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## REQUEST FOR TECHNOLOGIES

**Title:** Technology Demonstration of Improved Use of Hyperspectral Imagery to Assess Phytoplankton Communities, Coral Reef Environments and Aquatic Vegetation

**Date:** March 20, 2019

**Program:** The Alliance for Coastal Technologies (ACT)

**Application Deadline:** Application with signed cover letter must be received by 5:00 p.m. Eastern Time on April 22, 2019.

### Overview

The Alliance for Coastal Technologies (ACT) is currently accepting preliminary applications from individuals or teams of researchers, and/or sensor developers and manufacturers to participate in a technology demonstration aimed at improving data processing and algorithm development of hyperspectral imagery for research and management applications within shallow freshwater and marine aquatic ecosystems. This demonstration is envisioned to be the first step in a series of ACT Technology Demonstrations to evaluate and advance the utility and application of hyperspectral imagery observing systems. Hyperspectral imaging captures a diversity of spectral signatures that can be used to sense a wide range of surfaces, habitats, taxonomic groups, and the changes within these attributes over time. Hyperspectral imaging of aquatic targets has the potential to improve our understanding of the biological, physical, chemical, and geophysical dynamics of coastal ecosystems, but improved data processing protocols and algorithm development are needed to fully realize this potential.

For this Technology Demonstration, ACT will be supplying several types of hyperspectral data sets along with associated *in situ* observations needed for calibrating and validating output response variables (described in this document). We are not expecting participating teams to generate new observations or develop completely novel data processing routines. Instead, we invite participating teams to apply their unique hyperspectral analysis tools to the data sets provided and to take advantage of a shared community engagement. Like all ACT Technology Evaluations, participation in this effort will be voluntary and free of charge for qualifying applicants. Results from each participating team will be made available to the public in online published reports co-produced by the teams along with ACT and its' Technical Advisory Committee. Proprietary information and intellectual property rights will be protected as required, but it is the goal of this program to work in an open-source, broad community context. At the end of the testing period, participants will be supported to participate in an invited workshop to share results and organize plans to develop peer-reviewed publications to maximize the impact of the work.

### Synopsis of ACT Program

ACT is a component of US IOOS, funded by NOAA and EPA, and a partnership of research institutions, agencies, state and regional resource managers, and private sector companies interested in developing, improving, and applying sensor technologies for studying and monitoring aquatic

environments. ACT was established on the understanding that instrument validation and data processing protocols are necessary so that effective existing technologies are recognized and promising new technologies can be made available to support both successful coastal science and resource management, and the long-term success of Integrated Ocean Observing Systems (IOOS). The specific functions of ACT are to serve as: (1) an unbiased, third-party testbed for evaluating existing, new, and developing coastal sensors and sensor platforms, (2) a comprehensive data and information clearinghouse on coastal technologies, and (3) a forum for capacity and consensus building. It is important to note that ACT does not certify technologies or guarantee that a technology or data protocol will always, or under circumstances other than those used in testing, operate at the levels verified. ACT does not seek to determine regulatory compliance; does not rank technologies/algorithms or directly compare their individual performance; does not label or list technologies/algorithms as acceptable or unacceptable; and does not seek to determine “best available technology” in any form. ACT will avoid all potential pathways to picking “winners and losers” and the public disclosure of participant proprietary information.

Following on the recommendations of an ACT/NOAA sponsored workshop on *Hyperspectral Imaging of Coastal Waters* at the University of Hawaii at Manoa, May 15-16, 2018, ACT is pursuing a series of Technology Demonstrations to help advance the utility and application of hyperspectral observing systems for coastal research and management. The following four Technology Demonstration projects were identified and ordered based on technical readiness, complexity, and resource requirements: 1) Processing algorithm round-robin, 2) Mooring calibration/validation of hyperspectral remote sensing, 3) Controlled observations in tanks/mesocosms and 4) Flight comparison using Portable Remote Imaging Spectrometer (PRISM) as standard.

### **Focus of the Round-Robin Processing Algorithm Technology Demonstration**

Remote sensing of the coastal zone, especially via hyperspectral imaging, currently lacks a developed set of best practices. This includes, but is not limited to, sensors, radiometric calibrations, geometric calibrations, geophysical variable choices, field validation, and algorithms. Of course, the specific algorithms chosen for a project depend on the geophysical variables to be retrieved from the remote sensing data, but even within a single application area (e.g., coral reefs, harmful algal blooms (HABs), kelp forests etc.), there are numerous competing approaches. Thus, while hyperspectral remote sensing is moving towards routine deployment, it still has one foot firmly planted in the realm of research and development, and there is much to be gained in a collective effort to advance best practices.

The goal of this demonstration activity is to evaluate capabilities and maturities of different algorithms in order to advance the operational use of hyperspectral remote sensing. Each participant will have access to the same data sets and attempt to achieve the same objective(s) within the particular data-set application selected. The data sets comprise calibrated hyperspectral imagery and ground/water validation data. These are existing real data, including both airborne and in-water, as collected during recent field campaigns (e.g., CORAL, HypsIRI Preparatory Campaign, NOAA GLERL cyanoHAB monitoring). In the event that the available data sets do not support a targeted application then we can incorporate additional data simulated via radiative transfer modeling (e.g., Hydrolight/Ecolight, MODTRAN, 6S). The former has the benefit of representing real-world conditions, while the latter has the benefit of providing exact values for all geophysical parameters of interest as well as system noise and environmental uncertainty (i.e., perfect and complete validation data).

Specific designated algorithm may include assessment of water quality and phytoplankton diversity, quantification of coral cover, determination of giant kelp canopy area, biomass, and Chl:C ratios, and/or minimizing error in atmospheric correction. Based on ecological or physical understanding of the system to be studied, broad objectives would be defined *a priori* at the protocol workshop (see below), and participants would implement their algorithms to meet one of those targeted objectives based

on their research application. Participants would be welcome to demonstrate capabilities beyond the stated objectives, as well. It is expected that participants would be building on current approaches versus novel development of algorithms in order to complete testing within the proposed schedule.

To be most useful, it is desirable to make all submitted algorithms open-source. However, it is recognized that commercial vendors may not wish to share their valuable intellectual property. Final testing protocols and a detailed test plan will be developed with the aid of applicants and a Technical Advisory Committee to evaluate these specific parameters. Signed agreements on the protection of proprietary intellectual property and rights of publication will be established between ACT and each participating team prior to the start of the Demonstration.

**Eligible Participants:**

- Individuals or Teams of Researchers from academic institutions, state and federal agencies, and private sector companies.
- Developers and Commercial manufacturers of hyperspectral imagery sensors, platforms, and applications.
- Members of the Technical Advisory Committee identified below may participate on project teams.

**Benefits of Technology Demonstration:**

ACT will provide participating teams with an independent, scientifically objective process and data sets for testing their algorithms in a diverse range of coastal marine and freshwater environments. The objectives have been identified as research and management priorities. Moreover, ACT results will provide potential investors and users of hyperspectral imagery with information on how these technologies perform in comparison to other in situ or multi-spectral reference methods. Through this process of demonstration, ACT will ultimately aid in the implementation of accurate and reliable technologies that will enable more effective monitoring and an increased understanding of coastal resources and processes.

Specific benefits for technology developers, manufacturers, and vendors:

- Access to expertise in demonstrating, verifying, and applying coastal monitoring technologies.
- An opportunity to test technologies under diverse environmental conditions of national interest.
- An unbiased, reputable evaluation of technology performance.
- Increased credibility from having independent performance data.
- Increased product recognition nationally and internationally through ACT outreach.
- A potential market advantage that customers and users may consider in their technology purchasing.
- Increased confidence for investors.

Specific benefits for technology users:

- Timely information on sensor or model performance to address an environmental emergency.
- Easily accessible information on sensor technologies for application in coastal environments.
- Credible technology performance verifications and demonstrations independent of developer, manufacturer, or vendor claims.
- Performance-based verification and demonstration testing addressing realistic data quality objectives under varying environmental conditions.
- ACT, EPA and NOAA review of verification and demonstration results.

**Application Process and Acceptance for Rapid Response Evaluation:**

The application and acceptance process consists of four steps: (1) a preliminary application, (2) conditional acceptance, (3) participation in a protocol workshop, and (4) agreement on a final test plan. The tentative schedule and deadlines for each step are provided below.

**Step 1. Preliminary Application** - Applicants (researchers, developers, and manufacturers) are requested to provide summary information about the algorithmic approach to be tested, any data requirements necessary to successfully perform the testing, proposed testing protocols, and the specific output or outcome that can be evaluated on the basis of the available *in situ* data. Sufficient information about the algorithm should be provided to ensure a clear understanding of the proposed test plan, including the scientific and engineering principles of operation and previous performance data (if applicable). The application should include appropriate peer-reviewed literature, technical articles, reports, processing steps/flow diagrams, and other related materials to enable the reviewer to fully understand the technology and data processing routines used to support the application. Include appropriate details about the technical readiness or challenges of applying the test procedures in more broad research and management applications. The application should identify the key role of each participating PI on the team along with a two-page CV for each participating investigator. The length of the application should target 3 pages, exclusive of the CV's. Criteria for acceptance will include: (1) Demonstrated knowledge and experience as evidenced by publications, reports, proposals; (2) Technical Merit of Proposed Approach; and (3) Scientific Contribution – how would it benefit research or management.

**Step 2. Conditional Acceptance** - All applicants that meet the requirements for an ACT Technology Demonstration will be identified and accepted contingent upon successful completion of Steps 3 and 4. Preliminary acceptance will be sent to applicants within two weeks of the initial application receipt. ACT encourages working in teams and if individuals submit similar algorithms for working on the same data set we would offer the opportunity to combine the proposals. However, combining proposals would not be required, i.e. Multiple, individual proposals using a similar approach and data set will be accepted.

**Step 3. Participation in Protocol Development Workshop for Full Application** – Upon review and conditional acceptance of the Applications, potential participants will be invited to a Test Protocol Development Workshop where further details of the data sets and final test plans will be established. The workshop is tentatively scheduled for the week of May 20, 2019 and participants will include ACT staff, Technology Advisory Committee, QA/QC Coordinator, and representatives for each qualifying applicant. Travel costs will be supported by ACT as allowed by the participants' Institutions. Formal Test Plan agreements identifying details of what will be provided by ACT, and proposed deadlines and reporting responsibilities for the participating teams will be established at the workshop and distributed to all parties prior to establishing final Participation Agreements.

The final Test Plan will be based on standard scientific testing practices and include:

- Requirements for qualifications of test personnel.
- Requirements for health and safety of test personnel, the public, and the environment.
- Proposed methods and procedures for verification including: a) set-up, b) period of operation, c) operation parameters, d) experimental design with number of replicates and controls, e) demobilization, and f) QA/QC.
- A standard measure or existing, accepted standard reference material to be calibrated by.
- A standard measure or existing, accepted method to be tested against for performance comparison.
- Proposed methods and procedures for storing, retrieving, analyzing, and reporting data.

**Step 4. Agreement on Test Plan** - The draft Test Plan will be externally reviewed by the Technical Advisory Committee, which consists of Federal, State, and Academic research professionals, for appropriateness of experimental design and statistical analyses. After review, a Final Test Plan will be submitted to the qualifying applicants. For this particular Data Processing and Algorithm Development Demonstration, we recognize that Test Plans for individual teams may have unique components and stated output goals. Furthermore, ACT will not conduct direct comparisons of the data processing protocols or outputs being evaluated by participating teams in the published final technical reports.

However, the goal is to use an open community approach with the objective of providing improved methods and application of hyperspectral imagery and we will support all efforts to publish results in the public scientific literature. To the extent possible we will strive for the standardization of Test Data Sets which include both hyperspectral radiometry and appropriate in situ ground truth observations to allow simultaneous assessment of the various technologies and permit end-users to draw their own conclusions regarding the sensor and/or kit that best meets their needs.

**Deadlines and Dates:**

- Applications must be received by 5:00 p.m. Eastern Time: April 22, 2019
- Notification of Conditional Acceptance: April 30, 2019
- Workshop with participants to finalize Protocols, Test Agreements: May 21-22, 2019
- Release Data Sets and Conduct Testing: June – November, 2019
- Submission and Review of Participant Project Reports: November – December 2019.
- Participant workshop to evaluate results and outline final reports and publications: January 2020.
- Publish final ACT technical reports: April 2020
- Target Manuscript publications May 2020

**Demonstration Agreement:**

A legal participation agreement (the Agreement) between ACT and qualifying applicants will be drafted to state that all parties agree to conduct the evaluation in accordance with the approved Test Plan and that all non-proprietary results will be released to the public. The Agreement will also state that there will be no modifications to final Test Plan, regardless of unforeseen circumstance encountered during testing, without written consent from all parties. Furthermore, the Agreement will clearly state that although the developers, manufacturers, or vendors will be allowed to view the Demonstration Statements before they are released to the public, they will not be allowed to make changes to the final report. ACT will consider inclusion of comments (in the form of a one-page letter) from the developers, manufacturers, or vendors as an appendix to Demonstration Statements. Finally, it will be noted that all data collected during verifications by the instruments tested are the property of the proponent and cannot be used by any other party without consent. The Agreement will be signed by the ACT Director and the appropriate representative from the qualifying applicant's organization.

**Additional Information and Forms:**

Please visit [www.act-us.info](http://www.act-us.info) for additional information on the ACT program, details on the ACT Evaluation Process, and to download required application forms. More information can also be obtained by contacting Dr. Mario Tamburri ([tamburri@umces.edu](mailto:tamburri@umces.edu)) or Dr. Tom Johengen ([johengen@umich.edu](mailto:johengen@umich.edu)).

**ACT Hyperspectral Evaluation Steering Committee**

- Dr. Tom Johengen, Univ. of Michigan
- Dr. Margaret McManus, Univ. of Hawaii
- Dr. Eric Hochberg, Bermuda Institute of Oceanography
- Dr. Andrea Vander Woude, Cherokee Nation Businesses at NOAA-GLERL
- Dr. Raphe Kudela, UC Santa Cruz

**ACT Hyperspectral Technical Advisory Committee:**

- Dr. Kyle Cananaugh, UCLA
- Dr. Jon Kok, Australian Inst. of Marine Sciences
- Dr. Blake Schaeffer, U.S. EPA
- Dr. Sherry Palacios, Bay Area Environmental Res. Inst.
- Dr. Heidi Dierssen, Univ. of Connecticut
- Dr. Steve Ackleson, U.S. Naval Research Lab