# *Safety and Security Applications for Micro-Unmanned Surface Vessels*

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*Abstract* - As the challenges of maritime safety and security evolve we are forced to closely examine emerging threats and to develop a maritime strategy that embodies solutions for current and a widening array of future threats. Robotic platforms have proven to be an effective tool for gathering information in support of land based security and disaster response and are now being explored in an effort to support maritime security, search and rescue and disaster response.

This paper discusses existing and potential use of micro-unmanned surface vessels (USVs) in support of a range of maritime security issues and identifies a comprehensive, low-cost tool to combat future terrorists, while addressing maritime security and safety considerations

*Keywords – Unmanned Surface Vessels (USVs), first responders, sensors, actionable intelligence, ISR, standoff, safety, persistent surveillance, man-portable, autonomous.*

## I. INTRODUCTION

The maritime environment brings with it a wide range of unique consideration; severe weather, corrosion and issues pertaining to immersion in salt water, waves and a constant motion, strong ocean currents, etc., however, the use of robotic platforms in this environment may be even more beneficial than has been previously demonstrated for land based applications. The initial encounter with an unknown maritime vessel can be potentially hostile, and yet unarmed, first responders are often the first to encounter unknown vessels along the continental US coastline. Hydronalix produces the EMILY (Emergency Integrated Lifesaving Lanyard) unmanned surface vehicle (USV) shown in Fig.1. used by first responders to provide assistance to swimmers in distress. Additionally, man portable micro-USV platforms equipped with a wide array of sensors and communications capabilities have been operated in support a range of intelligence surveillance and reconnaissance (ISR) missions such as; searching for sunken wrecks with side scan sonar, mapping bathymetry and identifying underwater anomalies, mapping electro-magnetic anomalies, hyperspectral imaging

This work has been supported in part by CCAT, NOAA, DARPA, NAVFAC, US Navy and GLIMS.

*Fig.1. Emergency Integrated Lifesaving Lanyard (EMILY) operated by first responders around the world*

below the waterline and surface observations with both visible and infra-red imagery in addition to environmental atmospheric measurements. One such platform is the Hurricane EMILY developed for NOAA and shown in Fig.2. that is equipped with a wide array of meteorological sensors

*Fig.2. NOAA's Hurricane EMILY platform during testing off the Malibu coast, California*

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for measuring atmospheric conditions and water temperature in the open ocean. The platforms can operate autonomously or with operator intervention, and data can be stored on board and/or streamed in real-time via radio or satellite communications links.

The smuggling of narcotics, humans or arms into the U.S. has increased recently often through the use of small open vessels that are used to transfer the cargo to U.S. recreational vessels or secluded beaches. Many vessels attempt to come in during the evening and early morning hours running dark to conceal their cargo. First responders, (firefighter, lifeguards), are often first to encounter these vessels as they might be reported by other boaters of the general public. The primary goal of first responders is to ensure the safety and accountability of the people on board and delivering first aid if needed. But in a growing number of incidents, these first encounters can be hostile due to the desparate measures taken by individuals to evade capture. Micro-USVs can play a role in this event and provide early covert observation of the vessel of interest, thereby providing actionable intelligence for the first responders, from which a plan of action can be determined leading to greater safety.

Searching of waterways and harbors for suspicious packages and other anomalies that might be attached to vessels or dropped to the bottom is also of importance as harbor security becomes increasingly more important. Micro-USV platforms can provide an array of underwater maps that might better identify and precisely locate the position of suspicious underwater anomalies. Regular mapping of harbor environments would allow for "new" anomalies to be quickly identified and acted upon.

Persistent monitoring of weather conditions and particularly micro-climates is very important to a wide array of users so that appropriate choices can be made particularly in the preparation for potentially inclement conditions. Determination of water quality and contaminant levels is also of vital importance in responding to potential terrorist activities or natural disasters, and the ability to quickly map contaminant levels and determine their rate of spread and dissemination will aid response activities. A micro-USV developed for open ocean weather monitoring for NOAA as shown in Fig.3 can be reconfigured for additional sensors to monitor not only atmospheric conditions but to sample water contamination and report the findings via a satellite link. These platforms could be deployed from large manned vessels and left to autonomously patrol selected bodies of water reporting the data back at regular intervals through a short burst data satellite connection.

*Fig. 3. NOAA's Hurricane EMILY micro-USV platforms on board the Shearwater research vessel.*

The following sections describe the use of micro-USVs for three potential scenarios.

1). Routine Intelligence, Reconnaissance and Surveillance (ISR) mission to provide increased awareness for coastal surveillance.

2). First responder tool for stand off first encounter

3). Mapping and underwater observations in support of port security, as well as search and rescue assistance.

## II. Potential Micro-USV Applications

### *A. Routine ISR asset for increased awareness*

Coastal ISR activities are currently carried out by a range of manned vessels both from the surface and air. Due to the distances that are involved, coverage is often sparce and due to limited resources and cost, cannot be covered on a regular basis. The US Coast Guard, CBP and Los Angeles County Fire Department Lifeguard Division (LACOFDLG), while each have different mandates often cooperate in monitoring activities. Even so, an ISR asset that could operate indepentently to provide additional, around the clock information on weather, surface vessel traffic and potential situations, would be very beneficial.

Over the past few years several incidents involving Panga boats [1] have occurred along the Californian Coast with what appears to be increasing regularity. In May 2013 a 35-foot-long panga boat that was found on a secluded beach in Montaña de Oro State Park. It was the fifth such panga boat discovered on local beaches in the last year. San Luis Obispo County sheriff's deputies recovered a cache of what is believed to be marijuana and arrested 14 people. More recently a panga boat was found on Crystal Cove CA and 24 people were arrested [2]. These incidents often involve the trafficing of drugs, human cargo and other contraband. While most have resulted in the arrest of culprets, incidents have turned volatile as highlighted by the tragic loss of a US Coastguard when his boat was rammed by smugglers [3] in 2012.

Recently there have been several incidents of panga boats racing up the Californian coast as shown in Fig. 4. Mexican boats carrying marijuana loads have landed on remote shores more than 300 miles north of San Diego [4]. Two pangas were found near Big Sur. Another landed on the secured beaches of Vandenberg Air Force Base, while other smugglers left $4 million worth of marijuana bales strewn along the beaches near Refugio State Park. While most of the Mexican immigrant smugglers drop off their human cargo loads in southern California near San Diego, the marijuana smugglers are traveling farther north to avoid detection. For the last three years, some of the smugglers have been using the Channel

*Fig.4. Image showing the apprehension of Mexican smuggling boats as they race up Californian coast. (Courtesy NBC News Nightly 13th July 2013)*

Islands National Park, a chain of environmentally sensitive islands off the Ventura and Santa Barbara coastlines, to refuel or to hide from U.S. Coast Guard patrols.

Under these situations, a micro-USV ISR platform could perform multiple operations and provide significant insight into the situation at hand in real time, thereby helping to provide actionable intelligence that might lead to improved safety and security for those involved. In addition to providing visual clarification of the smuggling behavior, detailing the number of people involved and helping assess the required intervention resources, the micro-USV platforms would be able to monitor large areas of coastline for a broad array of illegal behavior which would not only involve panga vessels looking for safe landing along the coastline, but also the monitoring of littoral fishing activities and potential local poaching activities. The long duration and relative stealthy nature of these vessels would mean that they could be operated covertly at day or night and could therefore gather important imagery of activities that might be required for prosection in a court of law.

### *B. Near real-time access to data*

The ability to remotely access data in near real time and over long periods of time can be essential in assessing the type of resources needed to respond to a situation. If temperature and barometric pressure data can be collected for instance, every 15 minutes from a remote location where an "event" occurs, first responders can have first hand knowledge as to the environment they are responding to. Similarly in the case of an environmental disaster such as the contamination of a body of water, the ability to access chemical data from a number of micro-USV platforms strategically located over tens or hundreds of miles can lead to an improved determination as to the drift of the contamination and the potential hazard posed to coastline, populated regions and wildlife alike.

Hydronalix has recently equipped the 15 micro-USV platforms fabricated for NOAA and DARPA with a short burst data (SBD) satellite communications system. The SBD data link enables the retrieval of data (up to 340 bytes) from the micro-USV at regular intervals (typically between 1 and 60 minutes) and the sending of data (up to 270 bytes) to coincide with the uplink. The iridium SBD 9602 modem allows data to be collected through the Internet to predetermined email addresses that can be used from personnel devices or laptop computers. Additionally, new mission instructions can be uploaded to the micro-USV in a similar manner.

The data that is autonomously retrieved from the sensors on board the micro-USV is compressed into a binary form for transmission and sent via an Internet connection up to 5 email addresses that can be selected by the account manager. Upon retrieval the data needs to be parsed to place it in a manageable form for reading. The Gumstix mission computer autonomously manages the sensor interrogation, data collection and sending at the designated intervals.

### *C. Stand-off tool to assist first responders*

First responders are often the first to encounter panga boats or illegal fishing activities as these activities are often reported by the public in response to events which seem out of place. The priority for first responders in any of these situations is to ensure human safety and where necessary to provide assistance. In light of many recent events and the potentially hostile response that may be encountered there is a desire to gather more information about the vessel in question prior to providing immediate assistance. A micro-USV such as EMILY equipeed with a simple still or gimballed camera such as that shown in Fig. 5 has therefore been considered as a method of providing near real time situational awareness.

The ISR platform shown in Fig. 5. has been operated by NOAA to gather images of marine life (mammals such as dolphins in their natural habitat) without disturbing them. The camera system can be fixed or gimbaled and the images can either be triggered remotely and stored on board on an data card that can be viewed at a later time, or transmitted in real time through WiFi over short ranges of approximately 200m to 500m.

In additional to the ISR platform, the EMILY lifesaving

*Fig.5. Micro-USV platform equipped with a high-resolution camera used by NOAA for imaging mammals and other animals in their natural habitat.*

micro-USV can be driven to provide floatation to swimmeres in the water who may have been expelled from a panga boat and left to swim ashore. In either situation, the micro-USV provides an interim platform that can assist the first responder while they better assess the "situation" and determine a course of action.

### *D. Littoral Searching and Mapping*

The micro-USVs have been used in the USA and in Nepal, Canada and Scotland as a platform from which to mount sensors for underwater surveys. The platforms can be remotely controlled (RC) or operated autonomously through the use of an autopilot. In the US, the Piccolo [5] and Ardupilot [6] autopilots have been used (independently) to direct the micro-USVs but for foreign operations it is often easier to operate by RC as export licenses are needed to operate with these autopilots. To support data capture and logging the micro-USV was also equipped with a waterproof computer and operating system manufactured by SeeByte [7], Edinburgh, Scotland. The computer acts as a central controller for mission planning and execution as well as for the processing and mapping the side scan sonar data through the software SeeTrack [8]. SeeTrack takes raw side-scan sonar and GPS data and georeferences the images to provide referenced bathymetry. The mission computer was equipped with a wireless modem connection allowing short-range interaction with an operator and eliminating the need to connect directly to the system to access and download data.

In Nepal glacial end moaraine lakes were mapped [9] using side scan sonar and a bathymetric map of the bottom depth and key features was constructed in support of a study that predicted the lake's propensity to "Glacial Lake Outburst Flood" (GLOF). The platform was manually driven down the center of these moraine lakes and the SeaTrack software located on the on-board mission computer continuously reconstructed and georeferenced the images. These images were remotely downloaded via WiFi to the operator's computer when the platform came within range, making the platform relatively easy to operate and accessible to data recovery in hostile environments. Lake Imja Tsho is located at 5010m approximately 8km from Mt. Everest.

Within the US, micro-USVs have been operated within the littoral regions to search for wrecks and other anomalies using low-cost, side scan sonar. The micro-USVs are readily deployed from the beach, from helicopters or from manned vessels at sea and can provide a real time data stream of the sonar imagery through WiFi to a range of personal devices such as iPhones, iPads and portable computers. When operated remotely (as opposed to autonomously) the operator can use the image generation map that is built up to ensure the platform is driven over the entire region of interest as shown in Fig. 6. In Malibu, CA, the Micro-USVs were operated by the Los Angeles Fire Department to search for a yatch which had broken it's morings and sunk in the surf. The yacht was quickly found within approximately 15 minutes, imaged and its location identified prior to sending a diver into the water, greatly reducing the risk to human life and accelerating the search process.

Side scan sonar is a powerful tool for imaging underwater environments and searching for anomalies that are in the water column or resting on the bottom. Other targets of interest however might be invisible to sonar, burried in the sand or silt and other sensors are usually available for searching these anomalies.

Irrespective of the type of sensors used, the micro-USV platform can be configured to autonomously follow a series of waypoints as shown in Fig. 7, that enable the platform to map littoral regions and identify the location of conductive targets. Figure 7 shows a mission plan that is over 610m in length and took nearly 6 hours to complete [10]. Conductive anomalies burried in the sand or silt and in shallow water can be observed using electromagnetic sensors. One standard sensor that is operated in the detection of buried ordnance and mines is the EM61. While these sensors are used commercially for

*Fig.6. Georeferenced side scan sonar map generated from a remotely operated Micro-USV searching for a sunken yacht. Malibu 2010. (Courtesy SeeByte)*

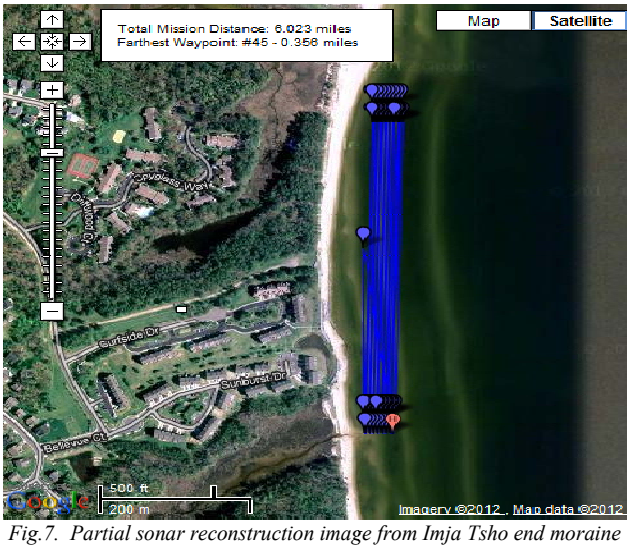


*Fig.7. Partial sonar reconstruction image from Imja Tsho end moraine lake, Nepal, Oct.2010. (Courtesy Google Maps)*

ordnance detection they can also be used to detect metallic objects such as discarded firearms, or waterborne or burried improvised explosive devices (IEDs). The routine surveying of regions and application of change detection algorithms to determine the location of "new" anomalies is one of the many knowledgment management strategies [11] being considered to defeat IEDs above and below the water.

### *E. Sensor Selection*

There are a large range of small, lightweight sensors that are suitable for unmanned platforms and the specific sensor selection (or suite of sensor selections) will depend on the duration, available power, data bandwidth and whether the data is required in real-time, or whether the data can be post processed. Typically, if the data is processed at a later time, a small subset of the data is streamed back to the operator in real time so that we can maintain knowledge that the unmanned platform is operating correctly as well as determining specifically when data anomalies occur. This can help with the overall mission execution particularly if the data collection is out of sight [12].

In the future, sensors will be further miniaturized and their power requirements reduced, both of which support additional use on unmanned systems. There is a considerable body of work focused on the development and packaging of sensors for chemical, biological and nuclear detection but these systems currently do not work from a large stand off distance and still require the sensor to be colocated with the "threat" so that the airstream or water source can be sampled directly. Unmanned platforms are therefore the transportation of choice for these sensors as they eliminate the need for human exposure to potential threats.

## III. SUMMARY

Unmanned surface vessels that are man portable and easy to operate are currently being used by a range of first responders, scientists and government agencies to gather data and provide assistance in the maritime environment. The micro-USVs can be operated through remote control over short ranges or can be equipped with an autopilot and operated autonomously. They can be configured to store data onboard or the data can be sent in real time through WiFi or a satellite connection that allows data to be diseminated anywhere with an internet connection. A number of platforms are available that have been configured to operate in the open ocean for longer periods of time. These platforms operate remotely and can be tailored to provide perimeter surveillence and ISR activities for several days if desired. They can also be configured to operate with first responders as a stand off assessment tool that can be deployed form a manned vessel or helicopter to gather real time data on potential threats.

In the future it seems likely that micro-USV platforms will be used as mobile weather stations at sea, collecting information on the local sea state and weather conditions,or local sea contamination conditions, and that this data would become part of a larger management plan that will provide leadership with the specific information necessary to make informed decisions about the environment, terrorist activities, natural or man made disasters or maritime accidents. Currently unmanned surface vessels for use in the open ocean, riverine and littoral waters are a new and growing area for unmanned systems. In the future it is expected that multiple unmanned vehicle platform types will be operated over large areas and that the sharing of information between autonomous platforms [13] will provide a safer maritime environment and improved security for mariners and society in general.

## ACKNOWLEDGMENT

This work has been supported in part by the following programs; San Diego State University Research Foundation under contract # 55961B 7846 "Man portable unmanned surface vessels for first responders"; DARPA Contract # HR0011-12-C-0073 "Long Duration Autonomous Surface Vessel (USV) for Open Ocean Station Keeping"; US Navy Contract # W31P4Q-10-C-R190 "Micro-Unmanned Surface Vessel (USV) Prototype Fabrication"; NAVFAC Contract # N61331-09-D-0021-DO0006 "Hydronalix Report for Autonomous Ordnance Mapping Demonstration"; NOAA Contract # RA133R11CN0188, "EMILY USVs for Oceanic and Atmospheric Research to Acquire Atmospheric Measurements in and around Hurricanes". The authors also wish to thank first responders in Los Angeles County Fire Department Lifeguard Division LACOFDLG; Depoe Bay OR, Fire and Rescue; Green Valley AZ, Swift Water Rescue; Northwest Marana AZ, Swift Water Rescue; and the community of Westerly Rhode Island who have continued to train and work with micro-USVs to improve water safety.

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