

A Low-Cost Airborne EO Oceanographic Measurement System

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LONG-TERM GOALS

With the emphasis of the ONR Coastal Dynamics Programs on model-driven experiments, there is a need for reliable measurements to develop, drive and validate shoaling wave models. Measurements by research vessels and *in situ* instruments provide data at discrete points while measurements by satellite sensors provide only snapshots of a large area. This project seeks to develop a system capable of addressing the need for medium-area, time-series measurements for the advancement of shoaling-wave models, and this past year is an expansion of this SBIR project to support transition of developed capability to USN and USMC acquisition programs.

OBJECTIVES

Develop a passive, electro-optical imaging system that can be mounted and flown in an aerial photography aircraft to produce time-series imagery of the ocean surface suitable for scientific research. The system is designed for low-cost production through the use of commercial-off-the (COTS) components and low-cost operation through the use of commercial airplanes.

APPROACH

The system design is based on technology developed for the Airborne Remote Optical Spotlight Sensor (AROSS) and adapted for use on commercially available aerial platforms. AROSS was developed as a research and development (R&D) system that acts as a surrogate for future UAV payloads that would be used in combat in denied areas. The AROSS design approach was to utilize a turret-type positioner, digital framing camera, and integrated Global Positioning System/inertial measurement unit (GPS/IMU), with a computer-based data acquisition and control system. Attitude and position information is provided by the GPS/IMU, which was mounted on the camera rather than on the airframe. The control system uses this information, along with differential GPS corrections, to calculate the camera pointing direction and maintain the intended geodetic location of the aim point in close proximity to the center of the image while maintaining a standoff range suitable for military applications.

Although AROSS is a demonstrated success, its routine use is limited by its significant cost to operate. While not expensive by military standards, the per hour cost to fly the specialized UAV surrogate in which AROSS is mounted restricts its non-warfare-related, commercial uses and its participation in ongoing scientific research.

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14. ABSTRACT With the emphasis of the ONR Coastal Dynamics Programs on model-driven experiments, there is a need for reliable measurements to develop, drive and validate shoaling wave models. Measurements by research vessels and in situ instruments provide data at discrete points while measurements by satellite sensors provide only snapshots of a large area. This project seeks to develop a system capable of addressing the need for medium-area, time-series measurements for the advancement of shoaling-wave models, and this past year is an expansion of this SBIR project to support transition of developed capability to USN and USMC acquisition programs.					
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The new system designed and constructed in this SBIR project reduces operating costs by using commercial, aerial-photography aircraft, and simultaneously increases applications by providing up to four simultaneous images providing either spectral or polarimetric data having high spatial and temporal simultaneity. It is designed to replace the single panchromatic AROSS camera and extends into an aerial camera viewport, which is located in the floor of the airplane. This configuration enables the system to stare at geodetic locations at oblique angles at any location relative to the aircraft. The resulting system is a second-generation AROSS that continues to provide temporally coherent imagery while simultaneously enabling the investigator to split the optical signal into four channels. This new system naturally is called AROSS-Multi-Channel or AROSS-MC.

WORK COMPLETED

After its first flights at NCEX, AROSS-MC has participated in a number of research experiments and capability demonstrations. The NCEX data have been used in collaboration with Jim Kaihatu for analyses associated with shoaling wave phenomenology and with Todd Holland for comparisons of shoaling wave and surf characteristics derived from his land-site video cameras. These data also have contributed to an evaluation of the directional resolving capability of our 3-D spectral approach that, for example, has enabled us to separate the commonly occurring two beams of swell at the NCEX site, which was located in the lee of San Clemente Island. Data have been collected over a number of rivers and estuaries in an initial investigation of a new approach for remotely retrieving currents in these environments that are sheltered from ocean waves. Data have been collected nearby FRF for analysis of issues associated with our ongoing Tactical Littoral Sensing Program that is transitioning AROSS-related algorithms to the Navy COBRA Program. The system was modified and installed on a ship, and data collected as part of the Zircon and Topaz Experiments for the SSN Vulnerability Program, and is being upgraded for use in the Zircon II Experiment. Data have been collected as a central component of an anti-terrorism intelligence and surveillance capability in an urban environment demonstration in the National Defense Imagery Project at Fort Huachuca. Also, as an adjunct to this latter deployment, data were collected to support the Polarimetry Experiment (POLEX) for detection of military targets under foliage. These various applications of the system are on-going, with AROSS-MC continuing to be an important test bed for several projects that are developing requirements (both hardware and mission product) for future military systems. Finally, this SBIR expansion project has supported considerable documentation of system performance, see below.

RESULTS

Geometric transforms have been measured and incorporated that enable spectral and polarimetric data from the four cameras to be mapped to common pixels on the water/ground to an accuracy of better than 90%, a level that is required for precise spectral or polarimetric measurements (Hooper et al 2005). This is a critical result, as it enables automation for processing the very high number of images this type of system collects without the usual image by image rubber sheeting typically used in military ISR systems. An analysis has been performed to estimate the stability performance of the pointing system, using the image data for *truth*, and the results motivate use of this system, and this multi-image approach in general, for more demanding target-related military missions (Morris et al 2005). Data from NCEX have been used to measure the shoaling wave spectrum for comparison with models and, much to our surprise, these spectra easily resolve the complex directional components of the wave train when the experiment site was in the lee of San Clemente Island (Williams et al 2005). The data collected over inlets, estuaries and rivers have been used to evaluate a new approach for retrieving currents in these sheltered environments, potentially resulting in a new capability for support of Navy

SEAL ingress/egress missions (Dugan and Piotrowski 2003, 2004, 2005). The data have been used to retrieve bathymetry for use in shoaling wave models, and results compared for surf characteristics in conjunction with J. Kaihatu, providing and end-to-end validation of the forecasting system performance (Dugan et al 2004, Williams et al 2004). A summary of the status of this image collection technology, particularly as regards navigation accuracy, was invited by the *Institute of Navigation* (Dugan 2005). This is of great interest to the Navigator of the Navy as it pertains to new techniques for improving the accuracy of postings of geodetic products.

IMPACT/APPLICATIONS

The successful transfer of AROSS technology to a system capable of being mounted in a commercial aircraft has provided an enormously successful asset for continuing research for solving ocean-related problems affecting Navy and Special Forces activities. In addition, other agencies responsible for urgent response in coastal waterways, mapping and charting, and intelligence activities are applying the approach we have successfully applied in our AROSS and AROSS-derivative systems for a wide range of problems.

TRANSITIONS

AROSS-MC is the centerpiece evaluation system for the Littoral Combat FNC's Tactical Littoral Sensing (TLS) Program, which is transitioning to the USN COBRA ground station a number of littoral mission-specific ISR algorithms, developed using data from our AROSS-type systems. COBRA is a mission package for the Navy's *Fire Scout* UAV that is planned to be the aircraft for the Littoral Combat Ship (LCS). These algorithms support both the primary mission of the SD&D Assault Breaching System but also several associated ISR missions. They are the foundation for a number of potential expanded ISR missions presently under discussion as well. The present algorithms provide environmental products including wave spectra, bathymetry, water current and surf characteristics. They also provide target-related products such as detection and geo-location of surfaced mine-like objects.

In addition, the same approach is being used in closely associated programs that, at least in part, have been spawned by these results. A good example is the *Palantir* Program that has designed and is constructing a similar package with much larger cameras for collecting data for algorithm and CONOPS evaluation use on the Scaled Composites-Northrop Grumman *Proteus*. This sensor system will be used as a surrogate for the future Navy High Altitude Long Endurance (HALE) UAV being evaluated in the Broad-Area Maritime Surveillance (BAMS) Program. Another is a Riverine Warfare application in which the planned transition platform is National Technical Means (NTM) sensors.

In total, there is strong potential for transition of new capabilities for a wide variety of additional ISR applications for use on a variety of platform types, from tactical UAVs to theater UAVs to national systems.

RELATED PROJECTS

The success of AROSS-MC has spawned a number of related projects, several of which have been identified above.

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