**

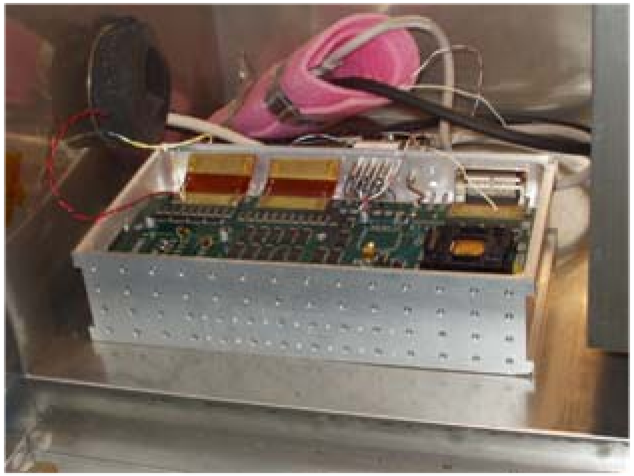
FPGA-Based On-Board Processor/Controller for Satellite-Borne Precipitation Radars

PI: Andrew Berkun, JPL

Objective:

Develop an electronics assembly suitable for earth orbit environment with the following capabilities:

- 4 channel radar data processing
- Radar and antenna timing control
- Software free operation
- Using processed radar data to target areas of rain.



Accomplishments:

Developed a 4 channel radar data processing unit that met all objectives with the following characteristics:

- 83-94% efficient timing solution
- Robust radiation upset correction approach
- Thermal design which allows operation up to 70° C
- Compatibility with normal spacecraft interfaces
- -75 dB sidelobes --> **1000x data reduction**
- Auto targeting --> **improves number of looks 6x in areas of interest**

System successfully demonstrated aboard airborne prototype deployments: CAMEX-4 (Aug-Sep 2001), AMSR-E experiment in Wakasa Bay (Jan-Feb 2003), LRR validation (May-Jun 2003).

Co-Is: Stephen Durden, Eastwood Im, Greg Sadowy, JPL

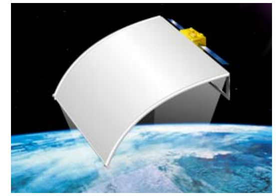
TRL_{in} = 2 **TRL_{out} = 5**

Second-Generation Precipitation Radar (PR-2) Adaptable for Multi-Mission and Multi-Orbit Applications

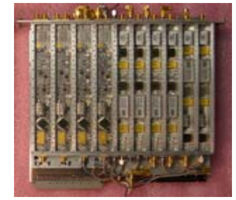
PI: Eastwood Im, JPL

Objectives:

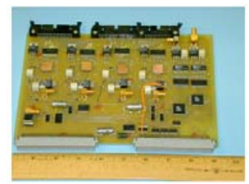
- Develop and demonstrate an advanced radar system and associated technologies to support the development the Global Precipition Mission (GPM)
  - Dual-frequency (14/35 GHz) to improve dynamic range and sensitivity on rain measurements
  - Factor of two improvement in radar resolution to reduce errors caused by rain inhomogeneity
  - Dual polarization to differentiate between liquid and frozen hydrometeors
  - Doppler capability to obtain vertical motion structure
  - Cross-track adaptive scan over ±37° to increase swath coverage



PR-2 system concept

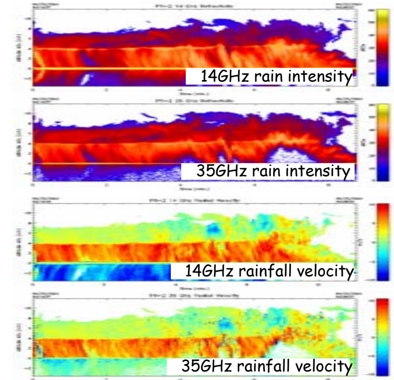


IF/LO board



ADC/AWG board

FPGA real-time processor board



Dual-frequency rain intensity and fall velocity profiles of hurricane obtained by PR-2 airborne experiment in Sep'2001

Accomplishments:

- Developed a 12-bit A-to-D Converter (ADC) and variable waveform generator (AWG) board to achieve 2x improvement in sample filtering and -60dB pulse sidelobe suppression capability
- Developed an FPGA-based real-time Doppler and adaptable scan signal processor with 40 ops/sec capability
- Developed a compact Intermediate-Frequency/Local Oscillator (IF/LO) module with 2 transmit and 4 receive channels
- Developed the conceptual design on a light-weight, wide-angular scanning, dual-frequency antenna
- Developed the spaceborne PR-2 design, and prototyped an airborne PR-2 simulator (a.k.a. APR-2)
  - Verified the all radar electronics performance through airborne testing in 2001
- APR-2 successfully acquired the first-ever measurements of simultaneous 14/35-GHz, dual-polarized rain intensity and vertical velocity profiles during the 4th Convection and Moisture Experiment (CAMEX-4) in 2001

Co-Is: S. Durden, G. Sadowy, S. Tanelli, A. Berkun, J. Huang, Z. Haddad (JPL); E. Smith (GSFC); Y. Rahmat-Samii (UCLA)

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

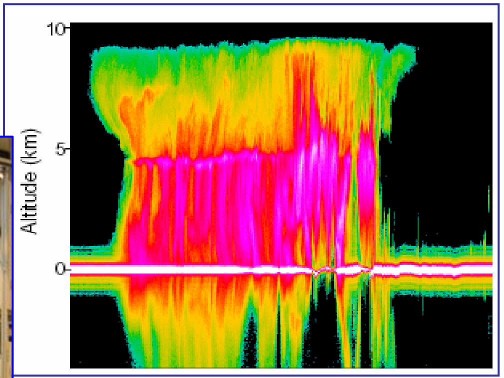
Advanced Precipitation Radar Antenna and Instrument (APRA)

PI: Eastwood Im, JPL

Objectives:

- Develop a half-size (2.6m x 2.6m) model of a light-weight, deployable, dual frequency, wide-angle beam-pointing antenna for spaceborne rainfall measurements.
- Incorporate the antenna's physical and performance characteristics into the overall system design of the Second-Generation Precipitation Radar (PR-2).

Airborne PR-2 simulator measured detailed rain structure of Tropical Storm Chantal during CAMEX-4



The structural model of APRA half-size antenna reflector prototype

Accomplishments:

- Completed antenna electrical performance characterization, including surface ripple distortions
- Completed Ku/Ka-band array feed design, fabrication, and performance assessment
- Completed the structural modeling of the membrane surface ripples
- ILC Dover completed prototype antenna build and reflector support structure
- Completed correlation of antenna model simulation with measured results
- Feed array performance characteristics satisfactory
- Studied the space dynamics for spaceborne APRA membrane antenna

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

ESTO Earth Science Technology Office

Ka-band Active Array for Remote Sensing of Precipitation

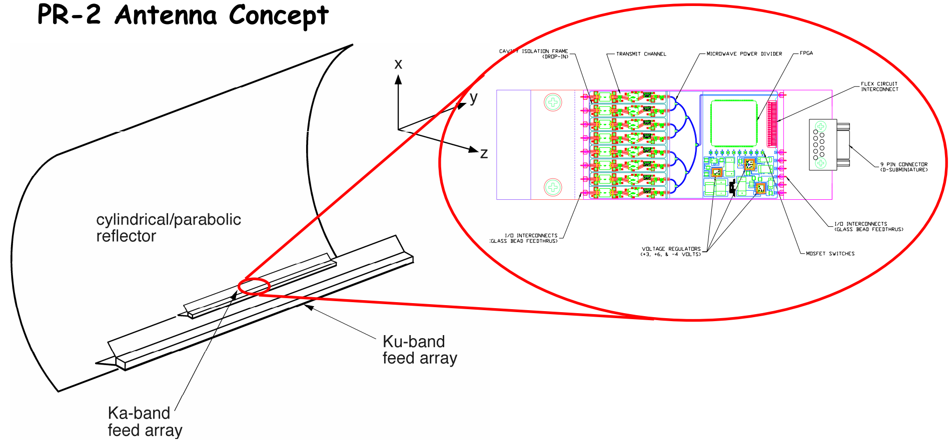
PI: Greg Sadowy, JPL

Description and Objectives:

- The PR-2 instrument will utilize two frequencies (14 and 35 GHz) and two polarizations to enable more accurate estimation of rain rates while increasing measurement swath width using adaptive scanning.
- Objective: To develop a dual-polarized electronically-scanned Ka-band (35 GHz) subarray for the PR-2 antenna.
- Development of this subarray will provide a proof-of-concept as well as a design that can easily be adapted for a future flight program.

Ka-band T/R Module 8-pack

PR-2 Antenna Concept



Accomplishments:

- Full array electromagnetic simulations complete
- Designed, fabricated and tested compact orthomode transducer
- Breadboarded and characterized MMICs
- Designed, fabricated and tested Ka-band phase shifter
- Designed and fabricated transmit and receive chain MIC (hybrid circuit) breadboards
- Designed LTCC 8-pack modules

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

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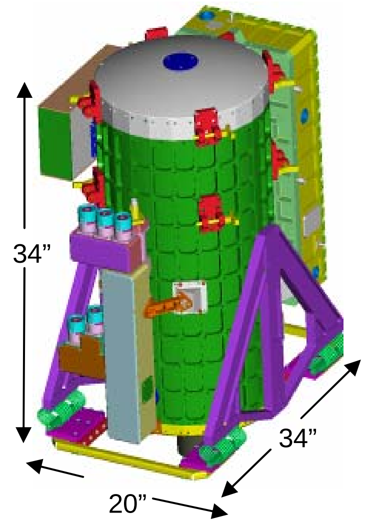
Lidar
Instrument Technologies
(Current and Completed ESTO Investments)

Technology Development for a Combined HSRL and O_3 DIAL Lidar

PI: Chris Hostetler, NASA Langley Research Center

Objective:

- Develop transmitter and receiver technologies suitable for a combined High Spectral Resolution Lidar (HSRL) and Differential Absorption Lidar (DIAL) instrument to measure tropospheric aerosols and ozone.
- Technology advances will enable unique and important measurements of ozone and aerosol optical & microphysical properties from space-based and advanced airborne platforms (e.g., UAVs) in support of the ACE Decadal Survey Mission.



Compact O_3 DIAL and HSRL Lidar Instrument Concept

Approach:

- Develop a diode-pumped , conductively cooled pump laser suitable for a combined DIAL and HSRL transmitter
- Develop a tunable UV Optical Parametric Oscillator (OPO) laser mated to the pump laser.
- Develop a high efficiency ozone DIAL aft optics receiver module.
- Evaluate and develop 355nm interferometric receiver breadboard for multi-wavelength HSRL measurements.
- Demonstrate a combined laser transmitter for multi-wavelength HSRL and O3 DIAL measurements

Co-Is/Partners:

Dr. Edward Browell, Dr. Johnathan Hair – NASA LaRC
Dr. Thomas McGee –NASA GSFC
Fibertek Inc, ITT Industries, Welch Mechanical Design

Key Milestones:

- Complete Ozone Receiver 5/07
- Complete Pump Laser Transmitter 9/07
- Complete Non Linear Optics (NLO) Module 12/07
- Integrate and Characterize Pump Laser and NLO 5/08
- Complete Interferometric HSRL Receiver 6/08
- Complete HSRL and Ozone System Integration 8/08
- Complete Ground and Flight Tests 11/08

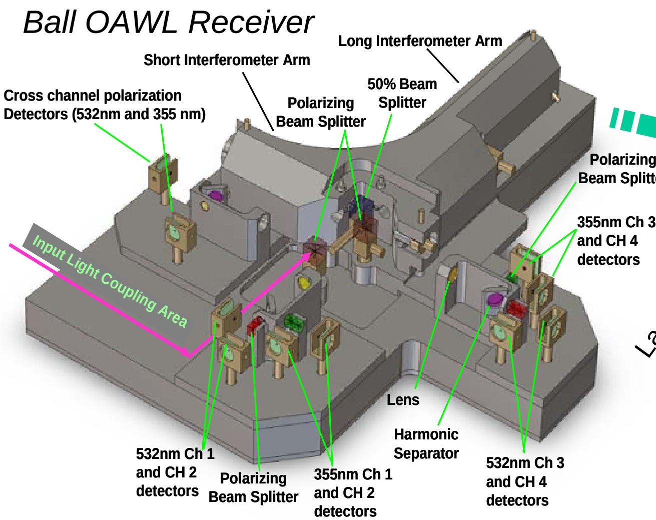
TRL_{in} =4 **$TRL_{current}$ =4**

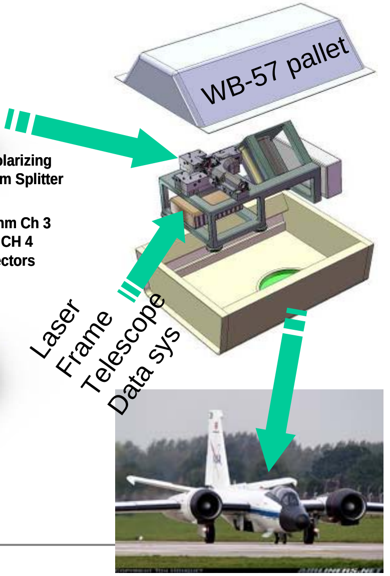
Development and Demonstration of an Optical Autocovariance Direct Detection Wind Lidar

PI: Christian J. Grund, Ball Aerospace & Technologies Corp.

Objectives:

- Develop a complete Optical Autocovariance Wind Lidar (OAWL) transceiver for airborne testing in support of the 3D WINDS Decadal Survey Mission.
- Achieve TRL-5 for OAWL by comparing WB-57 flight data with NOAA wind profilers and other corroborative measurements.
- Perform shake and bake testing to verify the alignment-free interferometer construction is suitable for space qualified design.
- Validate radiometric and integrated system performance models for space-based OAWL.
- Technology roadmap to TRL 7 for an all direct-detection wind lidar (aerosol and molecular)





Approach:

- Use science advisory board to ensure relevance
- Test and adapt the Ball OAWL 2λ receiver for aircraft operation
- Design/fabricate a complete lidar system
- Ground test against wind profiler and/or radiosondes and/or other ground-based Doppler Wind Lidar
- Ready system for autonomous flight
- Flight test in WB-57
- Corroborate against wind profilers. Validate space-based radiometric and integrated system models against test data
- Roadmap optimal direct detection DWL to TRL7

Key Milestones:

• Preliminary design review	08/08
• Science advisory board established	08/08
• Receiver shake and bake testing	10/08
• Critical design review (system)	02/09
• System integration complete	10/09
• Ground testing complete	12/09
• Airborne mods and autonomous control complete	05/10
• Flight Readiness Review	09/10
• Airborne testing complete	10/10
• OAWL flight performance report	12/10
• Space-based system models validated	03/11
• TRL7 technology roadmap complete	04/11

Co-Is/Partners: none

$TRL_{IN} = 3$

(Intentionally blank)

Information Systems Technologies

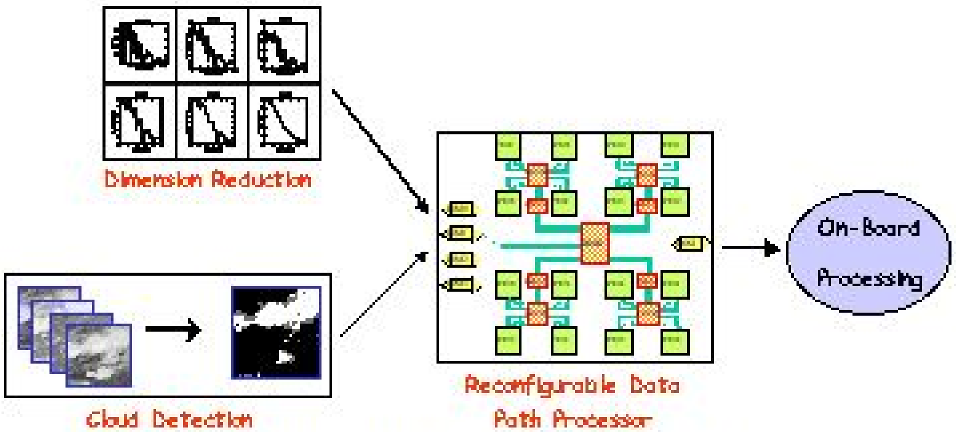
(Current and Completed ESTO Investments)

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

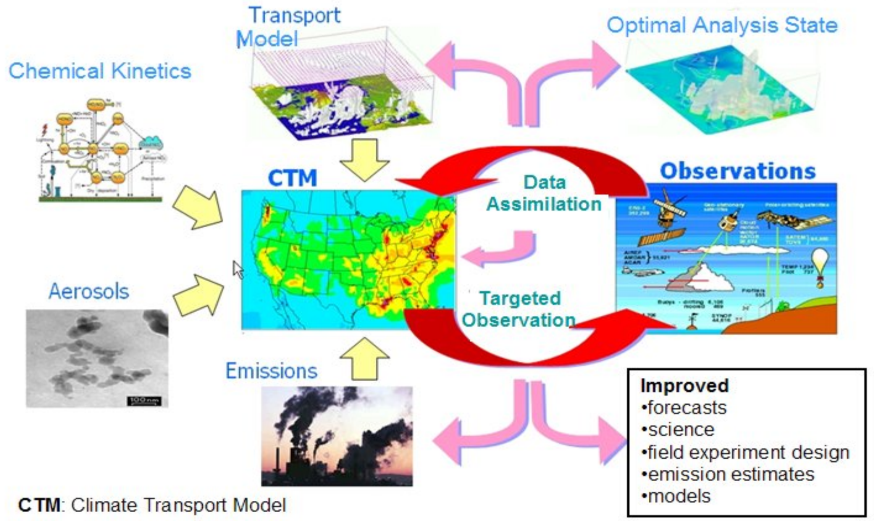
TRL_{in} = 3 TRL_{out} = 5

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 quantitative science return metric that can identify where and when specific measurements have the greatest impact.
- Provide collaborative campaign planning process among distributed users.



SOX Optimizes Observation Strategies for Air Quality Information Content

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-I's/Partners:

- Charles Miller, Kevin Bowman, Richard Weidner, JPL
- Adrian Sandu, Virginia Polytechnic

Key Milestones:

• SOX software Architecture Design	12/06
• SOX Interface Definitions	2/07
• SC-borne Sensor-web Ops. Explorer	9/07
• Air-borne Sensor-web platform simulation	3/08
• Dual platform campaign planner	9/08
• In-situ platform simulation	3/08
• Multi-platform campaign planner	6/09
• Complete SOX system	9/09

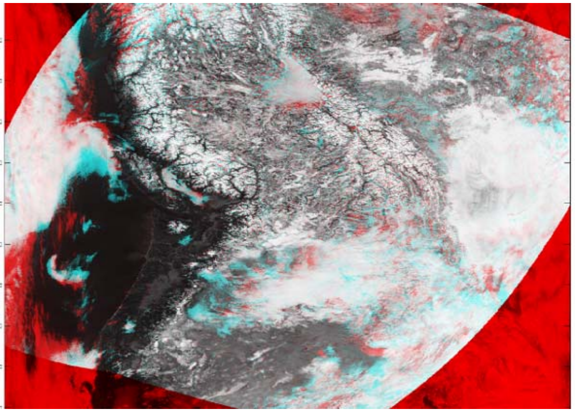
TRL_{in} = 3 $TRL_{current}$ = 4

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)

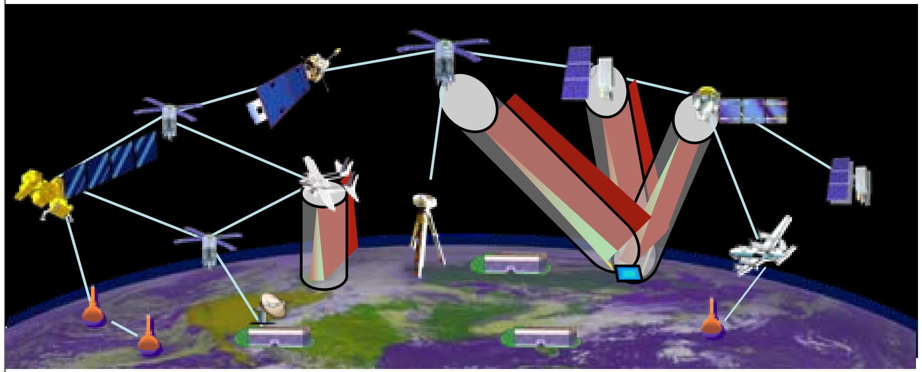
TRL_{in} = 3 TRL_{out} = 4

Sensor Web Application Prototype ("SWAP")

PI: Troy Ames, GSFC

Description and Objectives:

- Provide an engineering proof of concept for the meteorological sciences. It will include simple in-situ sensors on the ground to provide maximum accessibility by engineers, while still exploring sensors that will be useful in the future more complex science scenarios.
- Demonstrate sensor collaboration, dynamic cause-effect relationship between sensors, dynamic reconfiguration, and remote monitoring of sensor webs.
- Identify technology gaps where additional research will be required to achieve the sensor web goals.
- Assess candidate software architecture.



Sensor Web Concept: *NASA/GSFC: 2000 Survey of Distributed Spacecraft Technologies and Architectures for NASA's Earth Science Enterprise in the 2010-2025 Timeframe*

Accomplishments:

- Demonstrated a collaborative sensor web utilizing rain gauges, weather stations, and a simulated weather radar for the prediction of flash flood potential.
- Validated software architecture for creating collaborative sensor webs with dynamic sensor discovery, reconfiguration, simulation, and remote monitoring.
- Identified sensor web concept issues and challenges.

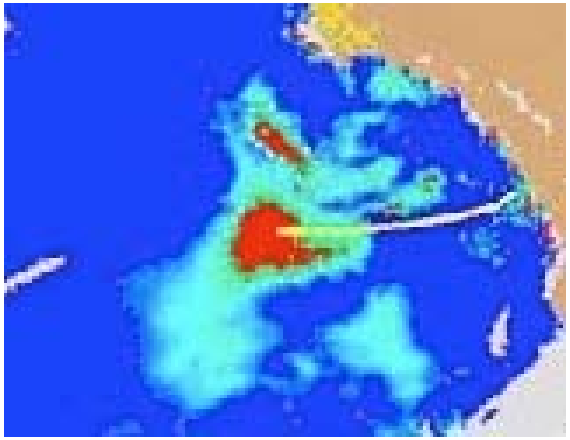
$TRL_{in} = 2$ $TRL_{out} = 5$

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: Richard Stumpf, NOAA

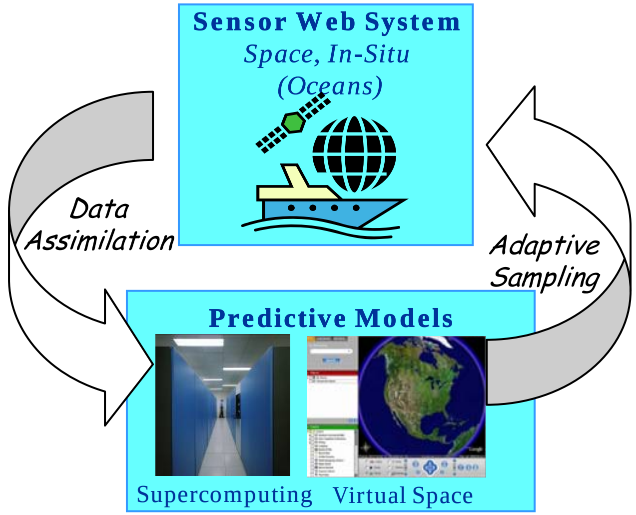
TRL_{in} = 4 **TRL_{out} = 6**

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

PI: Payman Arabshahi, University of Washington (UW)

Objectives:

- 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.
- Incorporate reconfiguration of sensor assets, adaptive sampling and autonomous event detection, targeted observation, location-aware sensing, built-in navigation on mobile nodes (Seagliders), and high-bandwidth, high-power observation on cabled seafloor and stationary nodes (mooring systems with vertical profilers).
- 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.



The task will have strong tie-ins with the NASA satellite oceanography and ocean science community, in charge of carrying out new experiments which will overcome limitations in current approaches.

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-I's/Partners:

- Andrew Gray (AGCI Inc), Yi Chao (JPL/UCLA)
- Sumit Roy, Bruce Howe / UW

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 Media Access Control (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 science data analysis from field demonstration 08/09

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

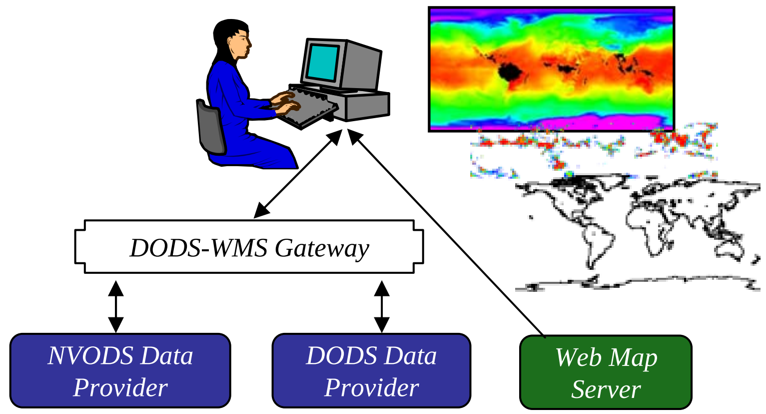
WMS Gateway to DODS Data Servers

PI: Peter Cornillon, University of Rhode Island

Objective:

- Enable prototype of gateway between Digital Oceanographic Data System (DODS) and Web Mapping Servers (WMS) to use external 'plug-in' visualization software, to promote data provider participation.
- Provide DODS-WMS Gateway in a readily installable form to National Virtual Ocean Data System (NVODS) and DODS data providers sites.
- Enable Geographic Information System (GIS) client access to a wealth of existing earth science data.

Enabling use of geographic data from a diversity of existing data providers and sources



Accomplishments:

- Implemented "plug-and-play" modules to enable customization without rebuilding the Gateway.
- Plug-and-play modules may be either compiled C++ class specializations or standalone programs.
- Merged external plug-and-play configuration information into Gateway's Capabilities XML document.
- Enhanced the Capability class to filter the Gateway's Capabilities XML to produce a WMS-1.1.0 compliant Capabilities response.
- Built a DODS-GDAL driver for using within the Gateway that can now be used by many other projects.

TRL_{in} = 5 TRL_{out} = 8

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

PI: Ashit Talukder/Jet Propulsion Laboratory

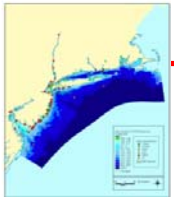
Objective:

Design, implement and test model-based control tools in the existing New York Harbor Observation and Prediction System (NYHOPS) sensor web with the following primary task objectives:

- Adaptive in-situ control of multiple resources in heterogeneous spatially distributed sensor webs
- Model based event detection and prognosis from distributed sensor measurements
- Off-line science validation of NYHOPS sensor web operational autonomy and control with CARDS
- Adapt the sensor web to study plumes, coastal storm surges for advanced warning and improved analysis

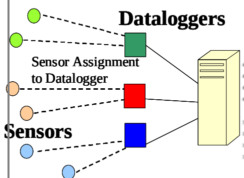
Ocean forecast model

Data assimilation, model improvement

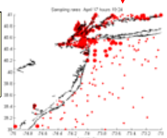


Event Estimation
Threat assessment (environment, intel)

Adaptive Predictive Controller
Mobile robot tasking
Static sensor operation
Comm. Management



Dynamic Assignment



Adaptive sampling of Static Sensors

Adaptive sampling: UUV coordination

Concept for Control & Resource Workflow Mgmt. of Sensor Webs

Accomplishments:

- Developed Model Predictive Control framework to adaptively manage real-time resources of a variety of fixed & mobile assets with limited resources to increase predictive power of existing ocean model
- Reduced wireless data transmission costs by 38% using adaptive relay station assignment
- Event detection algorithm designed for unexpected freshwater flow events
- Quantified model uncertainty for use in event detection
- Controlled path of unmanned underwater vehicles so as to maximally increase the utility of their sensor measurements
- Validated above adaptive resource management solution on real coastal NYHOPS sensor web data
- Visualize sensor web data & control outputs in 3-D using Google Earth.
- Implemented Metrics to quantify performance of sensor web control technique

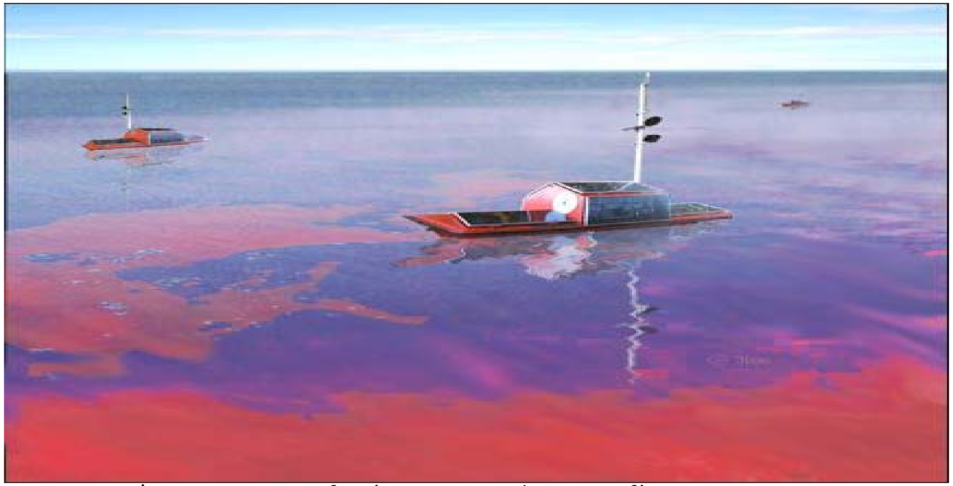
$TRL_{in} = 2$ $TRL_{out} = 4$

Telesupervised Adaptive Ocean Sensor Fleet

PI: John 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



Artist's conception of telesupervised sensor fleet investigating a Harmful Algal Bloom

Approach:

- Telesupervision of a networked fleet of NOAA surface autonomous vehicles (OASIS)
- Adaptive repositioning of sensor assets based on environmental sensor inputs (e.g., concentration gradients)
- Integration of complementary established and emergent technologies (System Supervision Architecture, Inference Grids, Adaptive Sensor Fleet, Instrument Remote Control, and OASIS)
- 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
- NOAA

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 $TRL_{current}$ = 5