Coastal and Ocean Airborne Science Testbed (COAST)

HOPE 2010

Hands-On Project Experience

A Training Opportunity for NASA Personnel

April 5, 2010

The Coastal and Ocean Airborne Science Testbed (COAST) Project will serve to train a team of scientists and engineers from NASA Ames and Goddard in the full scope (Phase A to E) of a flight mission according to applicable NASA Procedural Requirements. This training opportunity involves an Earth-science flight project that will advance SMD's science program by creating a unique capability combining a customized imaging spectrometer, sunphotometer system, and bio-optical microradiometers to simultaneously obtain ocean/coastal/atmosphere data sets available for improved in-water algorithms and atmospheric calibration. COAST will enable measurements of several properties of biological interest in the coastal ocean that are key to characterizing estuaries, river plumes, kelp beds, coral reefs, and phytoplankton including harmful algal blooms. These research areas are supported by NASA's Ocean Biology and Biogeochemistry, Biodiversity, and Hydrology Programs. The instruments, currently at TRL 8 and higher, will be flown over an Eastern United States site of significance for coastal and ocean biology on a Wallops-based NASA P-3 carrier aircraft integrated with the instrument suite. A detailed COAST Project cost and schedule estimate was developed with these baseline mission assumptions. Strategic trade studies will be conducted in Phase C to evaluate mission site, and carrier platform options that could result in technical, cost and/or schedule advantages. The COAST mission will initiate a new sub-orbital science capability for NASA science missions, addressing the challenges of an optically complex coastal ocean zone while providing a comprehensive training opportunity for a group of approximately 15-20 (COAST and APEX) future flight project team leaders at NASA Ames and Goddard.

Ames Research Center and Goddard Space Flight Center Partnership

Liane Guild, Ph.D., PI

Jennifer Dungan, Ph.D., PM

Maryland Edwards, PSE

Joaquín Chaves, Ph.D., Cal/Val

Philip Russell, Ph.D., Mentor

Randall Berthold, Mentor

Peter Zell, Mentor

Steven Dunagan, Ph.D., Mentor

Stanford Hooker, Ph.D., Cal/Val Mentor

Claire Smith, ARC Training Mentor

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C. Hands-On Project Experience Personnel Training

The Coastal and Ocean Airborne Science and Technology (COAST) Project in collaboration with the Ames Project EXcellence Development Program (APEX) is poised to execute a unique training strategy designed to generate systematic learning to provide hands-on Earth science flight project experience to enhance the technical, leadership, and project skills for the named trainee personnel as well as other Ames and Goddard technical personnel participating through APEX activities.

Our training strategy is characterized by three interrelated elements:

1. The design and sequencing of our training activities are based on the APEX Learning Lifecycle (**ALL**). ALL is derived from NASA's technical (APPEL) and leadership development models and Bloom's Taxonomy of Learning Objectives (Bloom, 1956). In brief, ALL integrates the progressive stages of learning and development within and across all phases of the COAST project life cycle (Figure C-1).
2. Training objectives for the designated named trainees (PI, PM, PSE, Cal/Val Scientist) as well as other members of the Ames and Goddard technical community will be targeted to producing results in two areas (Table C-1):
    i. Developing new knowledge and skills in mission-critical scientific, technical and leadership project practices.
    ii. Enhancing and advancing existing knowledge and skills derived from previous experience.
3. Our individual and team training objectives and activities are aligned with and anchored to our project life cycle, project plan, schedule, milestones and deliverables.

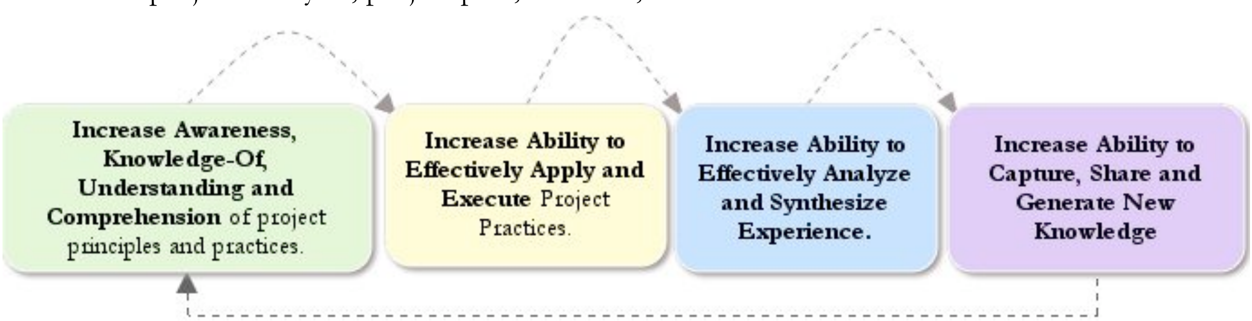


Figure C-1. The APEX learning life cycle.

APEX was launched in 2006 at ARC. Designed by and for project practitioners, APEX has evolved into an integrated system of learning and development programs and resources designed to strengthen and support the development of the Center's project leadership and system engineering expertise.

An alliance between HOPE and APEX is natural step forward for both programs. HOPE fills a gap in the current APEX model. As a result of project logistical constraints, APEX is currently unable to provide a complete Phase A to Phase E hands-on-project experience to APEX participants. By partnering with the COAST Project, APEX will benefit from its own hands-on- training experience and will apply these lessons to future iterations of the APEX model.

C.1 Project Team/Trainees

The designated, named team proposing COAST is as follows:

PI/Team Lead: Liane Guild (ARC)	PI Mentor: Phil Russell (ARC) Team Lead Mentor: Randall Berthold
PM: Jennifer Dungan (ARC)	PM Mentor: Pete Zell (ARC)
PSE: Maryland Edwards (ARC)	PSE Mentor: Steve Dunagan (ARC)
Cal/Val: Joaquín Chaves (GSFC)	Cal/Val Mentor: Stanford Hooker (GSFC)
	Training Lead: Claire Smith (ARC)

Dr. Guild has been a PI on several missions-of-opportunity but has not yet been involved in a formal, complete mission life cycle. The training will be invaluable as she steps up from science PI to mission PI. Dr. Dungan has experience in numerous science projects and has apprenticed on the LDCM Science Team, exposing her to formal mission project management. HOPE training will provide skills needed for her to manage flight projects. Ms. Edwards has been exposed to many elements of system engineering. This training opportunity is the next logical step to enable her to lead system engineering efforts on future NASA missions. Dr. Chaves, as a contractor post-doc, is poised to apply for new civil service positions that will likely emerge in FY11. Mentors for this core team of four trainees are highly experienced in their roles and in some cases will provide additional expertise for the specific mission proposed. Dr. Russell is the instrument PI on one of three instruments, the sun photometer, proposed in the mission. Dr. Hooker is the instrument PI on one of the other instruments, the microradiometer. The specific skills that the core group will acquire and enhance are listed in Table C-1. Skill building will also be available to ARC and GSFC personnel outside the core team through APEX activities. Past experience shows this will benefit 15-20 individuals.

Table C-1. COAST training objectives.

N = New **Project Knowledge and Skills Developed** as a result of HOPE Experience. **E= Existing Experience, Knowledge and Skills** Enhanced **by HOPE Experience.**

Mission-Critical Knowledge and Skills	PI *Guild*	PM *Dungan*	PSE *Edwards*	Cal/Val *Chaves*	Training Lead *Smith*
Aircraft Science Payload: Mission and System Design and Development.	N	N	N	N	N
NPRs 7120 and 7123 Compliance and Tailoring	N	N	E	N	N
Stakeholder Management	E	E	E	E	N
Requirements Definition and Development.	N	N	E	E	N
Life Cycle Cost Analysis	N	N	N	N	N
Identifying, Assessing, Managing and Mitigating Risk (Technical and Programmatic)	N	N	N	N	N
System Integration	N	N	N	N	N
Verification and Validation - including special challenges associated with COTS Product Verification	N	N	E	E	N
Systems Engineering Management: Planning and Execution	N	N	N	N	N
Project Planning, Analysis, Control and Evaluation	E	N	N	E	N
Configuration Management	N	N	E	N	N
Acquisitions Management	N	N	N	N	N
Science and Technical Data Management	E	E	E	E	N
Integrated Cost and Schedule	N	N	N	N	N
Multi-instrument Development, Integration, Testing, Verification and Delivery	N	N	N	N	N
Resources Management	E	E	N	N	E
Technology Development and TRL Analysis and Maturation	N	E	N	N	N
Mission Safety and Assurance	N	N	N	N	N
Technical Assessment and Reviews	N	N	N	N	N
Post-Flight Data Analysis	E	N	N	N	N
Inter-Center Collaboration	E	E	E	N	N
Inter-Agency Collaboration	E	N	E	N	N
Project Leadership and Team Development	E	N	E	E	E

C.2 Training Methods

The COAST Project plans to implement an integrated, systems approach to training as a means for transforming project experience into knowledge and for producing meaningful, concrete learning results. The primary methods of our training system include:

1. Individual Technical and Leadership Mentoring: Focused on each trainee's unique project role, challenges and development priorities.

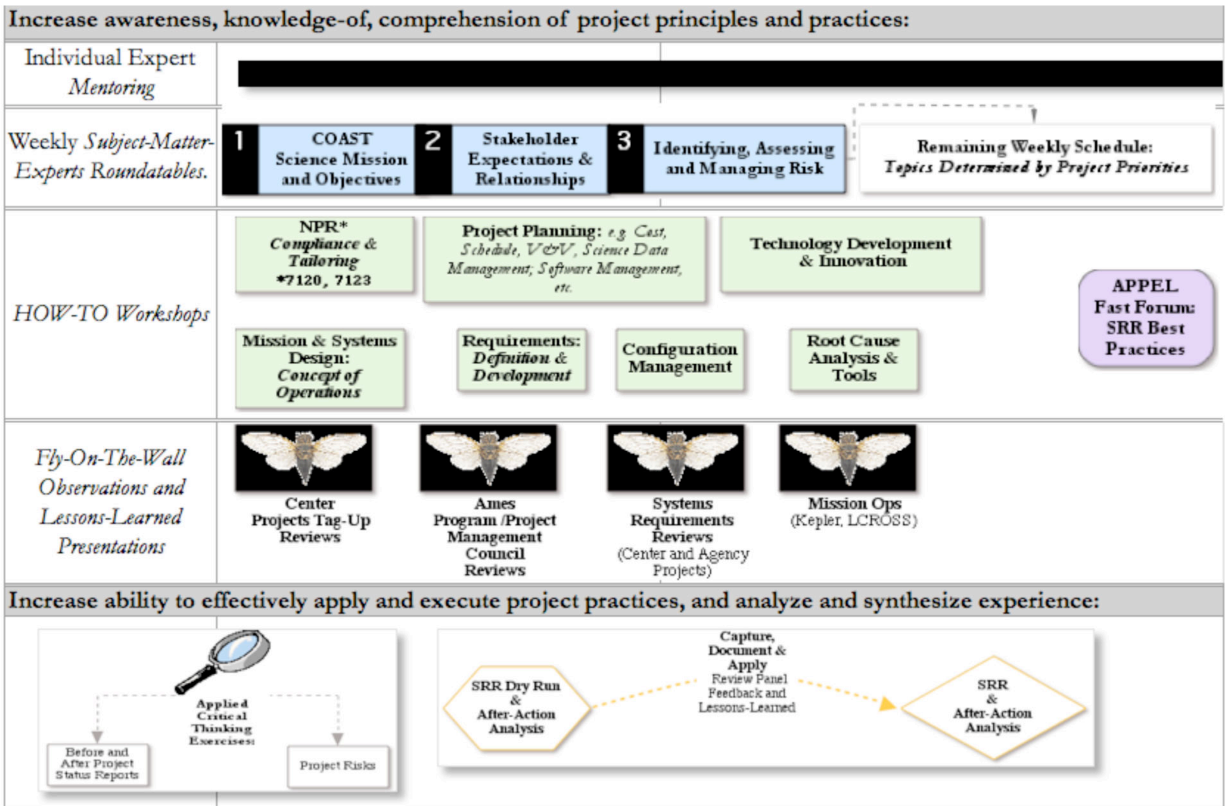
2. Team Development: An experiment in utilizing typical team processes as vehicles for developing and executing high-performance team practices.
3. Weekly, 2 hr. Lunch & Learn Roundtables: Focused discussion with subject-matter-experts addressing project issues and challenges in real-time.
4. Fly-On-The-Wall exercises: Providing individuals and the team opportunities to observe mission-critical project practices, identify and capture insights, and apply subsequent new levels of understanding to COAST project work.
5. Applied Critical Thinking NOW: Pre and post-status-report exercises in root-cause analysis and problem solving.
6. APEX ASSIST: Every member of the project team will have access to graduates of APEX programs, i.e. Systems Engineering (SEDP), Project Management (PMDP) and Foundations. APEX ASSIST is a one-hour review, critique and discussion of a team member's project product.
7. HOW-TO and Best Practices Forums: Designed to ensure and fortify the quality of project products.
8. Practice Reviews and After-Action Analysis: The COAST trainee team will prepare and deliver a full review dry-run for all mission-critical project reviews e.g., PDR, CDR, FRR. This Practice Review will be conducted before a panel that will include COAST Mentors, APEX Program graduates and participants and other invited guests.
9. Following each dry run, the team will conduct an after-action analysis, i.e. what was supposed to happen? What actually happened? Why were there differences? What did we learn from this experience? How will we apply this learning to the next project review?
10. Post Review/Phase After-Action Analysis.

Within the framework of the APEX Learning Lifecycle, the COAST Team training plan applies and integrates the multiple methods outlined above. The role of these activities in early phases are depicted in Figure C-2. The key objective of these training activities is the successful delivery of Phase-specific project products. Our training plan pays particular attention to Phase A by incorporating a common lesson-learned from many NASA projects, i.e. strong, effective work up front establishes the foundation for project success downstream. Similar methods will be used in Phases B through E. The trainee members of COAST Project team have been assigned experienced technical mentors. In addition, the PI, the team lead, will have an expert leadership mentor. The role of the COAST project mentors is to provide guidance, encouragement and a "knowing, critical eye" throughout the project.

Initially, the objective of each COAST mentoring partnership is to transfer explicit and tacit knowledge from mentor to trainee. Mentoring begins with a one-hour session facilitated by the APEX Program Manager. At this time, the trainee and mentor(s) discuss their respective expectations, needs, objectives and constraints (such as time). The trainee and mentor(s) will leave this initial session with a plan and schedule for

1. Baselining the trainee's technical and leadership capabilities particularly as they relate to the trainee's role and her/his Phase A deliverables on the COAST Project.
2. Defining the trainee's training priorities and objectives beginning with the trainee's Phase A tasks and requirements.
3. Virtual Mentoring: Online process where mentor can review, assess and critique trainee's project products.

Beginning in Phase B and through to the end of the project, the primary objective of mentoring is to produce tacit knowledge: the insight and "knowing" that is produced by the trainee's own direct experience. The mentor(s) facilitate this process by encouraging the trainee to use her/his own critical eye to explore and understand what she/he is doing and learning. Each mentor models "being a reflective practitioner" by asking probing questions rather than providing immediate answers.



Increase ability to capture, share, and generate new knowledge:		
PI Trainee: L Guild	Present @ APEX Lunch & Learn for Centerwide audience: *"COAST Mission"*	Invite and sponsor peer (PI on another project) to be a fly-on-the-wall at SRR practice
PM Trainee: J Dungan	Conduct and coordinate "Project Plan Review" with graduates of the APEX Project Management Development Program	Invite and sponsor peer (PM on another project) to be a fly-on-the-wall at SRR practice
PSE Trainee: M Edwards	Conduct and coordinate "Systems Engineering Management Plan Review" with graduates of the APEX Systems Engineering Development Program	Invite and sponsor peer (PSE on another project) to be a fly-on-the-wall at SRR practice
COAST Team	Real-time project blog and discussion forum (on NEN) for an Agency-wide audience	

Figure C-2. APEX Learning Lifecycle with details for the COAST project.

C.3 Creating, Capturing and Sharing Knowledge

The essence of the COAST Project Mission is to create and share scientific, technical and project knowledge, both explicit and tacit, both during and after the project life cycle.

During the project life cycle, the COAST Project Training Plan calls for the capture, documentation and sharing of new knowledge, i.e. discoveries and insights generated by the project and training experiences of the project team, e.g. ACT NOW Exercises and After-Action Analysis will lead to discoveries about how effective, critical thinking can be integrated into ordinary, typical project processes as compared to reactive models of problem solving, e.g. fire-fighting.

C.3.1 Knowledge sharing during project

During the COAST Project, the Training Plan calls for sharing knowledge both within and outside of the project team. Within the project, we will share and generate lessons-being-learned in real time during our regular team processes and through the use of COAST Blog or Twitter. In addition, the

COAST Project will provide WebEx (web conferencing and desktop sharing) for project practitioners working in other Ames projects, Goddard and potentially other Centers. In this way, both experienced and inexperienced project practitioners will be able to observe our experience in real-time i.e. to be a "Fly-On-The-Wall". In return, these "flies" can pose questions, ideas and comments to the COAST Project thereby adding to our training experience.

C.3.2 Post-mission knowledge sharing

Post-Mission success, the COAST Project plans to follow multiple paths for sharing the project's scientific, technical and learning experiences. For example, the COAST team will:

- Publish at least one peer-reviewed scientific/technical paper.
- Compose and submit a project story to APPEL's ASK Magazine.
- Earn an invitation to present at the APPEL Masters Forum and NASA's PM Challenge Conference.
- Deliver at least one HOW-TO Forum and one Lunch & Learn Roundtable for participants in APEX programs.

D. Science Investigation and Implementation

The scientific and technical objectives of this proposal are to integrate and fly a highly calibrated, robust airborne imaging spectrometer system, integrated with a tracking sun photometer system and bio-optical microradiometers, optimized for coastal ecosystems and ocean biology, biogeochemistry, biodiversity research (HOPE Goal 2). The imaging system will bring a unique capability for measuring features at the boundary between land and sea. It will be largely self-contained and readily portable between multiple aircraft platforms, including Unmanned Aircraft Systems (UAS). A major component of this proposal is an Ames-Goddard collaboration of early career and mentor civil servant and postdoctoral team members and early career collaborators in the development of:

- new technologies for a scientifically valid calibration methodology for the instruments, and
- a rigorous flight testing and validation plan for ocean and coastal research.

The primary instrument is the imaging spectrometer, a customized Headwall Photonics (Fitchburg, MA) imaging spectrometer (HIS) optimized for remote sensing of marine and freshwater ecosystems. This spectrometer has undergone advances and data system development by the UC Santa Cruz Airborne Sensor Facility (ASF) at NASA Ames Research Center where it is managed (J. Myers, ASF Lead). The ASF supports NASA's Airborne Science Program. Simultaneous measurements for empirical characterization of the atmospheric column will be accomplished using the Ames Airborne Tracking Sunphotometer (AATS-14) developed and managed by scientists (P. Russell, PI mentor) in the Atmospheric Science Branch at NASA Ames. The Ocean Biology and Biogeochemistry Calibration and Validation (cal/val) Office (CVO) team (S. Hooker, Cal/Val mentor) at GSFC has developed field microradiometer instrumentation (Biospherical Instruments, San Diego) that allows, for the first time, *in situ* measurements at the land/ocean boundary including optically shallow freshwater and marine ecosystems. These microradiometers establish a quality-assured ability to acquire and process measurements of the apparent optical properties (AOPs) of freshwater and marine (estuaries, coral reefs, and oceans) waters. A set of these microradiometers will be integrated for the first time with an airborne instrument suite. This new capability will be tested using the airborne instrument suite in a field campaign (Figure D-1). The field campaign will include a research vessel (R/V) equipped with CVO team members and instrumentation as well as an experienced NASA ARC research dive team (AAUS-certified) with expertise in field spectroscopy and biodiversity measurements in benthic ecosystems ranging in temperature gradients (~10-30ºC). The dive team will utilize an in-water field imaging spectrometer and underwater cameras in support of field measurements. Further, the Ames research dive team members have roles in the COAST project.

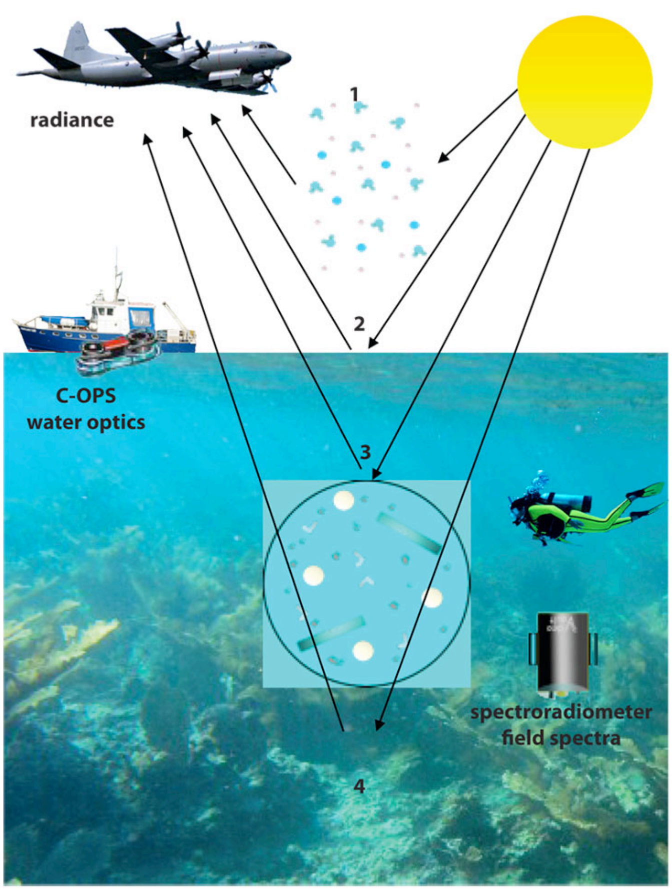


Figure D-1. Field operations will include R/V Gulf Challenger with the C-OPS optical profiler and field measurements and spectroscopy by AAUS divers. Airborne reflectance spectra are composites of reflectance from 1) the atmosphere (air molecules, aerosols); 2) the sea surface; 3) the water column (water molecules, phytoplankton, colored dissolved organic matter; and 4) the bottom (sediments, submerged aquatic vegetation, benthic types).

D.1 Scientific and Technical Justification

Current ocean color satellites such as SeaWiFS, MODIS, and the planned NPOESS VIIRS system are optimally designed for open ocean imagery, calibrated for low radiances and producing coarse spatial and spectral resolution. The coastal ocean, in contrast, is one of the most difficult places to accurately retrieve ocean color and benthic ecosystem reflectance (Dierssen *et al.*, 2006; Dunagan *et al.*, 2009; Guild *et al.*, 2009 a, b). Radiance signal magnitude is highly variable, ranging from very dark values in clear, deep water to very bright values at water's edge. Signals are also highly variable in space and time, due to many dynamic processes. Aerosol plumes from continental sources complicate the task of atmospheric correction. The spatial (~1 km) and temporal (~daily) coverage from the satellite instruments normally used for the open ocean is of marginal use in coastal waters. Water-leaving radiance in the blue, critical for discriminating pigments from colored dissolved material, exhibit low signals, which often become negative using standard reprocessing methods for MODIS and SeaWiFS. Additionally, the lack of mid-range spectral bands on most existing sensors makes it difficult or impossible to detect events such as "red tides" (Dierssen *et al.*, 2006), one of the main targets for coastal remote sensing. There is a clear need for high temporal, spatial, and spectral resolution data to meet these challenges; for the foreseeable future, this will require airborne instrumentation (Davis *et al.*, 2007).

The science goal (HOPE Goal 2) of this proposal is to advance SMD's science program by developing and flying a portable airborne sensor suite for NASA science missions addressing the challenges of an optically complex coastal ocean zone in support of research areas such as water quality, ocean productivity and biogeochemistry, coastal landscape alteration, coastal and estuarine ecosystem productivity, atmospheric correction, and regional climate variability. These science objective research areas are supported by NASA's Ocean Biology and Biogeochemistry, Biodiversity, and Interdisciplinary Research in Earth Science program areas. Further, this research will support interagency efforts and is aligned with the President's new agenda for regional climate change and the new executive order establishing the Interagency Ocean Policy Task Force (est. June 2009) that issued in December 2009 the Interim Framework for Effective Coastal and Marine Spatial Planning. The coastal and marine remote sensing data in the proposed work is directly aligned with the scientific data that will be utilized by the Ocean Policy Task Force as well as the existing US Coral Reef Task Force (est. 1998) for regionally and jurisdiction-developed plans and subsequent decision making. Further, data from the airborne sensor suite is aligned with ocean and coastal research areas of the Intergovernmental Panel on Climate Change (IPCC), US Climate Change Science Program, the Carbon Cycle Science Program, the North American Carbon Program (NACP), Global Earth Observation System of Systems (GEOSS), as well as integration with the International Ocean Color Coordinating Group. By providing suborbital data for validation, the proposed work has relevance to the following satellite missions: Aqua/Terra, Landsat-7, LDCM (Landsat Data Continuity Mission), EO-1, NPOESS, SeaWiFS and OCO-2. Further, this work is aligned with NRC-recommended missions including HyspIRI, Geo-CAPE, and ACE. Our primary goal is to improve the quality of coastal ocean optical property data to give better estimates and improved understanding of local processes and carbon fluxes in coastal oceans and inland hydrologic areas.

Scientific outcomes from this project will include:

- A flight-tested instrument suite suitable for cal/val activities for future NRC-recommended satellite missions, as well as currently operating and developing SMD missions
- Advanced payload capabilities for NASA's airborne carrier platforms
- A multi-sensor ocean/atmosphere data set available for improved atmospheric calibration and in-water algorithms
- Methodologies for empirical atmospheric correction developed for future airborne imagers of this type (e.g., JPL PRISM) when they come online
- Addresses the biological properties of an important coastal zone ecosystem (e.g., Gulf of Maine including inland water bodies)
- Enable a broad range of research activities in the coastal zone to support SMD goals and objectives
- Position the team for proposing Venture Class and SmallSat missions

Further, the proposed work will position NASA in scientific partnering and contribute to existing programs including Water Quality, Fisheries Management, and Global Carbon Cycle research initiatives, the Naval Research Laboratory National Oceanographic Partnership Program in the Gulf of Maine (or other sites), within the context of the long-term monitoring programs ongoing in the area as well as hypersaline extremophiles research in San Francisco Bay salt ponds recently funded by NASA Astrobiology Institute.

D.2 Relevance to SMD Science Goals and Objectives

Outcomes from the COAST project address the following overarching SMD/Earth Science questions (Table 2.1 in SMD Science Plan for 2007-2016):

- How is the global Earth system changing?
- What are the primary causes of change in the Earth system?
- How does the Earth system respond to natural and human-induced changes?

Further, COAST is aligned with these Earth Science research objectives in the same plan:

- Objective 3. Quantify global land cover change and terrestrial and marine productivity and improve carbon cycle and ecosystem models
- Objective 5. Understand the role of oceans, atmosphere, and ice in the climate system and improve predictive capability for its future evolution

More specifically, this project will enable measurements of several properties of biological interest in the coastal ocean, especially apparent optical properties (AOPs). These properties are key to characterizing estuaries, river plumes, kelp beds, coral reefs and phytoplankton including harmful algal blooms. Although the primary goal of this proposal is to demonstrate the utility of a high resolution airborne cal/val package, the data will also be used to address the biological properties of New Hampshire/Maine area, within the context of the long-term monitoring programs ongoing in these areas. Monterey Bay and the Florida Keys sites will also be evaluated for alternative mission sites. Some specific research program examples are provided. Note that we are not proposing to fully develop each application, but that these data, and the sensor platform, will be made available for addressing these research areas.

D.2.1 Water Quality

This is a major concern in the management of coastal and estuarine environments due to potential economic and health consequences. Products related to this application include:

1. The development and improvement of algorithms and models for the detection and prediction of Harmful Algal Blooms (HABs). Although some harmful algal species have optical characteristics that allow their detection under bloom conditions (e.g., *Karenia. brevis*; Carder and Steward, 1985), other toxic groups do not yet have a known specific optical signature (e.g., *Pseudo nitzschia* spp.). However, by understanding the environmental conditions that benefit and trigger these HABs and by developing remote sensing approaches to detect these conditions, predictive models of HABs can be improved (Anderson *et al*., 2006; Bissett *et al*., in press).
2. The optical characterization of coastal water masses and the monitoring of surface currents and water mass displacements. In order to monitor, understand and predict how natural toxic events and human-induced contamination and pollution propagate through and within coastal environments, we need to develop optical characterizations of water masses. In the past this characterization has been achieved by combining satellite measurements of chlorophyll and Sea Surface Temperature (SST). However, both these properties are non-conservative. Including the optical properties of the water and other optically derived properties that are independent from chlorophyll concentrations, such as suspended solids, Particulate Organic matter (POM) and Colored Dissolved Organic matter (CDOM), will increase the ability to characterize and track water masses (e.g. Kudela and Palacios, 2007).

D.2.2 Coastal Landscape Alteration

Changes in the coastline resulting from erosion and sea level changes will have an effect in both the use of coastal land and the navigability of deltas, estuaries and rivers. This proposal will facilitate improved optical algorithms for the quantification of suspended sediment load. Some recent advances in this effort using MODIS observations take advantage of the changes in the attenuation coefficient of wavelengths that correspond to our classical range of ocean color measurements (Li *et al*., 2003). However, the limited frequency of sampling and 1 km spatial resolution of MODIS has limited the utility of these products for coastal monitoring and management.

D.2.3 Coastal and Estuarine Ecosystem Productivity and Response to Climate Change

Understanding ecosystem productivity and response to physical and environmental forcings is required in order to quantify the role of this environment in elemental cycles. This is of particular interest in Fisheries Management and Global Carbon Cycle research initiatives. Priority products in this application are:

1) Improving algorithms for chlorophyll or absorbed radiation by phytoplankton in coastal waters. Hyperspectral data are much better able to define the chlorophyll absorption spectrum and the fluorescence emission spectrum, therefore offering greater potential for significant advancements (Hu *et al.,* 2005).
2) Improving models of primary productivity. To date, most primary productivity models have been validated only for open ocean waters and have used variability in SST as a proxy for variability in physiological properties of the phytoplankton assemblage. Recent efforts to develop alternative measures include chlorophyll natural fluorescence and/or the ratio between chlorophyll and particulate organic carbon (POC). Hyperspectral data at varying collect times will help to refine these methods.
3) Improving discrimination of coral reef and shallow water ecosystem degradation and change. Remote sensing challenges in these often optically complex heterogeneous ecosystems have improved success for benthic delineation using high spectral and spatial resolution imaging systems, like AVIRIS (Guild *et al*., 2009a, b; Hochberg *et al*., 2003)

D.2.4 Climate variability

Quantifying inter-annual to decadal changes in coastal flow patterns, ecosystem dynamics, and organic matter transfer across land-air-sea interfaces will require the development of climate-quality data records. The use of airborne data for this application requires well calibrated data, a stable sensor and the processing and archiving of climate data records. This will be particularly critical if a gap develops in the availability of satellite sensors (such as between MODIS and VIIRS).

D.3 Data Analysis and Data Archiving

D.3.1 Data Processing and Data Products

The ground-based HIS data processing software will leverage heavily off the code developed for the 50-channel NASA MODIS and ASTER Airborne Simulators, developed jointly at ARC and GSFC. This software was designed to accommodate a variable number of spectral bands, so can be readily adapted to the 120-band output for this hyperspectral system. It produces a standard Level-1B data product (pixels calibrated to at-sensor radiance and geo-located). This data format can be ingested by several commercial image processing software packages. The accuracy of the pixel geo-location will be a function of the quality of the platform navigation data used, but ±1 pixel has been routinely achieved using this data production system with the MASTER and AMS data, when incorporating data from the Applanix POS-AV system. The Level-1B data will be initially archived and distributed (via FTP) from the ASF data facility. Eventual incorporation into the DAAC system would be a NASA programmatic decision.

AATS-14 AOD and water vapor products will be produced using published AATS data-processing methods (e.g., Russell *et al.*, 1993; Livingston *et al.*, 2008) and archived in the Hipskind-Gaines format. This format has been used by nearly all the NASA Earth Science missions AATS has participated in over the past decade or so (e.g., ARCTAS, INTEX, SOLVE II). These products include error bars based on AATS calibration uncertainty and other error sources, calculated using our published methods (e.g., Appendix of Russell *et al.*, 1993).

The microradiometer data product is recorded in ASCII, comma-separated-format (CSV) using the FAT16 file format. In addition to the ASCII data representing the readings, the full calibration and configuration information from each microradiometer is also recorded to the data card the first time sampling is initiated. This is useful in tracking all calibration parameters such as offsets, range factors, in addition to firmware revisions, wavelength, sensor configuration, etc. This achieves the goal of having all instrument information available on the instrument data card. Data can be recorded with all channels sampled at speeds greater than 20 Hz including writing data to memory.

D.3.2 Atmospheric and sun-glint correction

Atmospheric correction of the hyperspectral data will be obtained using a suite of approaches. Previous investigators have shown that airborne data collected from multiple altitudes can readily be corrected (Gould and Arnone, 1997), although reflected sky radiance must be taken into account (e.g., Toole *et al.*, 2000; Hu and Carder, 2002; Gould and Arnone, 2002). We have obtained good results using a complex modeling approach which utilizes Tafkaa, a heavily modified version of ATREM (Gao and Davis, 1997; Gao *et al.*, 2000; Montes *et al.*, 2001; 2003). Tafkaa uses sets of predetermined tables of the atmospheric effects on radiance, given the solar and sensor geometry of the acquisition. Environmental parameters (which we will measure directly) that are needed include ozone concentration, aerosol optical thickness, water vapor, wind speed, aerosol model, and relative humidity. The atmospheric correction can then be constrained by comparison of the hyperspectral data to the *in situ* measurements. Finally, Chomko *et al.* (2003) have obtained good results by using a simultaneous ocean-atmosphere correction scheme, which is expected to work well in the presence of complex aerosol and marine optical constituents. Because we have direct measurements of both in-water constituents and atmospheric components, we can easily parameterize this type of atmospheric correction method. A spectral normalizing procedure will then used to remove the effects of sun glint (i.e., specular reflection from the water surface). This approach was developed by Hochberg *et al.* (2003) and modified by Hedley *et al.* (2005).

D.3.3 Comparisons to Satellite Data

During the field data collections, we will obtain MODIS Aqua, Terra, and SeaWiFS LAC data. Satellite observations will be used to compare accuracy of radiance retrievals and derived products versus the HIS and the *in situ* measurements. We will also use the high resolution atmospheric information to reprocess the MODIS data using regionally tuned atmospheric corrections to determine if the standard MODIS products could be improved with better calibration/validation.

E. Mission Implementation

The COAST proposed airborne mission includes integrating an instrument suite on board a trade-study-selected platform (Figure E-1) that will be flown over a trade-study-selected location. Examining these trade spaces will provide key training opportunities for the team reflecting typical flight mission early-phase activities. A baseline mission including the Wallops Flight Facility (WFF) P3-B flown over the Gulf of Maine has been scheduled and costed in this proposal. A successful mission will deliver three main science deliverables beyond the primary HOPE training objectives:

1. Development and integration of the first end-to-end package for simultaneous measurements of ocean color (modified HIS), aerosol optical depth and water vapor column content (AATS-14), and water bio-optical measurements (microradiometer-based multiwavelength radiometer package) all of which can be flown on a variety of airborne vehicles (e.g., Twin Otter, P-3B) using inputs from an associated precision navigation system. The HIS and microradiometer packages could also be flown on next-generation unmanned aircraft systems (UASs) and a modified AATS or its successor also has UAS potential.
2. Advanced calibration and validation (cal/val) protocols for ocean color through airborne missions of the modified HIS, AATS-14, and microradiometer package flown in conjunction with satellites and in conjunction with *in situ* cal/val measurements and well as moorings and ships.
3. High spatial resolution (2-20 m), atmospherically corrected and georectified ocean-color products (calibrated to at-sensor radiance) that will advance understanding of coastal freshwater and marine processes and productivity and improve coastal models. Our primary products will be well-calibrated water-leaving radiances; there are numerous applications for these data to

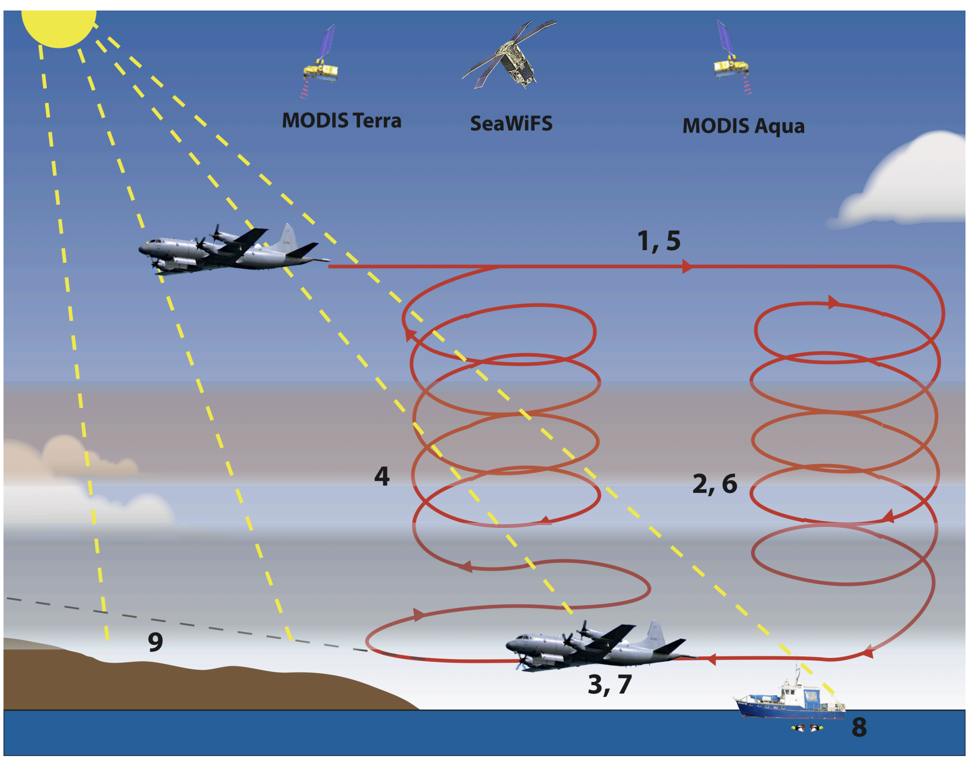


Figure E-1. Conceptual illustration of aircraft flight patterns proposed for COAST. 1. Transit to target. 2, 6. Spiral down to minimum altittude. 3, 7. Minimum altitude transect. 4. Spiral up. 8. Divers obtaining data in the water. 9. Exit from the flight sequences.

produce biogeochemically meaningful products.

E.1 Complete Flight System

The complete flight system includes the three main instruments and ancillary devices to support them. The proposed work will show technical readiness for flight of the imaging spectrometer and microradiometers. The AATS-14 has a TRL of 9 and has 14 years of flight heritage on the P-3B and Twin Otter.

E.1.1 Headwall Imaging Spectrometer (HIS)

The spectrometer in this proposal is a concentric push-broom hyperspectral imager of the Offner design, which was especially configured by the manufacturer for low-radiance oceanographic remote sensing (Figure E-2). One unique feature of the Offner spectrometer is a curved aberration-corrected diffraction grating that dramatically reduces the spectral distortions (smile and keystone) inherent in standard push-broom systems, which typically use some combination of flat gratings and/or prisms. This system has a very high quality original (as opposed to replicated) holographic grating, which is designed for optimal efficiency at 440 nm, unlike those intended for terrestrial applications. The Offner design allows for a relatively wide field of view without compromising spectral integrity, which is highly desirable for mapping large areas. This system has a 52.5º field of view that can be varied with interchangeable objective lenses. With the Offner, all spectra are acquired simultaneously, which is especially critical for an airborne system, where small perturbations of the platform would otherwise result in misregistration of the spectral bands. The system is further customized for ocean imaging with a cooled, blue-enhanced silicon detector array. Manufactured by Q-Imaging Inc., the Retiga-2000RV CCD array has 1600 x 800 elements, and is thermo-electrically cooled to -30ºC for increased sensitivity and radiometric stability. The sealed detector package also reduces the chance of contamination of the array surface due to condensation or dust. The array can be operated with variable regions-of-interest and binning schemes.

Figure E-2. Headwall Imaging Spectrometer (HIS).

E.1.2 Ames Airborne Tracking Sun Photometer (AATS-14)

Figure E-3. AATS-14—Ames Airborne Tracking Sunphotometer will make simultaneous measurements for empirical characterization of the atmospheric column.

AATS-14 (Figure E-3) measures solar-beam transmission at 14 discrete wavelengths from 354-2139 nm, yielding aerosol optical depth (AOD) at 13 wavelengths and water vapor column content. Azimuth and elevation motors controlled by differential sun sensors rotate the tracking head, keeping the detectors normal to the solar beam. The tracking head mounts outside the aircraft skin to minimize blockage by aircraft structures and also to avoid data contamination by aircraft-window effects. As noted above, AATS- 14 has been used extensively to test and improve AOD retrievals by MODIS, SeaWiFS, MISR, and many other satellite sensors. Also, AATS-measured AODs have previously been used in atmospheric correction of images of surface scenes (Spanner *et al.*, 1990; Wrigley *et al.*, 1992).

E.1.3 Bio-optical microradiometers

The microradiometer design was developed through SBIR phase I and II awards in response to a need for smaller, faster, and potentially less expensive radiometers that could be easily scaled to either more or fewer channels and more easily deployed in coastal waters. The entire assembly, including the photodetector, is located on a single circuit board. Each microradiometer is also equipped with a temperature sensor located close to the photodetector.

Microradiometers are the operational optical sensing units, each with a microprocessor, photodetector, optical filter package, data acquisition system, and communications electronics. Aggregators are used to bundle larger collections of microradiometers (Figure E-4) and auxiliary sensors (such as temperature) in individual instrument heads. Aggregators control the data flow to and from the microradiometers, they have on-board removable data storage (Micro-SD card) and power control, and have additional sensing roles including tilt angles, input voltage and current, internal humidity and temperature.

The proposed unit includes 19-brass-encased interchangeable individual microradiometers (for different applications) and one aggregator assembly. Included in the band selection are six bands commonly used for ocean color since the onset of the SeaWiFS mission. Also wavelengths are available down to 305 nm, so application-specific sensors such as UV-bands for CDOM or atmospheric correction, bands targeting phycocyanin and phycoerythrin pigments for flights over reservoirs and terrestrial waters (blue-green algae detection), or bands targeting natural fluorescence (for red tide, high sediment load, and primary

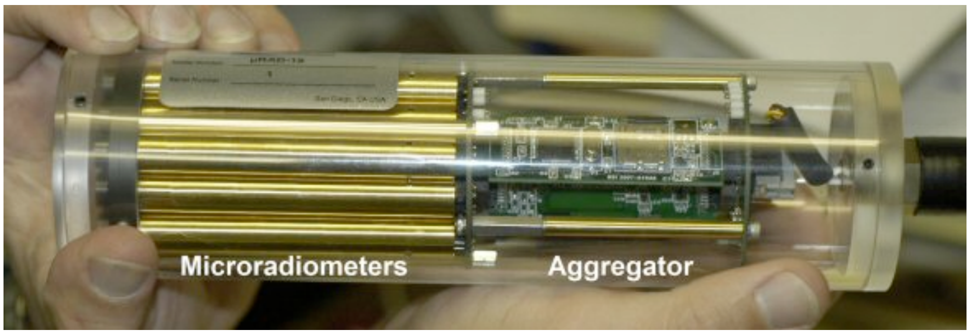


Figure E-4. Microradiometer and Aggregator boards. The microradiometer is sleeved in brass for support and isolation from electronic noise. The unit has 19 channels and an outside diameter of approximately 7 cm.

production applications) could be added. The microradiometer device is sensitive enough to detect moonlight in downward irradiance, yet remain unsaturated when viewing the solar disk in radiance mode.

E.1.4 Carrier

The Wallops P-3B serves as the baseline carrier platform. Carrier trade studies will also be performed on the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter and the ARC SIERRA UAS. The Wallops P-3B, which has already flown AATS-14, can be integrated with the HIS and microradiometers for local and regional sites. The Twin Otter aircraft has flown with the AATS-14 system previously and the HIS will easily mount over one of the nadir ports in that aircraft. The SIERRA UAS can only be integrated with the HIS and microradiometers for portability for remote destinations—and to allow these instruments to take data at a given altitude while AATS flies at a different altitude. Different constraints for different platforms will provide the trainee team with a realistic trade space that has the potential for future application.

E.2 Mission Design and Operations

E.2.1 Flight Date and Flight Planning

The proposed flight will be scheduled between August 1 and October 31, 2011. Mission duration is planned for approximately two weeks to include test flights and weather contingencies. The mission flight lines will be placed to optimize scientific data collection in the coastal zone to avoid sun glint and to fly strategic sites to collect calibration target data and to fly over field instrumentation associated with the R/V and in water measurement activities.

E.2.2 Field Operations and System Support

The ASF is well-positioned to provide the requisite support for engineering, calibration, and data production based on practical experience with the MAS, MASTER, and AMS instruments (it also maintains close ties with the JPL AVIRIS instrument team, which continues to pioneer scientific imaging spectroscopy). The ASF engineering staff has extensive experience operating science-grade instrumentation on extended field operations, often at remote locations. Deployment kits containing support equipment, a data analysis workstation, and a portable integrating hemisphere for pre-flight calibration, can largely be shared with these other facility instruments. Most of the standard operating procedures developed over the years for MAS and MASTER will be applicable to the HIS.

E.2.3 Instrument calibration and validation plan

The instrument calibration and validation plan consists of extensive characterizations of the instrument in the calibration laboratory, followed by field validation experiments.

E.2.3.1 Laboratory Calibrations

The HIS will be characterized in the ARC ASF calibration laboratory. This lab functions under the auspices of the NASA Earth Observing System Calibration Scientist at GSFC, and makes measurements that are directly traceable to the National Institute of Standards and Technology (NIST). The plan includes spectral and radiometric measurements, spatial characterizations, and environmental testing.

Measurements of the normalized spectral response function of each band of the system will be performed using a collimator illuminated with a scanning monochromatic light source (King, 1996, Arnold *et al*., 1996). This will also serve to quantify stray-light and second-order artifacts. Spectral distortions (smile and keystone) will be measured by viewing the monochromatic collimated beam at different incident angles, illuminating multiple points across the spectral dimension of the detector array. This will be further corroborated by viewing spectral line sources in the flat-field device mentioned below. To quantify radiometric response, the sensor will first view a flat-field light source device (Patterson, 1982), to establish the responsivity of each element on the detector array. Absolute radiometric calibration will be established by viewing a 76cm integrating sphere, which itself is characterized annually by the NASA EOS calibration team (Brown *et al*., 2005), and applying the derived flat-field corrections. The instrument will then be tested in a thermal-vacuum chamber to simulate a range of in-flight conditions, while viewing spectral and radiometric sources. This will establish the overall stability of the instrument, and help to refine the thermal management of the environmental packaging. Spatial characterization and lens focusing will be performed while viewing slit targets on a collimator.

E.2.3.2 AATS-14 Langley-plot Calibrations

The most accurate method of calibrating AATS-14 is by Langley plots acquired at a high mountain observatory (e.g., Schmid *et al*., 1998; Russell *et al*., 1993) —most often Mauna Loa Observatory (MLO) in Hawaii, which provides the benefits of high altitude, great distance from continental aerosol sources, supporting ozone and water vapor column measurements, and logistical support via a NASA-NOAA agreement. Our baseline COAST proposal includes one MLO calibration (pre- or post-mission), supplemented by calibration checks made on high-altitude flights and AATS-AERONET comparisons during COAST.

E.2.3.3 Field Validation Experiments

One field validation experiment is included in this proposal. It will consist of flying the HIS instrument, together with the AATS-14 and microradiometers at various altitudes over instrumented surface sites (R/V Gulf Challenger, S. Hooker, Cal/Val mentor) (Figure D-1 and E-1). The AATS-14 will provide a simultaneous empirical characterization of the atmospheric column (AOD and water vapor), which will be used to refine the radiative transfer component of the validation experiments (Russell *et al*, 2005; Schmidt *et al*, 2000). The in-water microradiometer system (C-OPS) that includes an underwater housing will be deployed from R/V Gulf Challenger during aircraft overflight and will determine apparent optical properties (AOP) in the shallow water sites. It consists of two radiometers: one measuring in-water upwelling radiance, and the other either downward irradiance or upward irradiance. Both radiometers are equipped with 19 wavebands and are mounted on a free-fall frame. The frame can be optimized for either slow descent rates for work in very shallow coastal waters sites, or faster descent rates for observations in the open ocean.

Validation experiments beyond the scope of this proposal would establish the stability and repeatability of the data. It is anticipated that the instrument would also eventually participate in the vicarious calibration experiments routinely conducted by other NASA airborne instrument teams, such as AVIRIS and MAS, on a piggy-back basis on other platforms.

Field teams of divers will also conduct *in situ* measurements with the GER 1500 handheld spectroradiometer (SpectraVista Corp.) in custom underwater housing. In water measurements will include spectral measurements (reflectance) of benthic types as well as surrogate measurements for calculating independent measurements of light attenuation (Kd).

E.2.4 Instrument test flight plans

The Wallops P-3B serves as the baseline platform for the COAST project. Initially a transect will be flown at 6,000 m MSL (mean sea level) over the measurement site, coincident with either a SeaWiFS or MODIS satellite over-pass, to collect ocean color and sea-surface temperature imagery, together with solar radiation measurements. The flight direction will be orientated to match the satellite path, within constraints to avoid sun glint in the imagery (Myers *et al*, 2005). Immediately following the over-pass, a descent to 100 m MSL will be made directly over the surface site to provide a profile of AOD, aerosol extinction, CWV, and water vapor density, which will be used to determine aerosol and water vapor layer heights for the imagery just collected. This will then be followed by a Minimum Altitude Transect at 100 m over the measurement site, providing AOD and CWV measurements of the full column viewed by the satellite, together with further image data. The scan rate of the HIS sensor will be adjusted in flight to provide contiguous imagery at both altitudes. Longer transects across the area at both altitudes will measure gradients and other spatial structure in the satellite scene. This basic cycle of high and low altitude passes, interspersed with vertical spirals, will be repeated several times during the mission, over multiple measurement sites, and other areas of interest.

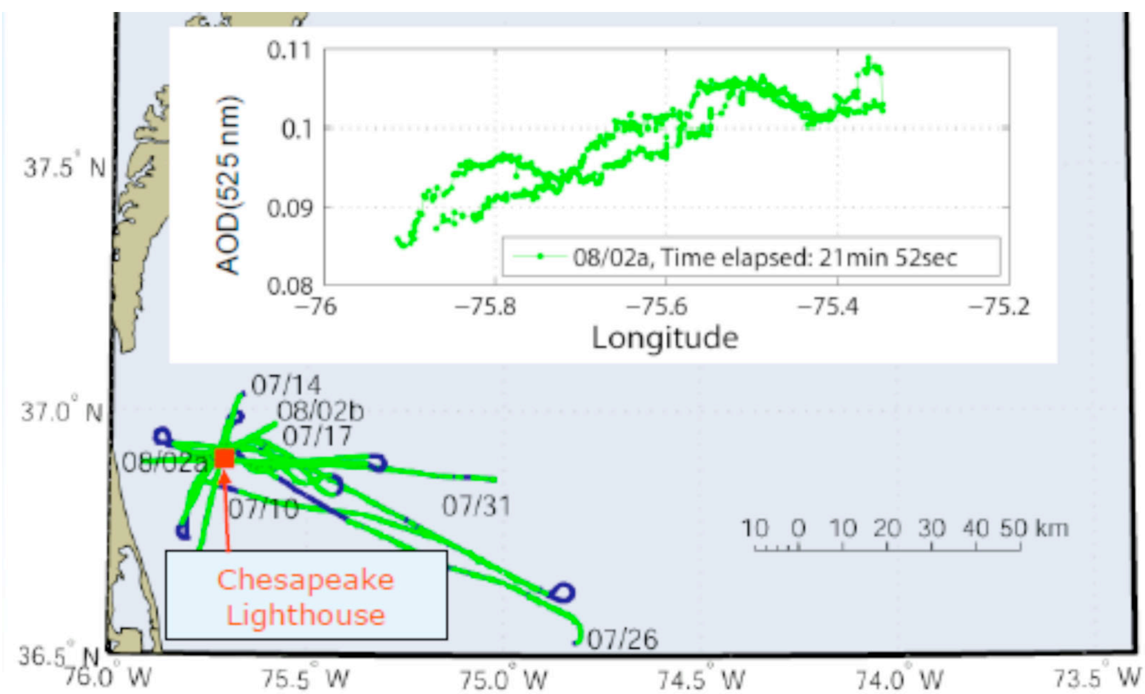


Figure E-5. Map: Low-altitude transects flown near the Chesapeake Lighthouse in CLAMS (Redemann et al., 2005). Inset: AOD (525 nm) measured August 2, 2001 by AATS-14 on forward and return legs.

A potential source of error in atmospheric correction is any change in AOD between the time of the AATS AOD measurements on the minimum-altitude transect and the HIS ocean color measurements on the higher-altitude transect (see Figure E-5). As a rough gauge of this potential error we have inspected AOD changes between low-altitude transects flown off the US East Coast in CLAMS (Chesapeake Lighthouse and Aircraft Measurements for Satellites; Redemann *et al.*, 2005). Such transect paths are shown in Figure E-5, along with a typical AOD result from one back-and-forth transect that took 22 minutes to fly. Over this period the West-to-East gradient in AOD (525 nm) (~0.036 per degree longitude) was preserved, and AOD differences between corresponding points on Eastward and Westward legs were <0.005. In the proposed measurements we will fly minimum-altitude legs both before and after the HIS measurements aloft, to provide an experimental record of AOD changes during the HIS measurements.

E.3 Science Payload Interface

The aircraft described in this interface definition is the NASA P-3B; however, the CIRPAS Twin Otter and the SIERRA UAS will be evaluated in trade studies to determine the most effective carrier. Since the NASA P-3B is a unique asset owned and managed by the NASA Airborne Science Program, the aircraft operations and protocols for instrument installation are well defined and managed outside this project.

The following payloads on the aircraft are developed, owned, and maintained by the instrument scientists as shown in Figure E-6, Aircraft Payload Interfaces.

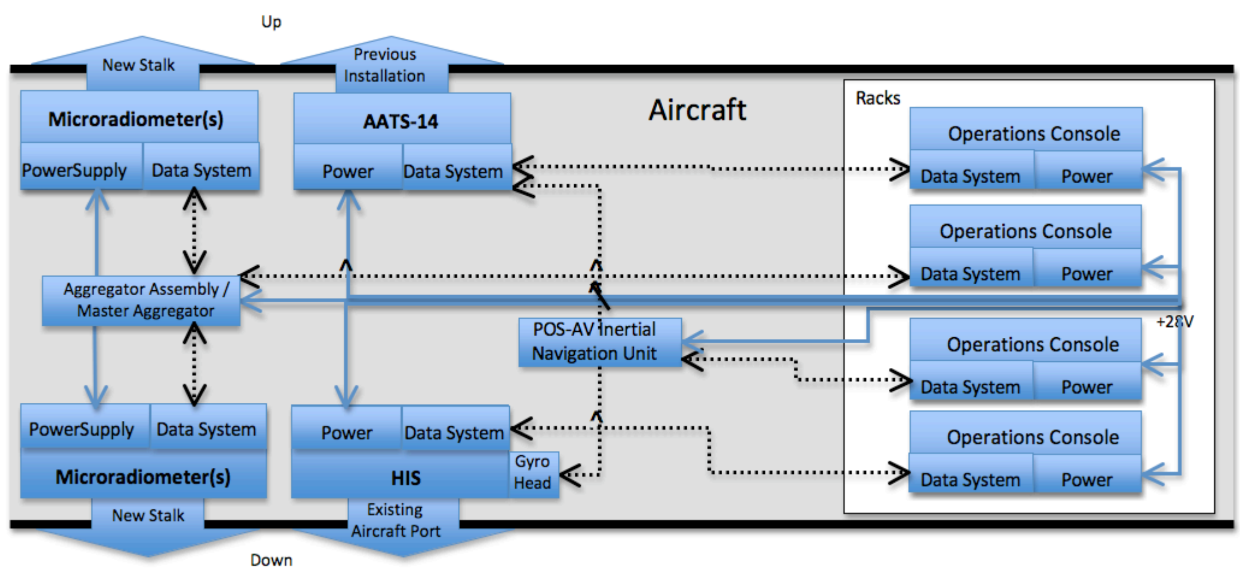


Figure E-6. Aircraft Payload Interfaces.

E.3.1 Headwall Imaging Spectrometer (HIS)

The HIS has flown on F-16 and Predator-B UAS military aircraft. All of the major subsystems of this sensor will be packaged in modified sealed canisters used for NASA aircraft that can be maintained at one atmosphere of pressure and temperature-regulated to remain above the ambient dew point to avoid condensation. The housing for the sensor head will include an optical window for the sensor to view through. This in turn will be shock-mounted to mitigate the G-forces and vibration encountered during operations on high performance aircraft.

Portability of the instrument between aircraft platforms is considered essential to maximize flexibility in designing multi-sensor payloads on large science campaigns, as well as to leverage research funds by being able to quickly respond to missions of opportunity. If no aircraft navigation data source is available, it can be flown with a third canister containing one of the NASA Applanix POS-AV (Position and Orientation System) units.

Since the HIS has not been installed on the P3B previously, the COAST trainee team has the responsibility to define the requirements for the mechanical interface and installation of the instrument in existing ports. The electrical and environmental requirements of the instrument interface for the aircraft will be developed by the instrument scientist in conjunction with the aircraft manager.

The HIS interfaces to the aircraft power input, a mount, the POS-AV INU Gyro Head, and the data system connectivity to the console (See Appendix I-4, Figure I-1). The mount will be an existing aircraft port that limits the risk and has certified procedures for airworthiness.

The airborne data capture system for the HIS will consist entirely of commercial components, integrated into a single small package. The Retiga CCD array module in this version of the VS25 produces digital data over a Firewire interface, so a frame-grabber card is not required. A single-board PC computer running the Linux operating system will ingest the data and control the camera operating parameters, including integration times, region-of-interest processing, and pixel binning. The system control software will be written incorporating a library of utilities provided with the Retiga array module. The option will be provided for key parameters to be changed in flight during a data collection mission. The data system will be configured to ingest external navigation data from a variety of sources, including an Applanix POS-AV stand-alone system, or the Next-Generation Navigation Data Recorder systems scheduled to be fielded by the NASA Airborne Science Program on their science platforms in 2009. Both of these systems are managed by the ASF, and are made available to NASA instrument teams as shared facility resources. The airborne data system will also include a GB Ethernet interface for satellite telemetry systems, developed for the NASA AMS wildfire sensor on the Predator-B UAS. This software-configurable interface has been demonstrated with Ku- and S-band telemetry hardware, and allows for real-time data relay and sensor command and control, when flown on platforms so equipped. This interface will also allow the sensor to exploit the payload computer in the new navigation recorder, which can be programmed to generate science data products autonomously on board the aircraft. This technology was demonstrated in 2007 during the NASA Western States Fire Missions, where the payload computer generated Level-1B and georectified Level-2 data products on board the Ikhana UAS in near-real-time. Ocean-color research algorithms could be similarly implemented (and modified in-flight) on this proposed sensor.

E.3.2 AATS-14

The AATS-14 has previously been installed in the P-3B aircraft and hence installation is defined, the hardware exists and is certified.

The AATS-14 interfaces include the aircraft supplied power input, the mechanical mount, the POS-AV INU, and the data system connectivity to the console. Since this instrument has been previously installed then the mount exists and the installation procedures are documented and accepted to meet airworthiness.

E3.3 Bio-optical Microradiometers

Since the Biospherical Instruments microradiometers have not been previously flown, the COAST trainee team has the responsibility to define the requirements for the mechanical interface and installation of the instrument in existing ports. The electrical and environmental requirements of the instrument interface for the aircraft will be developed by the instrument scientist in conjunction with the aircraft manager.

The microradiometers have a power and data collection system. The instruments will be positioned to be most effective when facing forward along the axis of the plane, at 40° from nadir and zenith. Positioned this way, the path of the plane provides the needed measurement geometry during level flight normal to the path of the sun. The radiance instruments are 7cm outside diameter and about 30.5cm long, with a telemetry cable on the back. This suggests a flat-plate port that does not need to be bigger than 7.6cm or so, oriented at 40º. The irradiance instrument should be mounted viewing the zenith beneath any non-focusing port, such as a hemisphere (in an ideal case, the horizon cutoff of the instrument would control the geometry). Similar installations offer risk mitigation with lessons learned for mounting instruments on a spar that was inserted up and toward a port on the plane. Some kind of vortex generator was installed to reduce the buffeting that the instrument would experience during flight. An instrument interface will send the data to a laptop. The deck box containing the Aggregator Assembly or Master Aggregator has connectivity to the console data system and the aircraft supplied power. This instrument has similar installation to the SSFR (Solar Spectral Flux Radiometer), an instrument that has already been flown on the P-3B along with the AATS-14.

Data sets are consumed with attached time stamps to coordinate across the concurrent data acquisition systems including the instrument, shipboard, and satellite data systems.

E.4 Carrier Services

The payload can be readily flown on most of the NASA airborne science aircraft using standard camera mounts. The primary platform for this proposal is the P-3B aircraft at NASA Wallops Flight Facility in Virginia. However, other aircraft are included in I-4 Carrier Services section as optional and/or additional carriers to be included in a trade study after award for consideration based on meeting mission requirements for science as well as programmatic cost and schedule.

The NASA Science Airborne Program manages the P-3B to support science missions. Due to the close proximity of approximately 435 miles of the study site, the aircraft will not be required to deploy to a remote operating site, and can be operated during normal business hours, obviating the need for crew overtime and travel costs. A contingence will be provided to forward-stage the aircraft at Pease AFB in New Hampshire on a daily basis, which is even closer to the study site, in the event that weather conditions are highly dynamic. The P-3B aircraft is equipped with suitable optical viewing ports shown in I-4, so no modifications to the aircraft will be required to accommodate the proposed payloads. The needed equipment rack for instrument operations is available. The total weight of the payload, including multiple onboard operators and science observers, is well within the capabilities of this aircraft. Electrical power requirement for the proposed instrumentation is also easily accommodated by the existing infrastructure on the P-3B.

E.5 Development Approach, Test, and Verification

Pre-phase A activities have been largely accomplished prior to this proposal. The development approach for this project will be to tailor the Flight Systems and Ground Support Project life cycle to meet the HOPE call for gates including the System Requirements Review (SRR) Phase A, Preliminary Design Review (PDR.) in Phase B, Critical Design Review (CDR) in Phase C, and the Flight Readiness Review (FRR) in Phase D.

The Science Requirements will be defined in the System Requirements and then written for product development and deliverables for each of the instruments, the aircraft, integration and data analysis. Traceability matrices will be development to communicate the state and complete the test and verification that the requirements have been met to agreed to success criteria. Validation using actual flights and the installed instruments will include the instrument PIs as well as the project PI participation to ensure flight readiness.

Control, documentation, and reviews for airworthiness will be incorporated into the schedule and coordinated across the team including ARC, GSFC, and Wallops. The schedule will be managed by the project manager to include the required gates including the Preliminary Design Review. The detailed plan for managing the technical effort will be defined in the System Engineering Management Plan, SEMP, after award.

The ARC Earth Science Division has agreed to make this HIS permanently available to the NASA community, as part of a facility instrument, should this proposal be awarded (see attached letter of concurrence). The development of a robust airborne data capture system, appropriate environmental packaging, and the requisite data acquisition and ground processing software, are the major elements of this proposal. The work will be performed at the ARC Airborne Sensor Facility (ASF) which has extensive experience in the fabrication and operation of airborne facility sensors for NASA, including the MODIS and ASTER Airborne Simulators (MAS and MASTER) and the UAS Autonomous Modular Sensor (AMS) system. The completed instrument will be thoroughly characterized in the ASF Calibration Laboratory. This will serve to verify calibration methodologies and establish instrument accuracy and stability.

E.5.1 NASA P-3B Aircraft

The NASA P-3B is fully supported resource and maintained to support science missions. The development approach for the aircraft includes the instrument installation that will be worked between the aircraft manager and the instrument scientists. This project will coordinate the aircraft schedule for instrument installation and flight scheduling.

E.5.2 Instruments

Once an instrument is delivered and installed, the COAST project will be a user of the existing NASA P-3B aircraft with the operational instruments. The calibration of the instrument is a critical element in the validation process which consists of extensive characterizations of the instrument in the calibration laboratory in compliance with NIST standards, followed by field validation flight experiments.

E.5.2.1 NASA P-3B Aircraft with the Bio-optical Microradiometers Instrument

The COAST project will define the requirements for the Biospherical Microradiometers instrument. The Instrument Scientist will complete the instrument development process including the careful radiometric and spectral calibration to be in compliance with the NIST standard.

E.5.2.2 NASA P-3B Aircraft with the HIS Instrument

Upon completion, the instrument will be characterized to the best extent possible in the ARC ASF calibration laboratory. This lab functions under the auspices of the NASA Earth Observing System Calibration Scientist at GSFC Space Flight Center, and makes measurements that are directly traceable to the National Institute of Standards and Technology (NIST). The plan includes spectral and radiometric measurements, spatial characterizations, and environmental testing.

Measurements of the normalized spectral response function of each band of the system will be performed using a collimator illuminated with a scanning monochromatic light source (King, 1996, Arnold *et al*, 1996). This will also serve to quantify stray-light and second-order artifacts. Spectral distortions (smile and keystone) will be measured by viewing the monochromatic collimated beam at different incident angles, illuminating multiple points across the spectral dimension of the detector array. This will be further corroborated by viewing spectral line sources in the flat-field device mentioned below. To quantify radiometric response, the sensor will first view a flat-field light source device (Patterson, 1982), to establish the responsivity of each element on the detector array. Absolute radiometric calibration will be established by viewing a 76.2cm integrating sphere, which itself is characterized annually by the NASA EOS calibration team (Brown *et al,* 2005), and applying the derived flat-field corrections. The instrument will then be tested in a thermal-vacuum chamber to simulate a range of in-flight conditions, while viewing spectral and radiometric sources. This will establish the overall stability of the instrument, and help to refine the thermal management of the environmental packaging. Spatial characterization and lens focusing will be performed while viewing slit targets on a collimator.

E.5.2.3 AATS-14

The airborne sun photometer is calibrated to measure aerosol optical depth using the Langley technique. We will conduct Langley-plot calibrations of AATS-14 at Mauna Loa Observatory (MLO). The exceptionally clean conditions at MLO typically yield Langley regressions with uncertainties in extrapolated top-of-atmosphere irradiance of a fraction of 1%. This project will support the pre-flight calibration with post flight calibration cost shared with the follow-on flight experiment.

E.5.4 Test Flights

Test flights with the instruments will be completed prior to operational flights to validate mission readiness. These test flights comprise about 15% of flight time and are included in the baseline mission schedule and costing.

F. Management

F.1 Management Roles and Responsibilities

COAST will be managed using processes consistent with NPR 7120.5D with appropriate and approved tailoring. HOPE program reporting relationships are shown in the organization chart

(Figure F-1). Dr. Liane Guild is the Project Principal Investigator (PI), accountable for the success of the science payload with full responsibility for its scientific integrity and scientific success. Dr. Guild is also the Team Lead, ultimately responsible for the project's execution. Dr. Jennifer Dungan is the Project Manager (PM), responsible for meeting the technical milestones, schedule and budget of the project. The PI and PM report to the HOPE Program Office at Langley on COAST. Maryland Edwards, as the Project System Engineer, is responsible for certifying system integrity for the instrument suite on the flight platform. Dr. Joaquín Chavez, cal/val scientist, is responsible for assuring the science objectives of the microradiometer deployment and field effort.

Guild, Dungan, Edwards, and Chaves are "shadowed" by HOPE mentors who are experienced in project science, management and system engineering. Dr. Randy Berthold (ARC Biospheric Science Branch) mentors Guild on team leadership. Dr. Phil Russell (ARC Atmospheric Science Branch) mentors Guild on project PI processes as well as act as the instrument scientist for the AATS-14. Pete Zell (ARC Project Management Office) mentors Dungan on project management. Dr. Steve Dungan (ARC Biospheric Branch) mentors Edwards on project system engineering. Dr. Stanford Hooker (GSFC Hydrospheric and Biospheric Science Laboratory) mentors Chaves on cal/val processes and science as well as act as the instrument scientist for the microradiometers. Claire Smith (ARC Workforce Development Branch) will develop and implement the formal APEX training plan for COAST and ensure the inclusion of trainees beyond the core team to achieve maximum benefit from "Fly on the Wall," "Lunch & Learn," practice reviews, and other APEX techniques. Qualifications for all named personnel are contained in Section I-2. Mission management, instrument engineering, and other instrument science roles will be filled by other ARC, GSFC, and WFF personnel covered by related, funded projects.

The Safety and Mission Assurance (S&MA) representative role(s) will be assigned as appropriate. This function submits to the independent technical authority of review boards, for COAST, this involves flight safety and "extreme environments" (involved in the in-water measurement component of the project plan). The baseline mission that has been scoped and costed in this proposal involves Wallops Flight Facility (WFF). In this case, the airworthiness reviews will be done by the WFF AFSRB. If another carrier is selected as a result of trade studies, a different AFSRB may be used. In the training component of the work (see Section C), practice reviews will be done by the ARC AFSRB. The ARC Extreme Environments Review Board will certify the safety of the in-water measurement campaign.

Critical project documents, such as schedule, system descriptions, risk matrices, trade studies and data will be configuration-controlled and documented using a NASA-approved system such as MINX or Sharepoint. Access control on the selected system is meant to ensure record retention objectives and meet NASA IT security requirements. A knowledge network to incorporate a wiki, calendar, discussion/blog, and file sharing will be organized to foster remote team collaboration. Since this is a streamlined project it is important to efficiently store and disseminate information across remote team members for flow of communication between individuals.

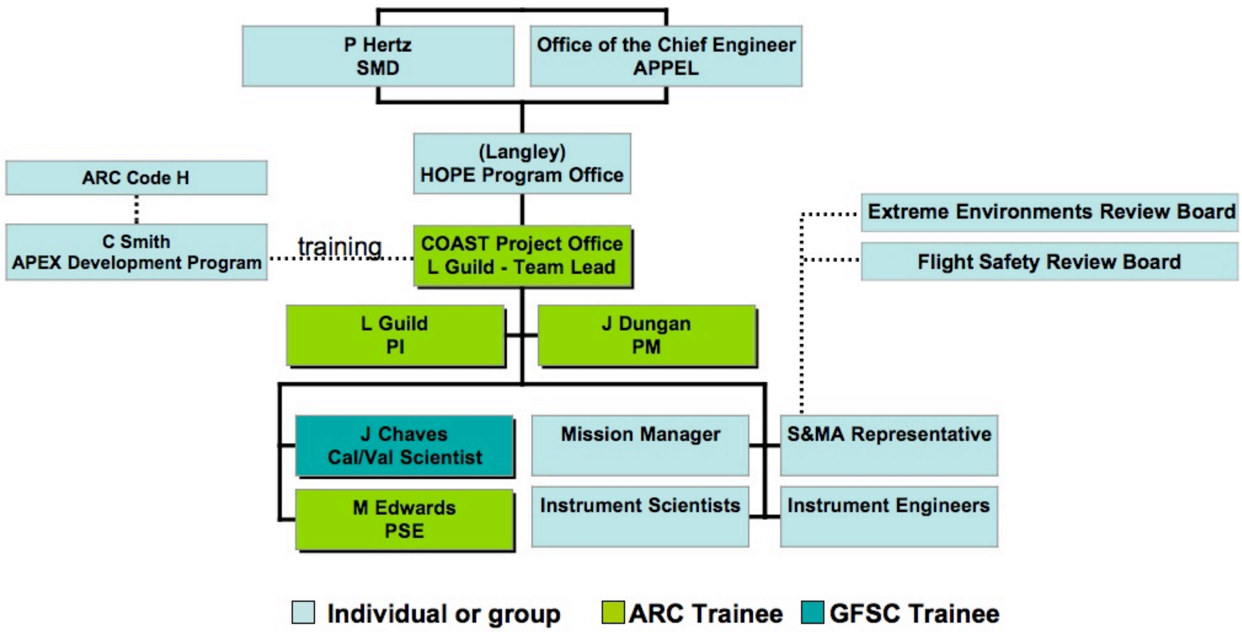


Figure F-1. COAST organization chart. Solid lines indicate reporting relationships; dotted lines represent other relationships.

F.2 Risk Management

Perceived primary (highest probability and impact) risks at the time of the proposal are listed in Table F-1.

Table F-1 COAST Risks and mitigations.

Risk	Mitigation
Carrier platform availability during Aug-Oct 2011 time frame	-Schedule reserves for presently undetermined carrier schedule -West coast versus East coast trade space
Weather at field campaign location	-Cost reserves available for extending team TDY at field site
Design and install angled mount on the aircraft for microradiometers	-Lessons learned from similar mounting for the SSFR -Experienced team with certified airworthiness procedures
Integration of the HIS on a new platform	-Use of high-capacity ports on the P-3B
Scaling training and science activity under $800K HOPE cost cap	-Descoping activities at key decision points -Cost reserves

The high TRL of the components lends confidence that the instrument package can be integrated and achieve flight-readiness. Nonetheless, there are significant challenges to the project using a trainee-team and the communication required across a mission of this complexity. More extensive risk analysis will be involved during training activities and especially in the mission trade studies to identify additional specific risks, evaluate risk probability, impact/severity, and timeframe, plan, track, mitigate and document risk according to NPR 7120.5B. The PM has responsibility for managing risk. Risk analyses necessary for this management is the purview of the PSE.

G. Cost & Cost Estimating Methodology

Table G-1. Total COAST Project Funding Profile (TABLE 1)

FY costs in Real Year Dollars (in thousands)

WBS# Element	FY2010			FY2011			FY2012			Grand Total		
	Requested Funding	Contribution	Total	Requested Funding	Contribution	Total	Requested Funding	Contribution	Total	Requested Funding	Contribution	Total
01 Project Management	17.04	5.17	22.22	117.44	32.58	150.03	11.69	2.86	14.54	146.17	40.61	186.79
02 Systems Engineering	5.50	3.67	9.17	34.63	23.09	57.72	3.04	2.02	5.06	43.17	28.78	71.95
03 Safety and Mission Assurance	3.27		3.27	20.61		20.61	1.81		1.81	25.69		25.69
04 Science	14.75	2.43	17.18	101.91	24.28	126.19	8.59	1.79	10.38	125.25	28.50	153.75
05 Payloads/Instruments	7.07		7.07	205.84		205.84	20.42		20.42	233.33		233.33
07 Flight Operations	2.45		2.45	17.10		17.10	2.10		2.10	21.64		21.64
08 Carrier Services	0.00		0.00	63.00		63.00	0.00		0.00	63.00		63.00
09 Ground Systems (Obs. Platforms)	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
10 Systems Integration and Testing	3.10		3.10	21.22		21.22	2.46		2.46	26.78		26.78
11 Training (Education) and Public Outreach	0.00	4.58	4.58	25.00	28.86	53.86	0.00	2.53	2.53	25.00	35.97	60.97
Reserve	12.00		12.00	71.97		71.97	6.00		6.00	89.97		89.97
Total Requested Funding	65.18		65.18	678.72		678.72	56.10		56.10	800.00		800.00
Contributions		15.85	15.85		108.82	108.82		9.20	9.20		133.87	133.87
Total Project Cost	65.18	15.85	81.03	678.72	108.82	787.54	56.10	9.20	65.30	800.00	133.87	933.87

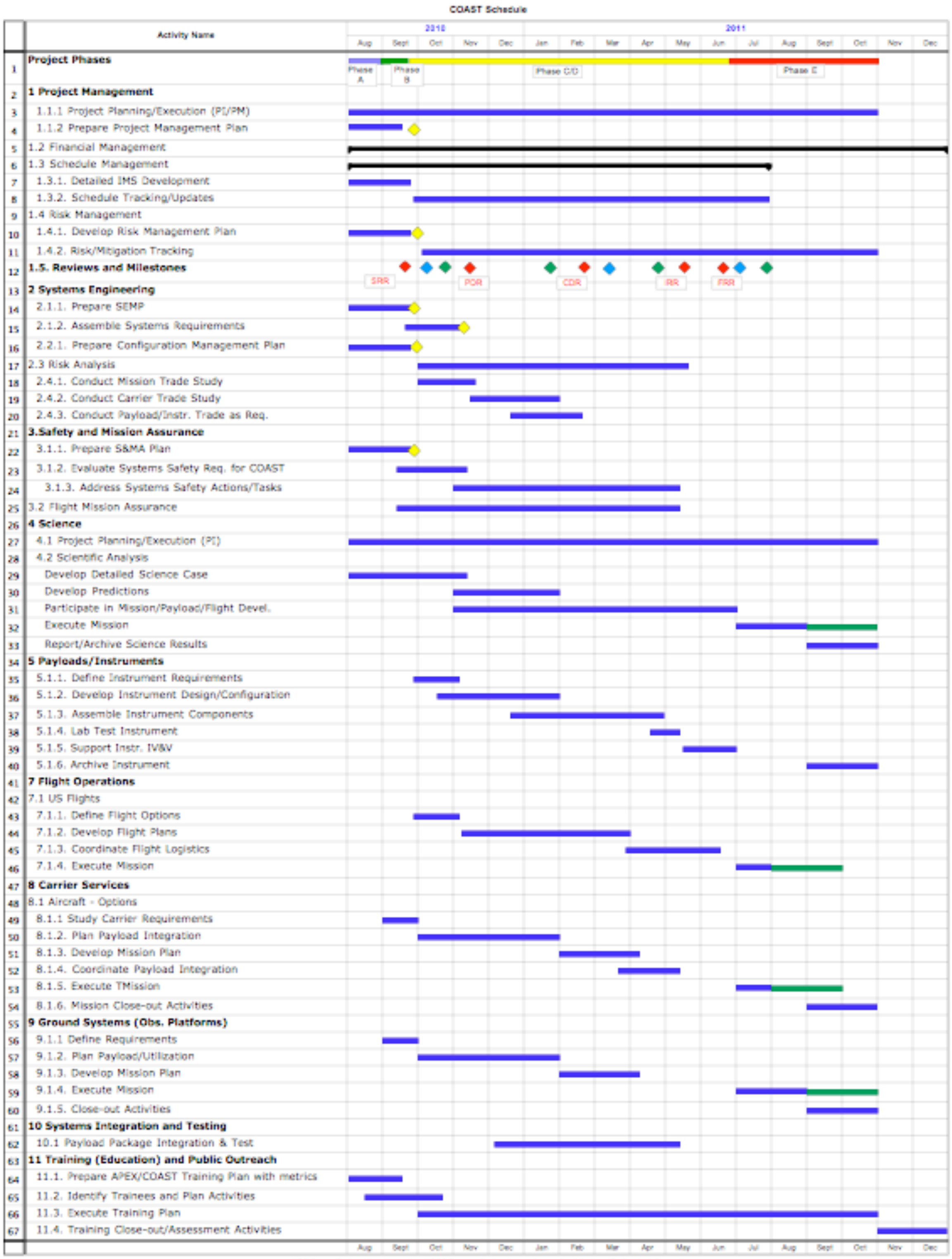
The requested project cost for HOPE: COAST is $800K, including an 11% reserve. With ARC-contributed direct costs and procurements totaling $134K, the proposed total project cost is $934K (Table G-1). In addition to contributed costs, the project leverages $2.85 million in previous development costs of instruments and associated hardware and software for the instrument suite. In particular, AATS-14 was developed at NASA ARC with support from several programs totaling well over $1 million for hardware development and testing. Data processing software to generate AATS-14 products has been developed and extensively refined in AATS-14 scientific missions since 1996, at a cost exceeding $200K. Investment in the modifications of the HIS, its data processing software and navigation system total $410K. NASA Goddard has previously invested approximately $1,240K in the hardware and software for the microradiometers.

The COAST mission cost is based on a bottom-up cost estimation model. The WBS based on the schedule was used for estimating the staffing effort and procurement. The WBS is developed based on the project objectives and the baseline mission of the P-3B deployed from Wallops Flight Facility to the Gulf of Maine. Level 3 is the lowest level identified at this stage of the costing but trainees will get further experience in developing cost estimates at Level 4 during the first few months of the project. Estimating costs for each activity in the WBS and roll up of these estimates are the two major steps for this technique. FTE and contractor work hours were converted to real year dollars based on the rates in the ARC standard-pricing template and rates provided by GSFC. The cost estimation for the activities is developed using various cost methodologies including analogous and parametric cost models, vendor quotes and COAST mentor's expert judgment based on similar missions with aircraft instruments. A margin of .3 FTE in the labor estimate is included for expanding or changing the schedule for instrument scientists and engineers to accommodate changes to the mission developed as a result of trade studies. An 11% cost reserve is reflected in Table G-1 that will be applied to risk mitigation, including instrument integration during Phase C/D and during the flight mission to mitigate weather risk.

H. Schedule

Activities have been initially scoped and estimated in FastTrack at WBS Level 4. For reasons of space, high-level and selected activities are shown in Table H-1, but detailed activities as listed are factored into this schedule with weekly granularity. The schedule incorporates the following key project activities. The Principal Investigator trainee, with guidance from the PI mentor, will lead the development of the System Requirements, define the mission trade space, manage the science team, develop the detailed scientific aspects of the coastal, atmospheric and water-column remote sensing problems execute the mission and lead the reporting and archiving of science results. The project manager trainee, with guidance from the PM mentor, will complete a Project Management Plan, do bi-weekly status reporting, coordinate staff and training activities, and do project close-out activities. She will also track and update the schedule and develop and track IV&V Management System (IMS) procedures. She will develop and complete a risk management plan and track risks and their mitigation. All relevant personnel will participate in the ARC Center Reviews, HOPE Program Reviews (ARC/GSFC), System Requirements Review, Payload PDR and CDR, Integration Readiness Reviews and Flight Readiness Reviews under the direction of the PM. The project systems engineer trainee, with guidance from the PSE mentor, will complete a Systems Engineering Management Plan and Configuration Management Plan, assemble systems requirements, maintain system documentation and the COAST data archive. The PSE will also lead the mission trade studies, including carrier and instrument trades. A designated contractor for ARC Code C will maintain the detailed budget, track financial status, and close out the project budget upon completion. The designated Safety and Mission Assurance representative will develop a S&MA plan, evaluate systems safety requirements, address systems safety actions and tasks and report to the ARC Safety and Mission Assurance Office.

Table H-1. Condensed COAST Schedule. Baseline schedule in blue; schedule reserve in green.



I. Appendices

I-1 Letters of Commitment

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, CA 94035-1000

D:200-1 March 29, 2010

Dr. Liane Guild
Principal Investigator, COAST Proposal
NASA Ames Research Center
Mail Stop 242-4
Bldg. N242, Room 209
P.O. Box 1
Moffett Field, CA 94035-0001

Subject: Letter of Commitment to the Coastal and Ocean Airborne Science Testbed (COAST) Mission proposal to the NASA HOPE Solicitation

Dear Dr. Guild,

NASA Ames Research Center (ARC) is pleased to contribute to the success of the Coastal and Ocean Airborne Science Testbed (COAST) Mission proposal in response to NASA's HOPE solicitation. The COAST mission will produce a highly calibrated, robust airborne imaging spectrometer system, integrated with a tracking sun photometer system and bio-optical microradiometers, optimized for coastal ecosystems and ocean biology and biogeochemistry research. Further, the imaging system will bring a unique capability for measuring features at the boundary between land and sea. This will be an Ames facility instrument suite that will fill research data gaps in the coastal zone.

ARC will fulfill its role on the COAST Mission in accordance with the submitted proposal, with the following responsibilities:

1. Contribute Ames Project EXcellence (APEX) training program and required resources, in Code H, as per the training plan in your proposal,
2. Contribute the Lead Trainer and identified mentors for the entire life cycle of the mission,
3. Provide overall Safety and Mission Assurance for the mission,
4. Provide the AATS-14 instrument and the Headwall imaging spectrometer, and
5. Offset Earth Science Project Office (ESPO) project costs for carrier integration and mission operations.

ARC has identified the resources necessary to support our role in the COAST Training Opportunity to conduct an airborne mission over coastal waters in support of SMD Science Mission objectives. The participation in APEX activities provided by the proposed HOPE training plan will benefit many aspiring mission principal investigators, project managers, and system engineers who will be resources for future Agency initiatives. I am pleased to fully endorse this proposal on behalf of ARC.

We look forward to working with you on this important mission.

Sincerely,

S. Pete Worden
Center Director

Concurrence:

Paul R. Agnew
Chief Financial Officer

NASA Ocean Biology and Biogeochemistry
GSFC Calibration and Validation Office
1450 S. Rolling Road, Halethorpe, Maryland 21227
+1·410·294·7451

2 April 2010

Dr. Liane Guild
Earth Science Division
NASA Ames Research Center, MS 242-4
Moffett Field, CA 94035-1000

Dear Liane:

Thank you for the opportunity to participate in the Coastal and Ocean Airborne Science Testbed (COAST) project. The Calibration and Validation Office (CVO) at GSFC is ready and able to fulfill the calibration and validation activities associated with measuring the apparent optical properties (AOPs) of seawater along with the relevant biogeochemical parameters, as well as the training components associated with Dr. Joaquin Chaves. As part of establishing a quality-assured ability to acquire and process measurements of the AOPs of seawater, GSFC has invested in three unique capabilities. The first is to develop a new AOP sensor that is significantly smaller than existing technologies, but with a dynamic range in keeping with the best commercial-off-the-shelf (COTS) sensors currently available, in terms of spectral coverage, sensitivity, and accuracy. The second is to record the data from these new so-called microradiometer sensor systems with strict adherence to the NASA sampling protocols. And the third is to process the data to geophysical units and final data products in keeping with the production of a climate-quality data record (CDR). The latter is defined as *a parameter of agreed importance to Earth observations, which has a spatial and temporal extent in keeping with the scales of interest, as well as a traceable uncertainty budget*. This definition is not used by all climate change investigators. It is established here as a sensible endpoint, because it is hard to imagine a climatic analysis is trustworthy if it is not based on parameters with traceable uncertainty budgets. The investments by GSFC in these three areas of research are as follows:

1. Microradiometer sensors	$ 660K
2. Data acquisition software	270K
3. Data processing software	310K
4. Total investment	$1,240K

Good luck with your proposal,

Dr. Stanford B. Hooker
Calibration and Validation Office, Director

I-2 Resumes

Liane S. Guild, Ph.D.
Principal Investigator Trainee

Research Scientist, Biospheric Science Branch (Ecosystem Science and Technology)
MS 242-4, NASA Ames Research Center, Moffett Field, CA 94035
Ph: 650-604-3915, Fax: 650-604-4680, E-mail: Liane.S.Guild@nasa.gov

Role in Mission:
Liane Guild will be the PI trainee and team lead in the design, development, and execution of an airborne flight mission with a payload suite offering a unique capability for science data collection in the coastal zone.

Experience:
2005 – PI, AVIRIS Mission over Puerto Rico and USVI
2005 – PI, AVIRIS Mission over Kaneohe Bay, HI
2004 - PI, AVIRIS Mission over FL Keys and Puerto Rico
2006-Present, PI, Coral Reef Ecosystem Health and Biodiversity (NASA IDS), NASA ARC
2000-Present, Research Scientist (Civil Servant), Biospheric Science Branch, NASA ARC
2000, National Research Council Postdoctoral Associate, Ecosystem Science and Technology Branch, NASA ARC
1989-1995, Research Scientist, JCWS, Ecosystem Science and Technology Branch, NASA ARC
1986-1989, Research Assistant, Dept. of Biological Sciences, Stanford University

Education:
Ph.D. (Ecosystems Ecology) - Oregon State University, Corvallis, OR, April 2000.
M.S. (Biological Sciences) - Stanford University, Stanford, CA. June 1988.
B.A. (Ecological Systems) - Humboldt State University, Arcata, CA. 1986.

Honors: NASA HQ Member Designee: US Coral Reef Task Force Steering Committee and Climate Change Working Group

Selected Publications:
Dunagan, S., B. Baldauf, P. Finch, L. Guild, E. Hochberg, B. Jaroux, L. Johnson, B. Lobitz, J. Ryan, S. Sandor-Leahy, J. Shepanski, 2009, Small Satellite and UAS Assets for Coral Reef and Algal Bloom Monitoring, 33rd International Remote Sensing of Environment, May 4-8, 2009, Stresa, Italy.

Guild, L., J. Goodman, B. Lobitz, R. Armstrong, F. Gilbes, R. Berthold, and J. Kerr, 2009, *Imaging Spectroscopy and Spectral Analysis in Support of Coral Reef Ecosystem Biodiversity Research*, 33rd International Remote Sensing of Environment, May 4-8, 2009, Stresa, Italy.

Guild, L., B. Lobitz, R. Armstrong, F. Gilbes, J. Goodman, Y. Detres, R. Berthold, and J. Kerr, 2009, NASA airborne AVIRIS and DCS remote sensing of coral reefs, Proceedings 11th International Coral Reef Symposium, Ft. Lauderdale, FL, July 2008.

Armstrong, R., L. Guild, F. Gilbes, B. Lobitz, andY. Detres, 2007, Water column corrections of AVIRIS data for hyperspectral characterization of benthic marine communities in Puerto Rico, Proceedings 5th EARSeL Workshop on Imaging Spectroscopy, Bruges, Belgium, April 23-25, 2007.

Guild, L., B. Lobitz, R. Armstrong, F. Gilbes, A. Gleason, J. Goodman, E. Hochberg, M. Monaco, R. Berthold, 2007, NASA airborne AVIRIS and DCS remote sensing of coral reefs, Proceedings 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica, June 25-29, 2007.

Guild, Liane, Barry Ganapol, Roberto Furfaro, Philip Kramer, Roy Armstrong, Art Gleason, Juan Torres, Radiative Transfer Modeling and Spectral Analysis of Coral Reefs, Ocean Optics XVIII, Fremantle Australia, October 2004, Proceedings, 2004.

Guild, Liane S., J.Boone Kauffman, Warren B. Cohen, Christine A. Hlavka, Darold Ward, 2004, Modeling Biomass Burning Emissions Amazon Forest and Pastures in Rondônia, Brazil, The Large-scale Biosphere –Atmosphere Experiment in the Amazon (Special Issue), *Eco. Apps.*, 14(4): S232-S246.

Guild, L.S., W.B. Cohen, and J.B. Kauffman, 2004, Detection of deforestation and land conversion in Rondônia, Brazil using change detection techniques, *IJRS*, 25: 731-750.

Guild, Liane S., J. Boone Kauffman, Lisa J. Ellingson, Dian L. Cummings, Elmar A. Castro, Ron E. Babbitt, and Darold E. Ward, Dynamics associated with total aboveground biomass, C, nutrient pools, and biomass burning of primary forest and pasture in Rondonia, Brazil during SCAR-B, *JGR Atmospheres, 103*(D24): 32,091-32,100, 1998.

Randall W. Berthold, Ph.D.
Team Lead and Mission Manager Mentor

Project Manager, Biospheric Science Branch
MS 242-4, NASA Ames Research Center, Moffett Field, CA 94035
Ph: 650-604-3408, Fax: 650-604-4680, E-mail: Randall.W.ßBerthold@nasa.gov

Role in Mission:
Randy Berthold will be the Team Lead Mentor and Mission Manager of an airborne flight mission with a payload suite offering a unique capability for science data collection in the coastal zone.

Experience:
2009 – Mission Manager, SIERRA test flight, Svalbard, Norway.
2007 to present – NASA Diving Safety Officer
2006 – Mission Manager, Small UAS Capabilities Demonstration, Ft. Hunter-Liggett, CA.
2000 to 2004 –Branch Chief, Science Payloads Operations, NASA ARC
1990 - 2000 – Project and Mission Manager (development and flight, non-human life science experiments) aboard NASA Space Shuttles and ISS

Education:
Ph.D. (Systems Management) – California Coast University, Santa Ana, CA.

M.S. (Systems Management) – University of Southern California, Los Angeles, CA.

B.S. (Environmental Studies) – University of California, Santa Cruz.

Honors: Chair, NASA Ames Research Center Extreme Environments Research Review Board; Chair, International Science Payloads Technical Review Committee

Selected Publications:
Berthold, R., and L. Guild. 2006. NASA Ames Remote Sensing Capabilities. Ocean Sciences Meeting, February 20-24, Honolulu, HI. *EOS Trans.* 87(36), Abstract OS25R-17.

Fladeland, M., R. Berthold, L. Monforton, R. Kolyer, B. Lobitz, and M. Sumich. 2008. The NASA SIERRA UAV: A new unmanned aircraft for earth science investigations. AGU Fall Meeting, Dec. 15-19, San Francisco, CA.

Guild, L., R. Armstrong, F. Gilbes, J. Goodman, A. Gleason, E. Hochberg, R. Berthold, J. Torres, and M. Johnston. 2006. Airborne Hyperspectral Remote Sensing of Coral Reefs of Puerto Rico, Florida Keys and Oahu. *Eos Trans.*, AGU, 87:36, Abstract OS13L-06, Ocean Sciences Meeting, Feb. 20-24, Honolulu, HI.

Guild, L., J. Goodman, B. Lobitz, R. Armstrong, F. Gilbes, R. Berthold, and J. Kerr, 2009, *Imaging Spectroscopy and Spectral Analysis in Support of Coral Reef Ecosystem Biodiversity Research*, 33rd International Remote Sensing of Environment, May 4-8, 2009, Stresa, Italy.

Guild, L., B. Lobitz, R. Armstrong, F. Gilbes, J. Goodman, Y. Detres, R. Berthold, and J. Kerr, 2009, NASA airborne AVIRIS and DCS remote sensing of coral reefs, Proceedings 11th International Coral Reef Symposium, Ft. Lauderdale, FL, July 2008.

Guild, L., B. Lobitz, R. Armstrong, F. Gilbes, A. Gleason, J. Goodman, E. Hochberg, M. Monaco, R. Berthold, 2007, NASA airborne AVIRIS and DCS remote sensing of coral reefs, Proceedings 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica, June 25-29, 2007.

Zajkowski, T., E. Hinkley, R. Berthold, and V. Ambrosia. 2006. USDA Forest Service Small UAS Demonstration Series. Proceedings, Association for Unmanned Vehicle Systems International (AUVSI) Conference, Aug. 29-31, Orlando, FL.

Joaquín E. Chaves, Ph.D.
Cal/Val Trainee

NASA Calibration and Validation Office
1450 South Rolling Rd., Halethorpe, MD 21227
410-294-0762, joaquin.chaves@ssaihq.com

ROLE IN MISSION:

Will participate on field radiometry measurements for calibration and validation purposes, as well as in the collection and analysis of field samples from the coastal environments targeted by the mission. Water samples collected concurrent with airborne sensor deployments will be analyzed for phytoplankton pigments using high performance liquid chromatography (HPLC), and other dissolved and suspended biogeochemical constituents that are amenable to remote sensing detection, such as dissolved and particulate carbon, and colored dissolved organic matter (CDOM)

EXPERIENCE:

2009 – Present, Research Scientist, Science Systems and Applications Inc., NASA

2007 – 2009, Post-doctoral Associate, Department of Ecology and Evolutionary Biology, Brown University, Providence, RI.

2004 – 2007, Post-doctoral Scientist, The Ecosystems Center at the Marine Biological Laboratory, Woods Hole, MA.

EDUCATION:

Ph.D. – University of Rhode Island, Narragansett (Oceanography) – 2004

M. S. – University of Rhode Island, Narragansett (Oceanography) – 1997

B. S – Universidad Nacional de Costa Rica (Marine Biology) – 1992

SELECTED PUBLICATIONS:

Chaves, J., C. Neill, S. Germer, S Neto, A. Krusche, A. Castellanos, and H. Elsenbeer. 2009. Nitrogen transformations in flow paths leading from soils to streams in Amazon forest and pasture. *Ecosystems* **12**, 961-972.

Chaves, J., C. Neill, S. Germer, S Neto, A. Krusche, and H. Elsenbeer. 2008 Land management impacts on runoff sources in small Amazon watersheds. *Hydrological Processes*. **22**, 1766–1775. DOI: 10.1002/hyp.6803

Stephen Dunagan, Ph.D.
Systems Engineer Mentor

Research Scientist, Biospheric Science Branch
NASA Ames Research Center
Mail Stop 242-4
Bldg. 242, Room 205
P.O. Box 1
Moffett Field, CA 94035-0001
Phone: [650] 604-4560
Fax: 650-604-4680

ROLE IN MISSION:
Stephen Dunagan will mentor Maryland Edwards in the role of Systems Engineer. He will also advise the project team on experimental design and instrument design factors as they impact the flight experiment.

EXPERIENCE:
March 2002 to present, Research Scientist, Biospheric Research Branch, Projects include 4-STAR Airborne Sunphotometer (Project Manager, Instrumentation Engineer), Right-of-Way Autonomous Monitoring Project (Systems Engineer), Western States Fire Mission (Systems Engineer), MARTE Robotic Drilling Project (Project Manager, Instrumentation Engineer), Kauai Coffee Project, (Project Manager, Instrumentation Engineer).

March 2000 to Feb. 2002, Technology Project Manager, National Rotorcraft Technology Center, Technology Development Manager for aerospace materials, flight operations and safety technology.

Oct. 1999 to March 2000, Branch Chief (acting), Ecosystem Science and Technology Branch.

1995 to 1999, Aerospace Engineer, Ecosystem Science and Technology Branch, Project included Kauai Pathfinder Mission (Instrumentation Engineer), SOFIA, AIRES instrument (Systems Engineer).

1984 to 1995, Aerospace Engineer, Rotorcraft Aeromechanics Branch, Specializing in non-invasive instrument for ground testing facilities, test operations.

EDUCATION:
BS, Mechanical and Aerospace Engineering, University of Missouri, Columbia, 1979.
MS, Mechanical and Aerospace Engineering, University of Missouri, Columbia, 1980.

PhD, Mechanical and Aerospace Engineering, University of Missouri, Columbia, 1986.

RELEVANT AWARDS AND HONORS:
2005 NASA Ames Honor Award, Project Manager

PUBLICATIONS:
Dunagan, S. E., B. Baldauf, P. Finch, L. Guild, E. Hochberg, B. Jaroux, L. Johnson, B. Lobitz , J. Ryan, S. Sandor-Leahy , J. Shepanski, Small Satellite and UAS Assets for Coral Reef and Algal Bloom Monitoring, 33rd International Symposium on Remote Sensing of Environment, Stresa, Italy, May 4-9, 2009.

Dunagan, S. E., Berthold, R., Fladeland, M., Pieri, D., 2007, Small UAS Technologies to Enable Earth Science Missions, 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica.

Dunagan, S. E., Eilers, J, Lobitz, B., and Zajkowski, T., 2007, UAS Enabled Communications for Tactical Firefighting, Proceedings of the AIAA Infotech@Aerospace 2007 Conference and Exhibit, Rohnert Park, CA.

Jennifer L. Dungan, Ph.D.
Project Manager Trainee

Research Scientist, NASA Ames Research Center, Biospheric Science Branch
Mail Stop 242-4
(650) 604-3618, Jennifer.L.Dungan@nasa.gov

ROLE IN MISSION:
Dr. Dungan will act as project manager for the COAST mission, responsible for the achievement of technical milestones, keeping the team to schedule and within budget.

RECENT EXPERIENCE:

2000 – Present, Research Scientist, Biospheric Science, NASA Ames Research Center.

1998 – 2000, Research Scientist, Earth System Science & Policy. California State University, Monterey Bay.

EDUCATION:

Ph.D. – University of Southampton, Southampton, United Kingdom (Geography) – 2000

M.S. – University of Wisconsin, Madison, Wisconsin (Environmental Monitoring) – 1986

B.A. – Wesleyan University, Middletown, Connecticut (Environmental Science) – 1981

PEER REVIEWING:

Member, Faculty of 1000 Biology/Ecology 2007-present

Associate Editor, *Remote Sensing of Environment* 2004-present

Associate Editor, *Int. J. of Applied Earth Observation and Geoinformation* 2002-present

Reviewer for other journals including *International Journal of Remote Sensing*, *International Journal of Geographical Information Science*, *Canadian Journal of Remote Sensing*, NASA, NSF and USDA research

SELECTED PUBLICATIONS:

Dungan, J.L. (2008) Geostatistics, entry in *Encyclopedia of Geographic Information Science*, Sage Publications.

Hashimoto, H., J.L. Dungan, M.A. White, F. Yang, A.B. Michaelis, S.W. Running, and R.R. Nemani (2008) Satellite-based estimation of surface vapor pressure deficits using MODIS land surface temperature data. *Remote Sensing of Environment*, 112: 142–155

Dungan, J.L. (2006) Focusing on feature-based differences in map comparison. *Journal of Geographical Systems*, 8: 131-143

Gamon, J.A., A.F. Rahman, J.L. Dungan, M. Schildhauer, K.F. Huemmrich (2006) Spectral Network (SpecNet)—What is it and why do we need it? *Remote Sensing of Environment*, 103:227–235.

Dungan, J. L., J. Frank, A. Jonsson, R. Morris and D.E. Smith (2003) Advances in planning and scheduling of remote sensing instruments for fleets of Earth observing satellites. In *Real-time Information Technology for Future Intelligent Earth Observing Satellites*, G. Zhou, O. Baysal, M. Kafatos and R. Yang, eds. Hierophantes: Pottstown, PA. 115-122.

Dungan, J.L. (2002) Toward a comprehensive view of uncertainty in remote sensing analysis. in: *Uncertainty in Remote Sensing and GIS*, Foody and Atkinson, eds. John Wiley & Sons. pages 25-33.

Moghaddam, M. and Dungan, J.L. (2002) Forest variable estimation from fusion of SAR and multispectral optical data. IEEE Transactions on Geoscience and Remote Sensing 40:2176-2187.

Dungan, J.L., J.N. Perry, M.R.T. Dale, P. Legendre, S. Citron-Pousty, M.-J. Fortin, A. Jakomulska, M. Miriti, and M.S. Rosenberg. (2002) A balanced view of scale in spatial statistical analysis, *Ecography*. 25:626-640

Maryland R. Edwards
Systems Engineer Trainee

Windchill and Portal Manager
ARC Engineering Directorate/Engineering Systems Division/System Engineering Branch, RESNASA Ames Research Center, Mail Stop 211-1
Bldg. 211 Room 120, Moffett Field, CA 94035

Phone: 650-604-3274; 650 279-2823 (cell)
Email: Maryland.R.Edwards@nasa.gov

ROLE IN MISSION:

Maryland Edwards will serve in the System Engineering role for the entire life cycle of the COAST project.

EXPERIENCE:

2004 – Present,SOFIA Program Windchill and Portal Manager

- Knowledge system architect and manager: defined system architecture and system configuration to meet the configuration management as the single authoritative source for the program data and documentation.

1998–2004, Ground Systems Engineering on Kepler Program

Evaluated CDR design on SOFIA project to meet the NASA standards for software assurance and safety.

- Defined ground segment functional block diagram to coordinate high level capabilities and interfaces and to verify preliminary design to the requirements
- Defined ground data systems architecture preliminary design to baseline external communications, performance, loading, and security.
- Defined ground segment architecture to baseline the software, hardware, facilities, and communications.
- Defined security framework and policies for project including data security categories, network topology, configuration management, export and ITAR compliance, and security documentation and deliverables.

1998-2004, ARC Center Network Engineer

Architect for center new communications backbone (from FDDI to Switched Gigabit Ethernet)

- Lead deployment of center infrastructure to new backbone architecture within schedule and costs while coordinating with each organization on center to move in a timely manner without disruption (included over 90 buildings and 14,000 nodes)
- Designed and deployed IP addressing scheme

1994–1998 JSC Engineering Directorate, Avionics Systems Division, Electronic Design & Dev Branch

- Lead for wireless network on the International Space Station
- Selected hardware based on technical capability and systems performance analysis;
- Directed architecture definition and design of hardware deliverables;
- Defined requirements for wireless and hardwire local area network;
- Completed certification of system for flight;
- Managed budget and schedules.

1989–1994 JSC Mission Operations Directorate, Space Station Ground System Division, Control Center System Branch

Project lead for mission control software systems

Lead design and development of display definition, user computation definition, expert system environment, test bed, early IVT capability, and user application integration.

EDUCATION:

1973 – B. S. in Math– University of Houston, Houston, Texas

Stanford B. Hooker
NASA/Goddard Space Flight Center/Code 614.2
Hydrospheric and Biospheric Sciences Laboratory
Greenbelt, MD 20771 USA

Stanford Hooker received his Ph.D. in Physical Oceanography from the University of Miami Rosenstiel School for Marine and Atmospheric Science in 1987. He held a postdoctoral position (1987–1988) at the Applied Physics Laboratory (Seattle, Washington) working with Dr. Tom Sanford, and a research scientist position at Areté Associates (Arlington, Virginia) where he worked with Dr. John Dugan on non-acoustic antisubmarine warfare research (1988–1991). He joined NASA to work on the SeaWiFS Project (1991) and was the Deputy Project Scientist when the mission office closed (2004). His areas of research include data acquisition, field calibration, and stability monitoring of optical instruments; intercomparison of above- and in-water optical methods; conception, design, and evaluation of optical instrumentation; and vicarious calibration and algorithm validation of ocean color remote sensors. His current responsibility is director of the NASA Ocean Biology and Biogeochemistry Calibration and Validation Office.

Relevant Publications (Last 5 Years)

Hooker, S.B., and L. Van Heukelem, 2010: "A Symbology and Vocabulary for an HPLC Lexicon." In: *Phytoplankton Pigments in Oceanography: Updates on Characterization, Chemotaxonomy and Applications in Oceanography,*. S. Roy et al. Eds., Cambridge University Press, London, (accepted).

Van Heukelem, L., and S.B. Hooker, 2010: "The Importance of a Quality Assurance Plan for Method Validation and Minimizing Uncertainties in the HPLC Analysis of Phytoplankton Pigments." In: *Phytoplankton Pigments in Oceanography: Updates on Characterization, Chemotaxonomy and Applications in Oceanography,*. S. Roy et al. Eds., Cambridge University Press, (accepted).

Neeley, A.R., C. Thomas, S.B. Hooker, and L. van Heukelem, 2010: "The Pigment Analyst's Guide to HPLC Hardware." In: *Phytoplankton Pigments: Updates on Characterization, Chemotaxonomy and Applications in Oceanography,* S. Roy et al. Eds., Cambridge University Press, (accepted).

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Philip B. Russell, Ph.D.
PI Mentor

Senior Research Scientist, NASA Ames Research Center, Atmospheric Science Branch
MS 242-5, Moffett Field, CA 94035-1000
650-604-5404
Philip.B.Russell@nasa.gov

Role in COAST:
Dr. Russell will provide mentoring for the PI, with particular emphasis on (1) project organization to address COAST overall goals, including training, measurements, and science, and (2) coordination of air, space, and surface platforms and instruments as required to capture the measurements needed for COAST science.

Relevant Professional Experience:

2008 – Platform Scientist, NASA P-3B in ARCTAS study of Arctic haze and boreal wildfires

2006 – Platform Scientist, J-31 aircraft in INTEX-B study of Mexico pollution and biomass burning

2004 – Principal Investigator, AATS instrument in INTEX-A study of pollution off NE US coast

1995-present – NASA Ames: Senior Research Scientist. PI on many airborne science investigations.

1995-1989 – ARC, Chief, Atmospheric Chemistry and Dynamics Branch

1988-1989 – ARC, Acting Chief, Earth System Science Division

1982-1989 – ARC, Chief, Atmospheric Experiments Branch

1982-1993 – ARC, Project Manager, Stratosphere-Troposphere Exchange Project (STEP).

1972-1982 – SRI International, Physicist to Senior Physicist, Atmospheric Science Center.

1971-1972 – National Center for Atmospheric Research (at University of Chicago and NCAR) Postdoctoral Appointee.

Education:

Ph.D. and M.S. (Physics), Stanford University (1971 and 1967, Atomic Energy Commission Fellow)

M.S. (Management), Stanford University (1990, NASA Sloan Fellow)

B.A. (Physics), Wesleyan University (1965, Magna cum Laude; Highest Honors)

Honors, Awards, and Community Service:

2005 – Elected Fellow, American Association for the Advancement of Science

2002 – NASA Ames Honor Award (excellence in scientific research)

1994-95 – Editor-in-Chief, *Geophysical Research Letters*, American Geophysical Union

1994 – NASA Ames Associate Fellow (excellence in atmospheric research; Ames's highest annual award)

1988 – NASA Exceptional Service Medal (for managing Stratosphere-Troposphere Exchange Project).

1989 – NASA Space Act Award (for inventing Airborne Autotracking Sunphotometer)

1989-2006 – NASA Group Achievement Awards

1979-82 – Chair, American Meteorological Society International Committee on Laser Atmospheric Studies

Publications:

Over 140 peer-reviewed publications. Selected publications relevant to this TO are listed below.

Russell, P. B., et al., Absorption Angstrom Exponent in AERONET and related data as an indicator of aerosol composition, *Atmos. Chem. Phys.*, 10, 1155-1169, 2010.

Russell, P. B., et al., Multi-grid-cell validation of satellite aerosol property retrievals in INTEX/ITCT/ICARTT 2004, *J. Geophys. Res., 112*, D12S09, doi:10.1029/2006JD007606, 2007

Russell, P., et al., Aerosol optical depth measurements by airborne Sun photometer in SOLVE II: Comparisons to SAGE III, POAM III and airborne spectrometer measurements, *Atmos. Chem. Phys.*, *5*, 1311–1339, 2005.

Russell, P. B., et al, Sunlight transmission through desert dust and marine aerosols: Diffuse light corrections to Sun photometry and pyrheliometry, *J. Geophys. Res.*, 109, D08207, doi: 10.1029/2003JD004292, 2004.

Claire Smith
APEX Program Manager

Human Capital Directorate
Human Resources Workforce Development Branch
NASA Ames Research Center
Mail Stop 241-3
Bldg. 241, Room 145B
P.O. Box 1
Moffett Field, CA 94035-0001
Phone: [650] 604-0553
Fax: 650-604-0878

ROLE IN MISSION:
Claire Smith will lead and facilitate the COAST Project training plan in coordination with Liane Guild, COAST Project PI.

EXPERIENCE:

1998-Present, Senior Training and Development Specialist, NASA Ames Research Center, Human Capital Directorate, Workforce Development Branch. Accomplishments Include:

- Design and manage The Ames Project EXcellence Development Programs.
- Established NASA Ames Research Center as "APPEL WEST" (1999) Pilot: Result: demonstrated feasibility of bringing APPEL curriculum to NASA field centers.
- Project Manager, APPEL's Project Scientist Career Development Initiative: Result: delivered product on time and within budget.

1972 – 1998, Expert Learning and Development Specialist Advisor. List of clients available upon request.

EDUCATION:
BA, Sociology, Bloomsburg University, Bloomsburg, Pennsylvania, 1970.

RELEVANT AWARDS AND HONORS:
2001 NASA Honor Award, Public Service Medal

1999 NASA Ames Honor Award

Peter T. Zell
Project Manager Mentor

Project Manager, NASA Ames Research Center, Project Management Office
Mail Stop 244-10, Moffett Field, California 94035
(650) 604-3690 Peter.T.Zell@nasa.gov

ROLE IN MISSION:
Peter Zell will serve as the Project Management mentor for the COAST Project. He will provide guidance to the COAST Project Manager, Jennifer Dungan, as she executes the full scope of this flight project learning opportunity.

EXPERIENCE: NASA Ames Research Center

3/2009 to Present - Project Manager for the Echelon-cross-Echelle Spectrograph (EXES) Science Instrument Project for the Stratospheric Observatory for Infrared Astronomy

5/2008 to 2/2009)- Project Manager for the Rigid Aeroshell Variable Bouyancy Air Vehicle Project

6/2005 to 7/2009 - Served as the Deputy Project Manager for the Crew Exploration Vehicle (Orion) Thermal Protection System Advanced Development Project

3/2003 to 6/2005 - Systems Engineer, Space Projects Division

4/1999 to 3/2003 - Technical Services Manager, Wind Tunnel Operations Division

6/1996 to 4/1999 - Facility Manager, National Full-Scale Aerodynamics Complex (NFAC)

9/1985 to 10/1996 - Wind Tunnel Test Engineer, NFAC

EDUCATION:
M. S. – California Polytechnic State University, San Luis Obispo, California (Aeronautical Engineering) - 1985

B. S. – California Polytechnic State University, San Luis Obispo, California (Aeronautical Engineering & Mechanical Engineering) - 1983

RELEVANT AWARDS AND HONORS:

United States Patent 7662459, Versatile Honeycomb Matrix Heat Shield, 2/2010

2008 Leadership Commendation for support of the Orion Thermal Protection System Thermal Protection System Advanced Development Project

2007 Ames Project Excellence (APEX) Award for Achievement upon completion of the Project Management Pathway

I-3 Equipment List (EL)

An Equipment List (EL) for the payload and carrier accommodation is shown below summarizing the main instruments in the COAST system including mass, volume, and power as well as level of development, heritage and source, in order to support validation of proposed design, and cost. Heritage is more fully described in section I.5.

Equipment List: Payload and Carrier accomodation

Instrument	Element Components	Weight/ Mass	Size - Outside aircraft	Size - Inside aircraft	Power Required	Type of Power	External Sensor Location	Level of development	Heritage	Source
AATS-14	a. Telescope head w electronics/data system cylinder	59.69-kilograms. (Includes 54.89-kilograms head w/elec., 0.45-kilograms isolator, 1.59- kilograms reinforc. Ring, 0.18-kilograms torque link, 0.32-kilograms mount bolts, 2.27-kilograms cable bundle.)	20.32-cm OD dome (hemisphere) atop 12.7-cm H pedestal. (Total H: 22.86-cm above A/C skin)	30.48cm D x 45.72cm H cylinder (+laptop computer for checkout & test flights)	5.5A 154 W peak or 4.2 A @ 500 W peak	28 VDC or 120VAC, 50-400 Hz with additional 25-kilograms power supply.	Top of cabin, nose, wing, or pod.	TRL 9	Partial Heritage	NASA ARC Environmental Research Aircraft & Sensor Technology (ERAST) Program.
	b. Operator station (laptop computer)	2.72-kilograms laptop & cable, 6.8-kilograms tray w/slides	N/A	Laptop computer. Optional tray mounts in 48.26-cm rack.	~0.8 A 92 Watts	120 V, 60 Hz	N/A			
	c. N_2 gas bottle	13.61-kilograms	19.05-cm Dia x 53.34-cm H	N/A	N/A	N/A	N/A			
HIS	a. Instrument	15 kilograms	0.3 m3	N/A	20W	28 VDC	Bottom of cabin in existing port	TRL 8	Partial Heritage	Headwall Photonics, 601 River Street, Fitchburg, MA 01420 www.headwallphotonics.com (978) 353-4100
	b. Operator station (laptop computer)	2.72-kilograms laptop & cable, 6.8-kilograms tray w/slides	N/A	Laptop computer. Optional tray mounts in 48.26-cm rack.	~0.8 A 92 Watts	120 V, 60 Hz	N/A			
Micro-radiometers	a. Microradiometer (19)	2 Kg each or 4 Kg total	75 mm diameter, 350 mm height (each: 19 grouped with aggregator)	N/A	180mA total (2*90mA each)	7.5 VDC	Existing Port to be determined	TRL 8	Partial Heritage	Biospherical Instruments Inc., 5340 Riley Street, San Diego, CA 92110 www.biospherical.com (619) 686-1888
	b. Aggregators									
	c. Master Aggregator	.5 Kg	N/A	7.62 cm in 48.26 cm rack						
	d. Operator station (laptop computer)	2.72-kilograms laptop & cable, 6.8-kilograms tray w/slides	N/A	Laptop computer. Optional tray mounts in 48.26-cm rack.	~0.8 A 92 Watts	120 V, 60 Hz	N/A			

I-4 Carrier Description

The primary platform for this proposal is the P-3B aircraft at the NASA Wallops Flight Facility in Virginia or the CIRPAS Twin Otter aircraft in Monterey, CA, since the AATS-14 Sun Photometer has already been integrated on these aircrafts and it is a major component of the calibration/validation plan. The P3-B aircraft configuration that supports the COAST requirements are shown in Figure I-4.1 P-3B and in Figure I-4.2 NASA GSFC WFF P3B Orion Port Layout.

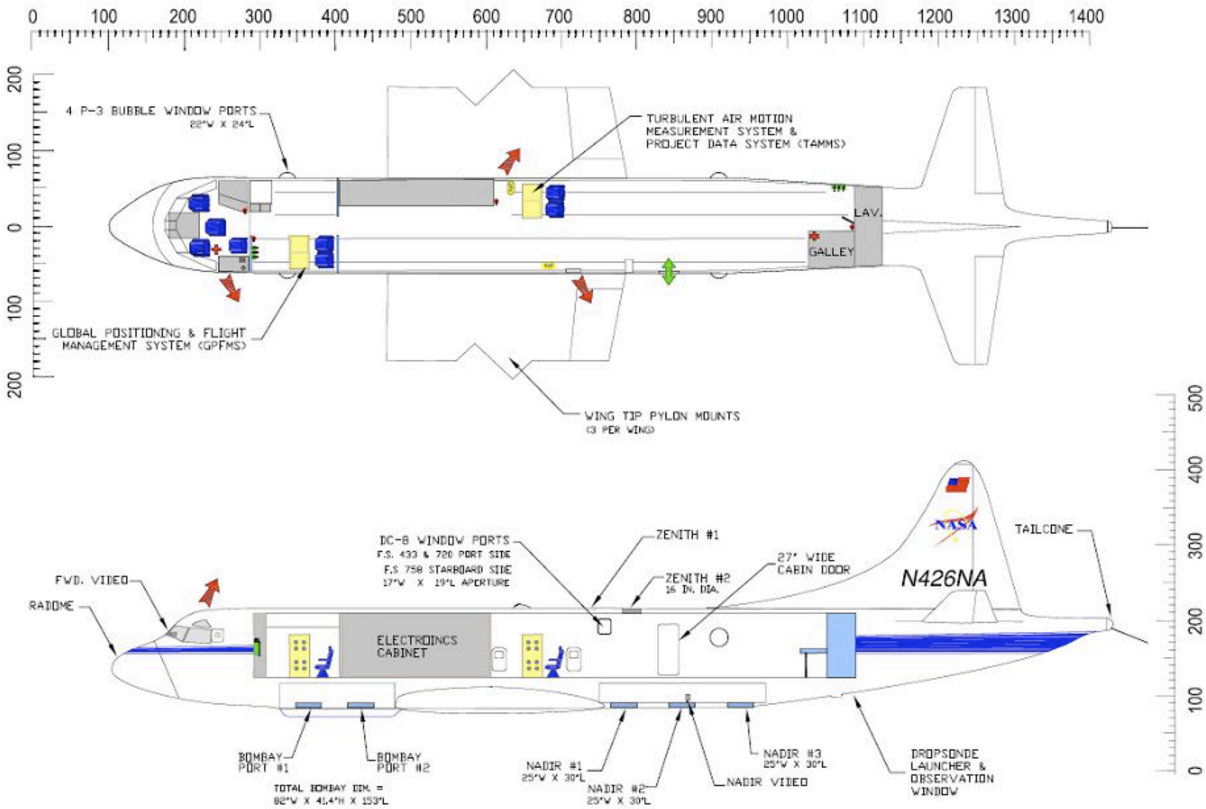

Figure I-1 P-3 Orion Observation / Sensor Ports

Figure I-2 NASA GSFC WFF P-3B Orion Port Layout.

Indeed the payload can be readily flown on most of the NASA airborne science aircraft. Other platforms to be considered in trade study include the following:

- CIRPAS Twin Otter aircraft in Monterey, CA;
- B200s, Twin Otter,
- ER-2,
- WB-57F,
- DC-8;
- SIERRA UAS;
- Ikhana UAS; and
- new Global Hawk.

The payload can be readily flown on most of the NASA airborne science aircraft, including the B200s, Twin Otter, ER-2, WB-57F, and DC-8 because the payloads can be mounted in the aircraft's standard camera mounts. The payload can be mounted in SIERRA UAS in the payload nose, in the Ikhana UAS in the aft portion of the sensor pod, and in the new Global Hawk in the aft Payload Area "J.

I-5 Heritage

Table I-5 lists the heritage of the instruments that will comprise the instrument suite.

AATS-14	Design	Identical	
	Manufacture	Identical	
	Software	Identical	
	Provider	Identical	
	Use	Identical	
	Operating Environment	Identical	
	Referenced Prior Use		Prior operational with mounts in P-3B ready for installation.
HIS	Design	Identical	
	Manufacture	Identical	
	Software	Identical	
	Provider	Identical	
	Use	Identical	
	Operating Environment		Flown prior but not installed in P-3B carrier
	Referenced Prior Use		Built and successfully operational on ground and aircraft
Microradiometer	Design	Identical	
	Manufacture	Identical	
including	Software	Identical	
Aggregator and	Provider	Identical	
Assemblies	Use	Identical	
	Operating Environment		Not flown before but is operational in ship
	Referenced Prior Use		Not installed in P-3B carrier

I-6 Acronyms and Abbreviations

AATS	Ames Airborne Tracking Sun Photometer
AAUS	American Academy of Underwater Sciences
ACE	Aerosols, Clouds, Ocean Ecosystems
ADC	Analog-to-digital Converter
AFB	Air Force Base
AFSRB	Airworthiness Flight Safety Review Board
ALL	APEX Learning Lifecycle
AMS	Autonomous Modular Sensor
AOD	Aerosol Optical Depth
AOP	Apparent Optical Properties
APEX	Ames Project EXcellence
APPEL	Academy of Program/Project and Engineering Leadership
ASCII	American Standard Code for Information Interchange
ASF	Airborne Sensor Facility
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVIRIS	Advanced Airborne Visible/Infrared Imaging Spectrometer
CADRe	Cost Analysis Data Requirement
C-OPS	Compact Optical Profiling System
Cal/Val	Calibration and Validation
CCD	Charged Coupled Device
CDOM	Colored Dissolved Organic matter
CDR	Critical Design Review
CIRPAS	Center for Interdisciplinary Remotely-Piloted Aircraft Studies
CLAMS	Chesapeake Lighthouse and Aircraft Measurements for Satellites
COAST	Costal and Ocean Science and Technology
CSV	Comma-Separated Format
CVO	Calibration and Validation Office
E/PO	Education and Public Outreach
EL	Equipment List
FAQ	Frequently Asked Questions
FTP	File Transfer Protocol
FY	Fiscal Year
GSFC	Goddard Space Flight Center
HAB	Harmful Algae Bloom
HIS	Headwall Imaging Spectrometer
HOPE	Hands-On Project Experience
Geo-CAPE	Geostationary Coastal and Air Pollution Events
HyspIRI	Hyperspectral Infrared Imager
IAT	Integration, Assembly, and Test
ICD	Interface Control Document
ITA	Independent Technical Authority
IV&V	Independent Verification and Validation
IT	Information Technology
ITA	Independent Technical Authority
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory
LAC	Local Area Coverage
MAS	MODIS Airborne Simulator
MASTER	MODIS/ASTER airborne simulator
MBARI	Monterey Bay Aquarium Research Institute
MLML	Moss Landing Marine Laboratories
MLO	Mauna Loa Observatory

MODIS	Moderate Resolution Imaging Spectrometer
MRR	Mission Requirements Review
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NEN	NASA Engineering Network
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPR	NASA Program Requirement
OCO-2	Orbiting Carbon Observatory 2
PDF	Portable Data Format
PDR	Preliminary Design Review
PI	Principal Investigator
PM	Project Manager
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
PRISM	Portable Remote Imaging Spectrometer
PS	Project Scientist
PSE	Project Systems Engineer
RY	Real Year
S&MA	Safety and Mission Assurance
SBIR	Small Business Innovation Research
Sea-WIFS	Sea-viewing Wide Field-of-view Sensor
SC	Student Collaboration
SEMP	Systems Engineering Management Plan
SMD	Science Mission Directorate
SOW	Statement of Work
SRR	Systems Requirement Review
SSFR	Solar Spectral Flux Radiometer
SST	Sea Surface Temperature
TDY	Temporary Duty Travel
TO	Training Opportunity
TMC	Technical, Management, and Cost
TRL	Technical Readiness Level
UAS	Unmanned Airborne System
UCSC	University of California, Santa Cruz
URL	Uniform Resource Locator
U.S.	United States
VIIRS	Visible/Infrared Imager/Radiometer Suite
WBS	Work Breakdown Structure
WFF	Wallops Flight Facility

I.7 References

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