

Littoral Battlespace Characterization Using Small Unmanned Aerial Systems

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Motivation: Few environmental regions are as dynamic as the littoral, where dramatic changes in winds, waves, and bathymetry can occur over time scales as short as a few hours. A long-term goal for the Littoral Dynamics Team within the Naval Research Laboratory (NRL) is to extract littoral meteorological and oceanographic (METOC) conditions from intelligence, surveillance, and reconnaissance (ISR) imagery collected by either space or airborne platforms in near real time. Our most recent efforts have focused on developing capability to provide actionable battlespace awareness for amphibious operations through the analysis of motion imagery from Small Unmanned Aerial Systems (SUAS). These systems are relatively inexpensive and are widely used within the Department of Defense.

Technical Approach: Although we have investigated a number of suitable platforms, our military customers commonly use the Raven B SUAS manufactured by Aerovironment, Inc. This platform, with a wingspan of 1.4 m and a weight of 1.9 kg, is ideally suited for low-altitude ISR. The system can carry either dual color video cameras with digital pan/tilt/zoom or a single infrared (IR) camera, downlinked live to a ground control station (GCS). Within the GCS, the video is timestamped and aligned with position and attitude metadata. Although direct orthorectification of imagery frames is possible using an external laptop computer, time latencies and sensor misalignments can result in geo-referenced mosaics with substantial errors. Instead, NRL has developed an image matching approach based on scale-invariant tie-points to automatically create mosaics suitable for littoral characterization that can be geo-registered using optimized metadata with only limited manual intervention.

Exercise Demonstration: This approach was demonstrated during 21–28 July 2008 in support of Exercise Trident Warrior 2008 and Exercise Rim of the Pacific (RIMPAC) 2008 while working from Bellows Beach, Hawaii. Our joint civilian and military team managed and flew the Raven B for purposes of collecting surf zone imagery in support of U.S. Navy and Marine Corps amphibious operations (Fig. 6). Military support, including transmission of our products to the fleet, was coordinated through the Naval Oceano-

graphic Operations Command, ISR Oceanography Directorate. This was the first time Raven B had been used for this purpose during a major exercise.

Five flights (averaging 55 minutes duration) over 4 days resulted in nearly 600 images and video clips. These clips were analyzed immediately after collection to create a number of timely environmental products (Figs. 7 and 8). These products were used by METOC personnel aboard the USS *Bonhomme Richard* (LHD 6) who indicated that these products were useful in planning RIMPAC landings at Bellows Beach.

A related part of the demonstration purpose was to develop, refine, and assess the concepts of operations (CONOPs) and tactics, techniques, and procedures (TTPs) associated with collecting Raven B overhead imagery for littoral characterization, planning, and tactical decision-making. By flying at various altitudes and flight paths (dwells, orbits, and strip maps), we were able to develop an optimal collection strategy and demonstrate that this system could provide quality, timely, and actionable intelligence that impacted operations through improved battlespace METOC characterization. For example, cloudy weather conditions on some mornings would have precluded the use of higher altitude surveillance platforms. The overall demonstration proved that effective METOC characterization of the littoral battlespace was possible by exploiting tactical, non-traditional METOC sensors, specifically imagery from a locally controlled SUAS.

Future Plans: Present METOC products that can be derived from these systems include geo-rectified mosaics showing surf zone characteristics, shorelines, hazards to navigation, and preferred vessel pathways. Some of our techniques for standardizing product types and formats require further development. In addition, numerical analysis of these videos has been shown useful for estimating wave direction and period, and will be used to derive bathymetry in the near future. We anticipate working with further amphibious demonstrations similar to Trident Warrior during 2009.

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**FIGURE 6**

UAS operator preparing to launch Raven B on Bellows Beach, HI. USS *Bonhomme Richard* (LHD 6) is visible near the horizon.

**FIGURE 7**

Image mosaic created while on-scene showing Bellows Beach landing area.

FIGURE 8

Example of an analyzed image product created from mapped Raven B video frame. Shoreline location and measured widths of littoral features are indicated.

