A Low-Cost Airborne EO Oceanographic Measurement System

J. Zandy Williams
Arete Associates
1725 Jefferson Davis HWY
Suite 703
Arlington, VA 22202
phone: (703) 413-0290 fax: (703) 413-0295 e-mail: williams@arete-dc.com

Contract Number: N00014-02-C-0183
http://www.aross.arete-dc.com

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.

OBJECTIVES

This effort will development a passive, electro-optical imaging system that can be mounted and flown in an aerial photography airplane 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 will be adapted to accommodate the necessary modifications 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, under contested conditions. 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 are provided by the GPS/IMU, which was mounted within the turret 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 approximate cost of $2000 per hour to fly the specialized UAV surrogate in which AROSS is mounted restricts its non-warfare or commercial use and its participation in ongoing scientific research.

The new system will reduce operating costs by using commercial, aerial-photography airplanes. It is designed to replace the large-format camera and will extend into the camera viewport, which is located in the floor of the airplane. This configuration will place the sensor near the skin of the fuselage and will allow the system to stare at a geodetic location at oblique angles. In addition to the needed modifications for use on commercial airplanes, the development of a next generation AROSS also represents an opportunity to develop a multi-channel sensor to replace the panchromatic camera in AROSS. The new system will be called AROSS-Multi-Channel or AROSS-MC.

WORK COMPLETED

Work on Phase II of the SBIR program began in May 2002 and the system design has been completed. As part of the design work, a point through analysis of the optical system was performed and included measuring the modulation-transfer-function (MTF). The payload housing was designed to accommodate the GPS/IMU and four cameras, each with a different bandpass filter. The payload will be integrated onto a computer-controlled, yoke-style positioner.

RESULTS

The MTF for the AROSS-Lite camera subsystem was obtained by measuring the MTF for the camera or CCD and multiplying the result with the MTF published for the lens. The CCD MTF was measured using demonstration cameras from the vendor and a high quality lens with a known MTF viewing a series of square-wave test targets. The resulting MTF was then divided by the measured MTF of the test lens, which had an MTF greater than 100 lines/mm (0.67 cycles/pixel), to obtain the MTF of the CCD shown in Figure 1.

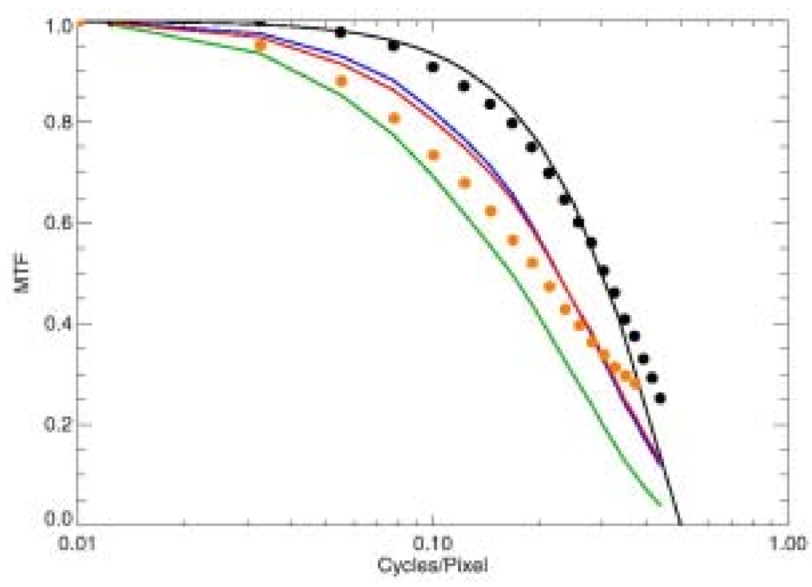

Figure 1: MTF Curve for the bare CCD and the full camera system [graph: CCD MTF is 1 at 0.03 cycles/pixel and lower, 0.9 at 0.1 cycles/pixel, 0.75 at 0.2 cycles/pixel and 0.25 at 0.5 cycles/pixel; Full MTF is 0.95 at 0.03 cycles/pixel and lower, 0.8 at 0.1 cycles/pixel, 0.6 at 0.2 cycles/pixel and 0.1 at 0.5 cycles/pixel]

The theoretical MTF for a fully-filled array is overlaid on the plot and matches closely with the measured result for the monochrome CCD. This indicates that the CCD is of high quality and the fill-factor is quite high. The final MTF for the camera/lens subsystem is also shown in Figure 1. Except for the largest aperture setting (f=1.5), the MTF indicates that the system should yield sufficient resolution to meet requirements. The 50% MTF value for the camera/lens system is at 0.25 cycles/pixel or half the Nyquist frequency.

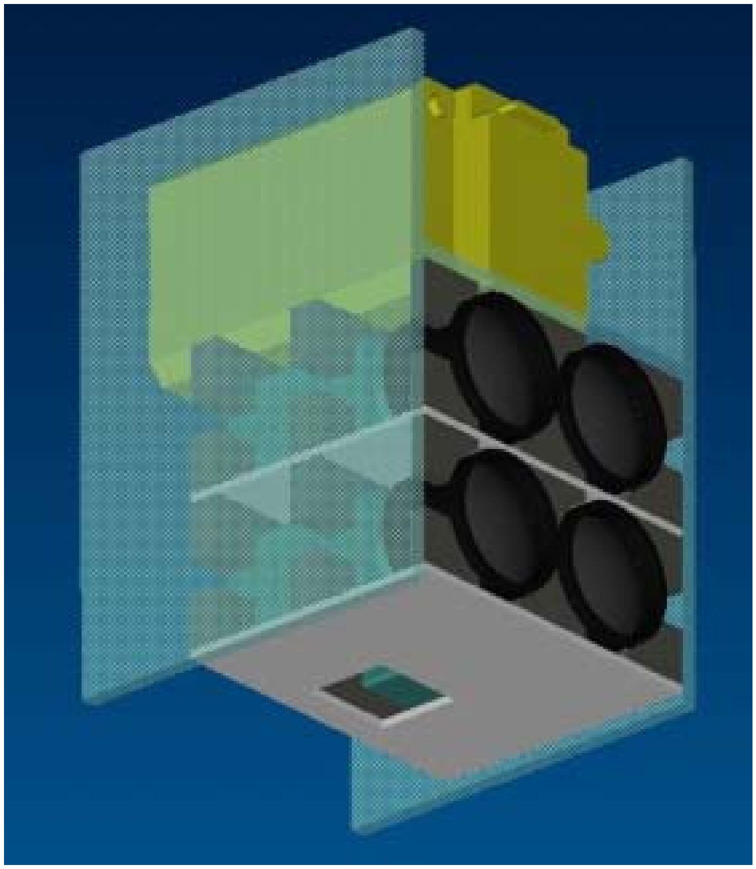

Figure 2: AROSS-MC Payload
[drawing: GPS/IMU positioned above two rows of cameras in a rigid housing]

The camera subsystem and the GPS/IMU will be mounted in an enclosed housing on the positioner. A rendering of the design is shown in Figure 2. The payload is designed to be compact and rigid. The cameras and GPS/IMU are mounted in a vertical stack allowing the cameras to be positioned as close as possible to the azimuthal axis of the positioner. By placing the cameras near the azimuthal axis, the range of grazing angles (GA) accessible to the system will be increased.

A schematic drawing and a rendering of the payload mounted on the positioner are shown in Figure 3 and Figure 4. The camera position on the positioner can be adjusted for clearance and balancing while maximizing the range of GA. The final, vertical location will be determined during the load balancing stage of the payload integration. Note that the payload is designed for variation of the positioner height from the airframe floor, which allows for variations in airframe thickness and optimization of the camera location on a per plane basis.

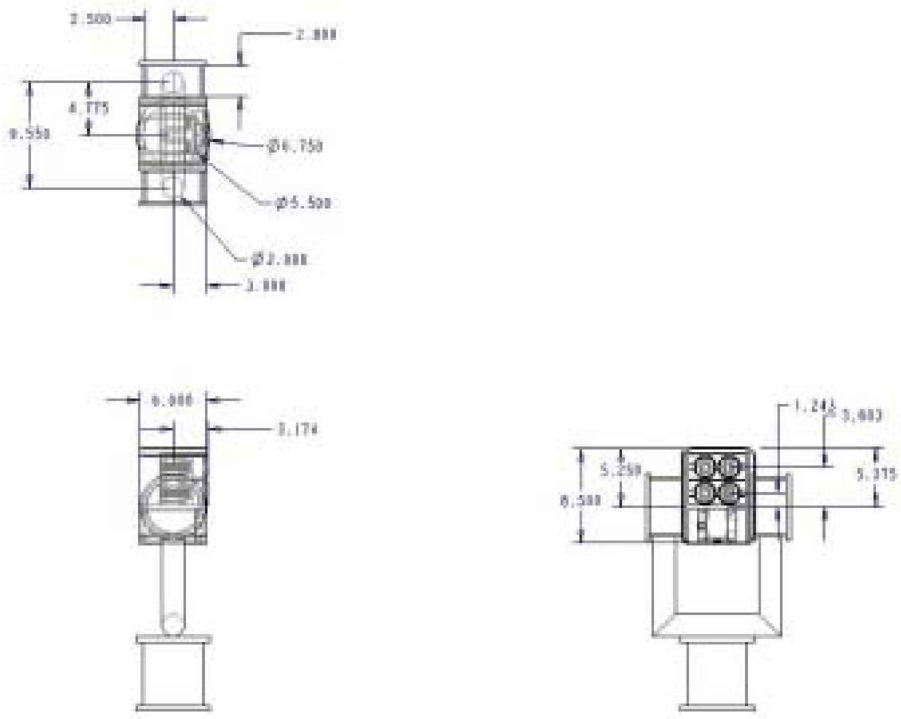

Figure 3: Schematic of AROSS-MC payload integrated onto positioner

IMPACT/APPLICATIONS

The successful transfer of AROSS technology to a system capable of being mounted in a commercial aircraft will provide an inexpensive oceanographic research asset. This asset will directly benefit the Navy wave modeling community who require wide-area measurements of observable parameters, including bathymetry, currents, and directional wave spectra, in the littoral zone. The lower operating cost of AROSS-MC will be more in-line with the budgets of typical field experiments designed to enhance scientific understanding of coastal processes. Government agencies responsible for coastal waterways, such as the Army Corps of Engineers, and mapping, such as NOAA and NIMA, represent potential customers who can utilize the low-cost rapid bathymetric and current survey capability of the new system.

TRANSITIONS

None

RELATED PROJECTS

The Airborne Optical Spotlight System (AROSS) is a compact, turret-based optical system designed and constructed for passive imaging of ocean waves using a small aircraft. The purpose of the system is to collect time series of images that are mapped to a common geodetic surface in order to extract the space-time characteristics of the waves. This is achieved by staring at a fixed geodetic location, and accurately measuring the imaging geometry. The system was designed to be compact and lightweight for future installation on an unmanned aerial vehicle (UAV), and has been installed on a specially modified, small, manned, single-engine aircraft for testing and experimentation. Tests have confirmed successful operation of the staring capability at moderate distances to a fixed target array on land and to the nearshore region with shoaling gravity waves. These capabilities are the result of a successful previous ONR-funded SBIR. More information can be found at http://www.aross.arete-dc.com.

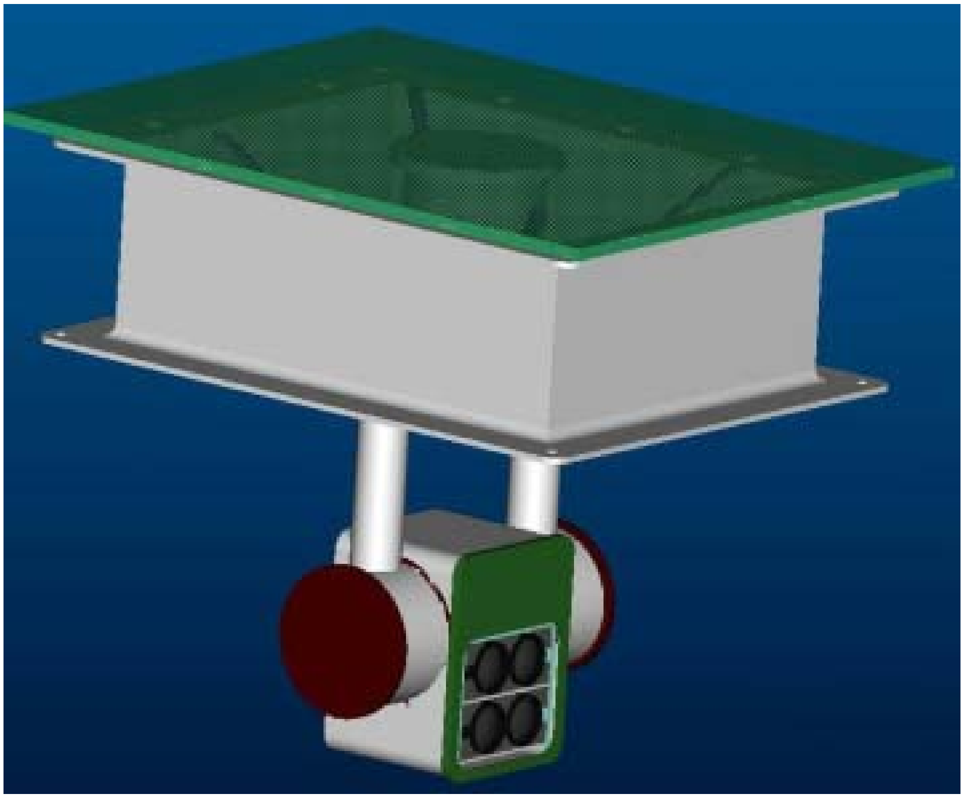

Figure 4: Rendering of integrated payload and positioner mounted on airframe viewport.

REFERENCES

Dugan, J.P., Piotrowski, C.C., Williams, J.Z., "Water depth and current retrievals from airborne optical measurements of surface gravity wave dispersion," *J. Geophys. Res*., 106 (C8), 2001, 16903-16915

Dugan, J.P., G.J. Fetzer, J. Bowden, G.J. Farruggia, J.Z. Williams, C.C. Piotrowski, K. Vierra, D. Campion and D.N. Sitter, "Airborne optical spotlight system for remote sensing of ocean waves" *,J. Atmos. and Oceanic Technol.*, 18 (7), 2001, 1267-1276

Dugan, J.P. and C.C. Piotrowski, Surface current measurements using visible image time series, *Remote Sensing of Environment*, Nov 2002 (in press).

Piotrowski, C.C., J.P. Dugan and J.Z. Williams, Accuracy of bathymetry and current retrievals from airborne optical time series imaging of shoaling waves*, IEEE Trans. Geoscience and Remote Sensing*, Nov 2002 (in press).