Acquisition Directorate
Research & Development Center

USCG RDC Low Cost Maritime Domain Awareness Pilot Study

Quick Look Report

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1 INTRODUCTION

This quick look report was created to accelerate the transfer of results and observations from the 30 day USV demonstration to the project's stakeholders and other interested parties. A more extensive report on this project is currently in development and scheduled for distribution in mid-2021.

In 2018, Congress directed the US Coast Guard to perform a pilot study and assessment of low-cost commercially available technologies that could enhance Maritime Domain Awareness (MDA) in remote Pacific regions with the primary focus of monitoring Illegal, Unreported, and Unregulated (IUU) fishing. Market research, industry consultations, and a Request For Information (RFI) were completed to understand the current state of satellite, airborne, surface, and underwater technologies in the market. Autonomous Unmanned Surfaces Vehicles (USVs) were identified as having the highest potential of increasing MDA in remote Pacific regions while remaining relatively low cost. A subsequent Request For Proposal (RFP) was issued for contractor owned/contractor operated autonomous USVs capable of meeting the following key parameters:

- Operate 30 consecutive days without refueling.
- Detect other vessels within a minimum 1 nautical mile (nmi) of USV.
- Provide notification of other vessel detection within 6 hours of initial detection.
- Ability to operate up to sea state 4 / Survive up to sea state 6.
- Ability to operate solely by beyond line of site communications.
- Record fuel burn rates, energy use/production, air temperature, sea state, GPS position, time and other vessel detections.
- Contractor operated command and control center in Honolulu, Hawaii.
- Operate in a 5 by 4 nautical mile area approximately 20 miles off the coast of Honolulu, Hawaii.
- Overall Technical Readiness Level (TRL) of 8 or higher.

After evaluating vendor submissions for the RFP, contracts were awarded to a) Spatial Integrated Systems (SIS) based in Virginia Beach VA, and b) Saildrone of Alameda CA. The 30 day demonstration was conducted in Honolulu, HI beginning on October 7th and concluding on November 5th, 2020. In conjunction with the 30 day demonstration, the RDC also purchased a USV to evaluate the feasibility and logistics of operating an autonomous USV in the operational Coast Guard.

Also pursuant to the 2018 Congressional funding direction, the National Academy of Sciences recently released Transportation Research Board Special Report 335, "Leveraging Unmanned Systems for Coast Guard Missions (2020)."

2 USV PLATFORMS

2.1 Spatial Integrated Systems (SIS)

To perform the 30 day demonstration, SIS developed *The Watcher*, a CG cutter boat-large platform modified with solar arrays, an MDA sensor suite, and autonomy controls. The base platform is powered by an inboard diesel engine capable of speeds in excess of 30 kts. However, to meet the endurance requirements for this mission, SIS added an array of solar panels to the deck structure, a battery bank to power onboard electronics when the diesel inboard engine is not running, and an auxiliary 200 gallon fuel bladder beneath the deck structure. The vessel is capable of being launched and recovered via trailer, davit, or crane. While the vessel is equipped with autonomous controls, it is still capable of hosting two operators and being manually operated if necessary/desired.

To fulfill the requirement of detecting another vessel, *The Watcher* was configured with a commercial radar dome and a Pan Tilt Zoom (PTZ) Electro-Optical Infrared (EO/IR) FLIR camera as seen in Figure 1 below. The system provides notifications of radar detections consisting of a plot as shown below. The FLIR is programmed to slew to the radar target and capture images of the appropriate detection.

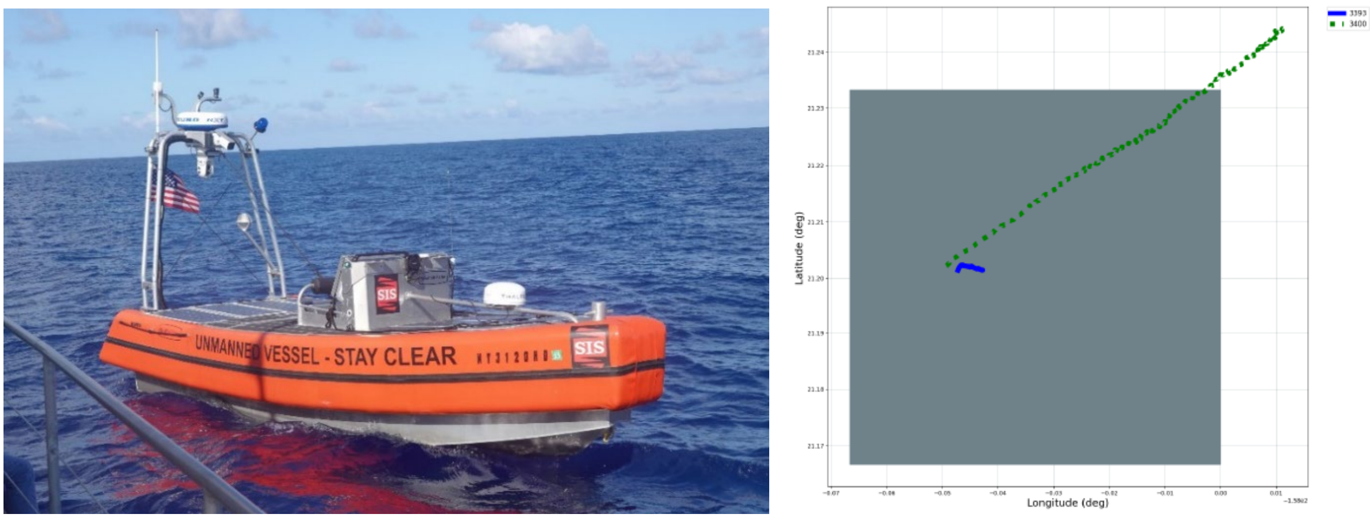

Figure 1. The Watcher in operation area (left) and example of a radar detection report (right).

Over the course of the 30 day demonstration, *The Watcher* demonstrated its ability to maintain position within the operation box and provided alerts every hour when another vessel had been detected. The primary behavior of this USV was to set and drift, meaning the vessel would position itself within the center of the operation box and then drift with the current towards the perimeter. Upon hitting the perimeter of the operation box, *The Watcher* would autonomously reposition itself to the center of the box. While repositioning itself back to the center of the operation area, it would use the diesel engine alternator to augment the solar powered battery bank. In addition to the set and drift behavior SIS also demonstrated *The Watcher's* ability to autonomously adhere to some collision avoidance behaviors in accordance with The International Regulations for Preventing Collisions at Sea (COLREGS) and perform an optimized search pattern. *The Watcher* was primarily operated out of SIS Headquarters in Virginia Beach via satellite communications. SIS also maintained a command and control trailer at a shipyard in Honolulu for support and additional communications capability.

2.2 Saildrone

Saildrone performed the 30 day demonstration utilizing six "Generation 6" Saildrones, which are 23' long fiberglass sailing vessels with a 15' fiberglass airfoil for a sail, analogously referred to as the "wing." These USVs (normally referred to as drones) utilize wind for propulsion while their inboard electronics are powered by solar arrays affixed to the wing and deck. These drones are capable of transiting at 2-3 knots or slightly higher in favorable wind conditions, operate with an average power consumption of 10 watts, and are capable of being launched/recovered via davit or crane. Saildrone has previously demonstrated drone deployments of up to a year without maintenance and has an extensive history operating scientific missions in remote or otherwise demanding environments, such as circumnavigating Antarctica and crossing the Bering Strait.

The drones have two detection mechanisms including Automatic Identification System (AIS) information and visual imagery. Other vessels emitting AIS can be detected beyond line of sight. Visual imagery is captured via a high resolution four-camera array, fixed to the top of the wing at approximately 15’ height of eye, which provides a 360° field of view of the surrounding area. The camera array captures imagery every five seconds and completes onboard analysis of each image using Saildrone’s proprietary Artificial Intelligence (AI) software which has been trained on vessel detection. Upon the AI determining a vessel has been detected, the drone sends the image, line of bearing to the detected vessel, and its own location to the Saildrone command centers. To conserve satellite bandwidth and ensure the command center is not inundated with alerts, the AI is configured to send only the clearest images approximately every 15-20 minutes. All other images are saved onboard and can be later accessed.

All Saildrones were controlled via a web portal accessible through the internet. Additional “view only” permissions were granted to the USCG participants which allowed for live updates of detections within the operational area. The web portal superimposed the location of each Saildrone at their current position, tracking history of vessels they detected, and historical tracking data of each drone. The portal also included a tab which organized imagery and tracking data from each detection that allowed the user to see a time lapse of maritime activity around the Saildrones. The portal was also utilized to re-task the Saildrones as they conducted a multitude of missions throughout the demonstration including search pattern execution, picket line formations, station keeping, and other MDA activities.

Figure 2. Saildrone operating in Penguin Bank (left), example detection of 60’ vessel (middle), and example detection of 30’ fishing vessel (right).

3 DETECTION ABILITY

3.1 Spatial Integrated Systems (SIS)

The Watcher was assigned a 20 square mile patrol area 15 miles southwest of Honolulu. *The Watcher’s* radar detection allowed for the USV to detect other vessels from up to 5 miles away and provided each vessel’s approximate coordinates in a report to operators for situational awareness. Additionally, the FLIR camera demonstrated a capability to slew to the radar target and capture images, however this ability was typically only successful when the targets were within four miles of *The Watcher*. The system recorded images every 10 seconds, however it did not possess any AI capability to determine which images should be sent with the alerts and instead would send imagery as it was captured. To conserve bandwidth, the satellite transmission of imagery from *The Watcher* was intermittently turned on just to demonstrate the vessel's capability. SIS will provide full imagery of detections to the RDC after they are downloaded from the vessels hard drive. Upon downloading these images, a more accurate FLIR detection range will be calculated.

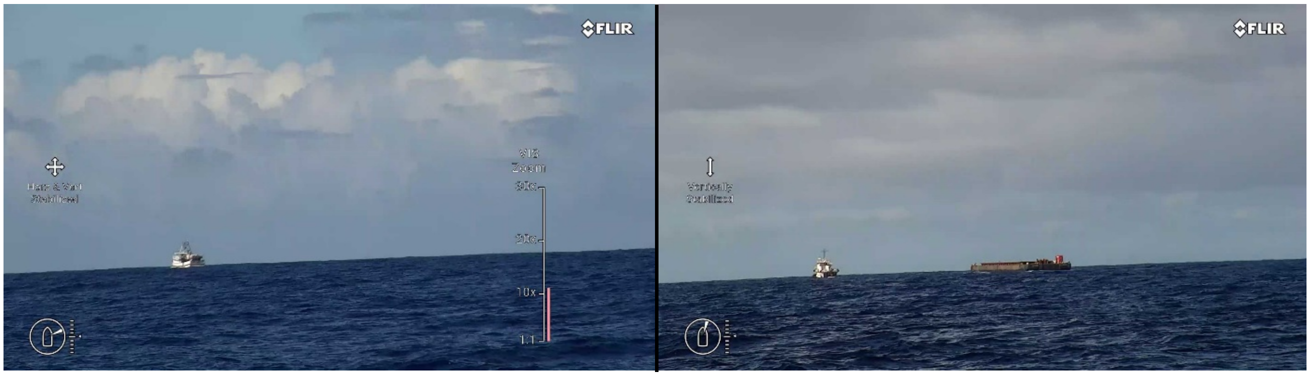

Figure 3. SIS Detection of 60' fishing vessel (left) and detection of tug and barge (right).

Additionally, the FLIR's ability to capture infrared (IR) images at sea was utilized during the demonstration. However, no useful imagery was captured using this technology based on what has been provided to date. After a review of the currently available IR images, no discernible vessel silhouettes could be detected. The lack of clear IR images from this vessel is likely due to *The Watcher* and target vessel movement and exposure lengths. IR cameras require a longer shutter speed durations to capture sufficient infrared light emissions. *The Watcher* was routinely subject to 3-6' waves, and is only 7 meters in length. Larger USVs are more suitable for capturing IR imagery due to their increased stability; stabilized IR cameras are another option but come at significantly increased cost.

3.2 Saildrone

Saildrone was assigned to patrol Penguin Bank, 25 miles southeast of Honolulu. Saildrone's proprietary on-edge visual imagery machine learning algorithms and AI system detected vessels within the images and provided detection alerts, typically within 15-20 minutes of the image being taken. The drones were also capable of detecting vessels based purely on AIS emission and provided tracking and imagery (when visible) of those targets. Tracking, with specific positions, was not available for targets detected by imagery alone as there was no built in range calculation. However it was possible to determine the general direction the vessel was traveling based on the lines of bearing for each detection. If two drones detected a vessel at the same time, the user could use the intersection of the lines of bearing to determine an approximate position of the vessel. The Saildrones were only capable of detecting vessels during the day as they did not have nighttime imaging capabilities due to power constraints. Saildrone demonstrated their ability detecting 40-60' vessels visually within 3-4 nmi. Larger vessels such as tankers could be seen in excess of 5 nmi. Additionally, Saildrone demonstrated their capability of detecting and identifying multiple vessels at the same time, which is useful for identifying at sea transfers. It is noted that the AI vessel detection was capable of sending false alarms and would occasionally misclassify a cloud or shoreline as a vessel detection. Further refining of the AI and machine learning will be required to filter out these false positives.

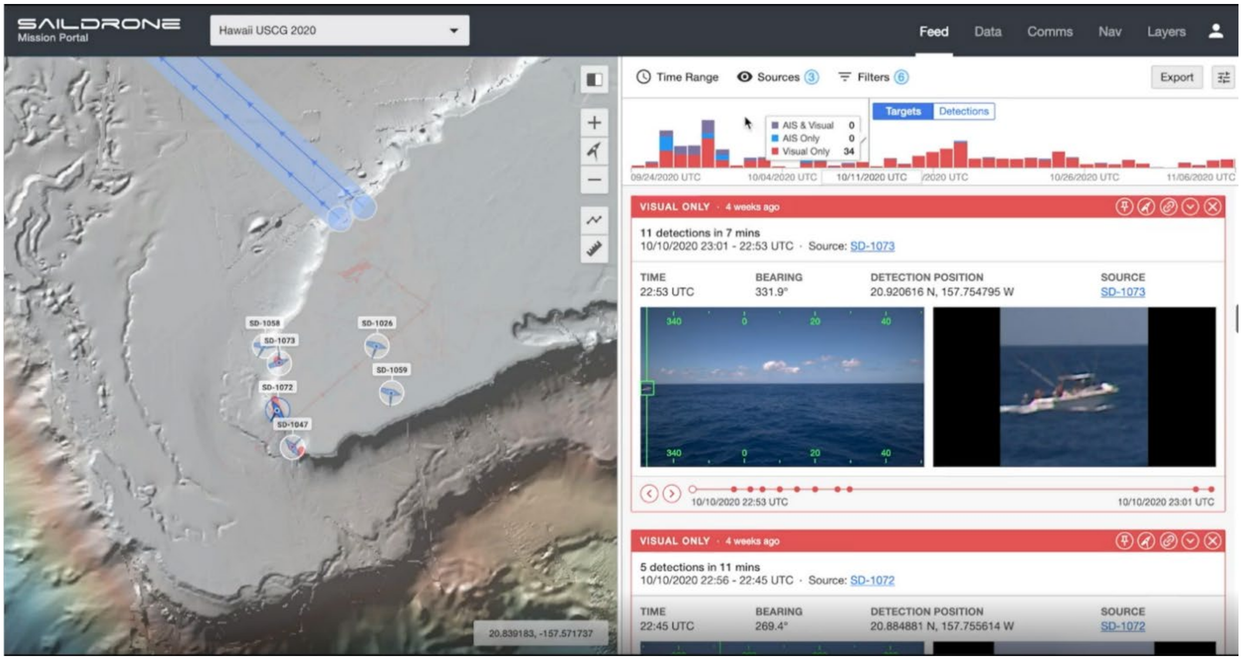

Figure 4. Image of Saildrone's online portal. Left window reports the real time position of each drone while the right window lists detections in a feed.

4 USCG EXPERIMENTAL VESSEL – 29RDC

In an effort to better understand the efficacy of a government owned and operated USV, the RDC purchased the *29RDC*, a 29' autonomous vessel from Metal Shark of Jeanerette, LA to be operate in Hawaii during the demonstration. The base vessel was the same as the USCG RBS-II, but was configured with a SM300 autonomy control system from Sea Machines based in Boston, MA. The SM300 system was designed to allow a vessel to be remotely or autonomously controlled, however the vessel's wheel and throttle remain fully functional, allowing an operator, if present, to take control at the helm if manual operation is desired. The USV was controlled by laptop with Sea Machine's user interface installed on it. To support unmanned operations the vessel was configured with cameras off the bow, stern, and within the cabin for situational awareness. The RDC accomplished dozens of autonomous navigation, search patterns, collision avoidance, and remote control operations. Additionally, the *29RDC* was operated multiple times by RDC watchstanders in New London, CT which demonstrated the vessels ability to be controlled from 5,000 miles away utilizing cellular service.

Figure 5. 29RDC USV underway.

5 CONCLUSION

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Overall, the demonstration showed that commercially available USVs are capable of performing some level of daytime MDA missions and are capable of 30 day endurance missions. Each USV proved its capability to detect other vessels in excess of a mile. Additionally, this demonstration was performed utilizing only one of the potential procurement models for these types of vessels. In lieu of the contractor owned and operated model used for this demonstration, future efforts could consider other modes of acquisition such as government owned/contractor operated, and government owned/government operated. These modes may also depend on how a USV is being used: *The Watcher* brings to mind a potential CG owned and operated cutter boat capable of autonomous operation, while Saildrone routines operates on a service-provider model.

The *29RDC* also provided valuable insight to the demonstration, as it allowed the operational CG a first-hand glimpse into currently available USV technologies and allowed them interactively plan and execute their own missions in real time. The RDC hosted dozens of partners and CG members, from junior enlisted boat drivers to senior officers, on the *29RDC.* These demonstrations provided exceptional feedback regarding how potential operations: using USVs in concert with cutters and other boats as a force multiplier; performance of reconnaissance missions; search and rescue augmentation through autonomously executed search patterns; and screening recreational and commercial vessel traffic. The *29RDC* was not constrained by the requirements for SIS and Saildrone, which allowed the RDC and other demonstration participants an in person experience of how these vessels operate and their potential for future operations.

This demonstration also highlighted the importance of the development and incorporation of AI and machine learning into future USVs. For the purpose of this demonstration, the MDA sensors being used were all capable of and did capture significant amounts of data. To speed processing and limit expensive bandwidth consumption, it is invaluable for the USV to conduct onboard (aka “on-edge”) processing to the greatest possible extent, limiting transmitted data to only that which is actionable to operators. This ability is dependent on the platform’s AI, and is critical to USVs’ success in long endurance and MDA missions.

This demonstration also reaffirmed that the USCG is not alone in its effort to enhance MDA, and CG partners were eager learn more about the USV evaluation. News of this demonstration spread across a multitude of government agencies which resulted in participation from the U.S. Immigration and Customs Enforcement, U.S. Customs and Border Protection, Navy Research Laboratory, Office of Naval Research, National Oceanic and Atmospheric Administration, Scientific Advisors for the US Navy, The President’s Intelligence Advisory Board, and Congress.

Lastly, it was observed that future persistent MDA efforts, enhanced with autonomous USVs, will likely be best with a layered solution. USVs like Saildrone are capable of performing MDA missions for up to a year without maintenance, however their low transit speed does not allow them to pursue a target of opportunity to collect more information. In contrast, *The Watcher* is only capable of 30 days endurance, but has the capability of traveling at speeds in excess of 30 knots and can be instructed to pursue a target upon detection for better imagery. A system where these USVs worked together could prove to be a valuable tool for future MDA capabilities.