A Novel Multi-Sensor Airborne Mapping Tool for Ecosystem Monitoring

Poster #CD34B-0130

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I. Problem Statement

The US Armed Services rely on strategic island and coastal sites for training and testing. To sustain these activities, they must comply with environmental regulations requiring monitoring and mitigating impacts on these sensitive coastal ecosystems. Traditional, boots-on-the-ground methods of assessing environmental impacts are limited in scope and costly.

II. Objectives

Objective: To demonstrate the use of integrated aerial remote sensing technologies to meet the DoD's diverse monitoring and management challenges over broad areas, at high resolutions, and with reasonable costs.

Specifically this work will:

- Develop high-resolution land-to-sea digital elevation maps (DEMs) and shallow water benthic habitat maps for each demonstration site, using aerial LiDAR and hyperspectral data
- Illustrate use of these products to assess military training impacts (or lack thereof) in coastal areas.

III. Technology / Methodology

Primary technologies to be demonstrated:

1) The Modular Aerial Remote Sensing System (MASS), developed by Scripps Institution of Oceanography, which includes hyperspectral and topograhic LiDAR imaging systems. This work extends the MASS to include bathymetric LiDAR.

2) The Coastal Waters Spectral Toolkit, a hyperspectral data processing methodology for benthic habitat classification in development at the Naval Research Lab (NRL).

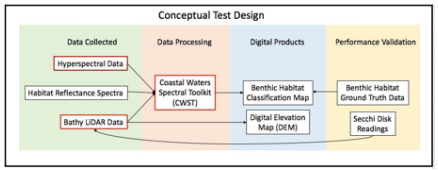

Figure 1: Conceptual Test Design.
Technologies/methodologies to be demonstrated are outlined in red.

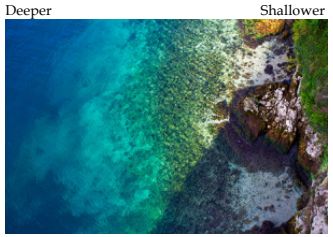

Figure 2: Incorporation of bathymetry (LiDAR) is expected to improve habitat classification, as demonstrated by change in optical properties of corals with water depth.

IV. Demonstration 1: San Clemente Island, CA

Site Location

Figure 3. San Clemente Island Training Range

Data Collection and Sampling Plan

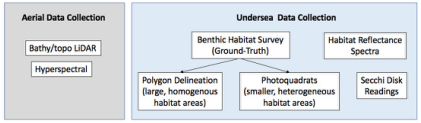

Figure 4. Conceptual diagram of field data collection

Table 1. Summary of data collected.

Data Type	Sampled Via	Number of Samples
Aerial		
Topographic/Bathymetric	Riegl VQ-820-G LiDAR	Continuous installation coastline
Hyperspectral	Specim AisaKESTREL	Continuous installation coastline
Visible photographs	Nikon D810	Continuous installation coastline
Undersea		
Large, homogenous habitat areas	Polygon delineation	4+ per habitat type
Patchy habitat areas	Photo quadrat transects	20+ per habitat type
Water clarity	Secchi disk	2 replicates at each new large-scale site
Local reflectance spectra* (*supplemental to existing in CWST)	NightSea DiveSpec	3 replicates, 10 locations per habitat type

Figure 5. Benthic habitat types targeted for classification.

Aerial Data Collection

Test flights: April 2017. Aerial data collection: July 27-Aug. 1, 2017.

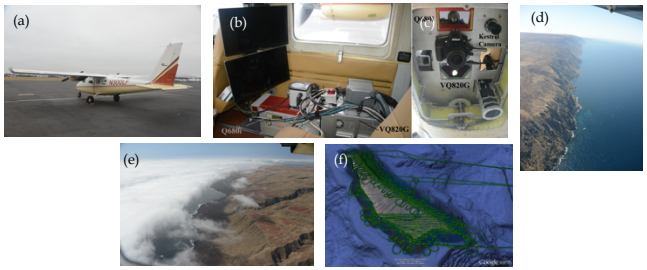

Figure 6. (a) Partenavia P68 aircraft with (b) aerial remote sensing system (MASS) installed; (c) view ports on bottom of plane; (d,e) flight conditions; (f) flight tracks.

Underwater Ground Reference Data Collection

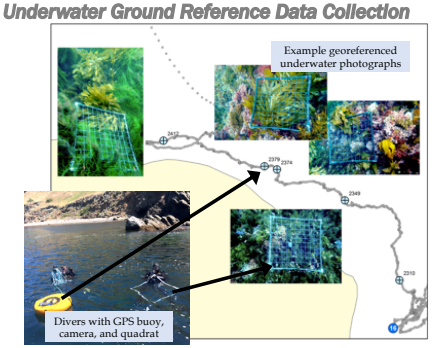

Figure 7. Undersea validation dataset collected includes 300+ georeferenced digital photos of sea floor/benthic habitat type, plus polygons delineating large, homogenous habitats around the island.

Undersea data collection: July 20-27, 2017.

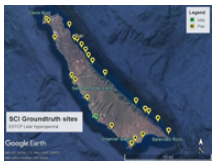

Figure 8. Locations of diver-collected photo quadrat reference data

V. Data Processing and Early Results

LIDAR-derived bathymetric data

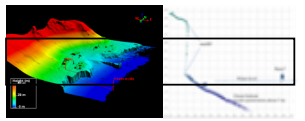

Figure 9. (Left) Land-to-sea DEM of NOTS Pier area. (Right) Land-to-sea profile of red line on DEM.

Hyperspectral data

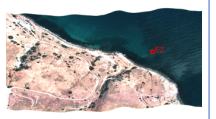

Figure 10. Section of hyperspectral imagery data (image shows true color, RGB). Site in red is a location of ground reference data collection.

In-situ habitat spectra

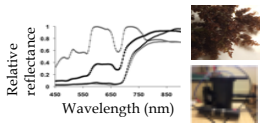

Figure 11. (Left) Example reflectance spectra. (Right top) Example red alga from San Clemente Island. (Right bottom) Underwater spectrometer (DiveSpec) used to obtain in-situ reflectance spectra of benthic types.

NRL's Coastal Waters Spectral Toolkit (CWST) — Currently processing

- Generates a database of all probable combinations of bottom reflectance spectra (determined by benthic cover, water depth, and water column optical properties) using a radiative transfer model
- Compares remotely sensed spectra to database spectra to make classification
- Advantages of this approach: physics-based. Relies on few assumptions, applicable to the greatest number of habitats, and therefore of greatest value to the Navy.

Validation against ground truth data [Fearns *et al.*, 2011]

Benthic Habitat Map

Military impacts assessment to support effective environmental resources management

Table 2. Performance objectives for demonstration

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
Modular Aerial Remote Sensing System (MASS)			
High-resolution, georeferenced, seamless land-to-sea digital elevation map (DEM)	Accuracy and resolution	Topographic and bathymetric LiDAR data; GPS reference points	Lidar point cloud density of 10/m2; 10cm or greater vertical accuracy; DEM horizontal resolution <= 1m.
	Water penetration depth	Bathymetric LiDAR data	Either: 1) 80%+ of listed depth capability of the bathymetric LiDAR system (80% of 10-20m for the VQ-820 and 15-30m for the VQ-880) , or 2) 1 Secchi depth for the VQ-820 and 1.5 Secchi depths for the VQ-880.
Historical topographic change detection (Demonstration Site 1 only, as we have a high-quality DEM here from previous work)	Topographical change volume	Current DEM deliverable generated from LiDAR data; Historical DEM from our previous work at San Clemente Island in October 2014	Detection of erosion/accretion with volume changes of 2.5m2. Detection of volume changes smaller than 2.5m2 would be even more successful.
Coastal Waters Spectral Toolkit (CWST)			
Benthic (undersea) habitat classification maps	# of distinguished benthic habitats; classification accuracy	Hyperspectral data; lidar data; ground truth data	80% classification accuracy of homogenous habitat types; 70% or greater accuracy of mixed-habitat pixels
Qualitative Performance Objectives			
Modular Aerial Remote Sensing System (MASS) and Coastal Waters Spectral Toolkit (CWST)			
High-resolution, georeferenced, seamless land-to-sea digital elevation map (DEM)	Area surveyed	Topographic and bathymetric LiDAR data	Large area along the coast, spanning from coastal land features seaward to the outward extent of benthic communities of interest or the depth limits of the bathymetric LiDAR.
Identify any impacts of DoD training, testing, and other activities on coastal habitats, on land and under sea	Capability of data to show habitat conditions in areas of military use	Topographic and bathymetric LiDAR data; seamless land-to-sea DEM; habitat classification maps	Identified any links between military operations and topographic change (erosive features found) and/or benthic habitat changes

VI. Next Demonstration:
Marine Corps Base Hawaii, April 2018

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