ERDC/CHL CHETN-IV-131
April 2024

US Army Corps of Engineers®

Uncrewed Survey-Vessel Conversion

by David A. Nguyen

PURPOSE: The purpose of this study was to investigate the uses of an uncrewed survey vessel to maintain mission readiness of all federal navigation channels and ports. Developing an uncrewed survey vessel capable of collecting data in a riverine environment may increase the efficiency and resiliency of the US Army Corps of Engineers (USACE) missions and USACE districts to conduct surveys during post natural disasters and pandemics. This document describes the installation, enhancement, and modification of the commercial-off-the-shelf (COTS) system, the Sea Machines SM300, on a US Army Engineer Research and Development Center (ERDC) survey vessel to create a semiautonomous survey capability.

INTRODUCTION: Hydrographic surveys are vital datasets for the validation of numerical models, monitoring of current channel conditions, and many other applications to support USACE districts. USACE is responsible for keeping all federal navigable channels and ports open for safe commercial operations. Some USACE districts conduct high-frequency surveys in areas such as Southwest Pass, Louisiana. The bathymetric datasets collected are used for future planning of dredging projects and identifying potential shoaling locations. The duration time of these surveys can produces a high-risk environment for the survey crew in which vessel operators are induced to fatigue, complacency, and environmental hazards. Research is being conducted to expand and revolutionize the USACE hydrographic surveying capabilities with the addition of a full-size optional crewed and uncrewed survey vessel. This would enable USACE to become more efficient in surveying and resilient in respect to high-risk missions and pandemics. A COTS system was purchased that includes semiautonomous features such as waypoint navigation, object avoidance, collaborated following and manual remote operation. This system, like many of its kind, was intended for mainly open-ocean and coastal environments. This COTS system was integrated into an existing ERDC vessel, allowing for the ability to evaluate and modify the current system capabilities to conduct inland waterway surveys. Additional research and development is needed to expand current capabilities and tailor the system to USACE requirements. There are many areas that need improvement before this vessel can be operated fully autonomous such as small object detection, machine learning (ML) / artificial intelligence (AI)–generated survey missions, operational and safety regulation, and automated vessel failure procedures.

This document focuses on the installation of the SM300 system by Sea Machines Robotics (SMR) (Sea Machines Robotics, Boston, Massachusetts; *https://sea-machines.com/*) for the development of an uncrewed riverine survey vessel. This content is focused on the key components installed to allow the SM300 to operate.

BACKGROUND: Advancing the capabilities within USACE to survey autonomously could increase productivity and safety of survey missions. USACE is responsible for conducting post-hurricane surveys to ensure safe transit for all federal navigation channels as well as conduct daily channel condition surveys to keep the transportation industries up to date on the current channel conditions. These surveys provide preplanning data for future dredging projects and track shoaling to keep the maritime transportation industry operational. These survey missions require significant

amounts of labor and cost. In an effort to reduce cost of these surveys, the ERDC Coastal and Hydraulics Laboratory (CHL) Research Vessel (R/V) *MARTIN* was converted to perform semiautonomous operations.

VESSEL DESCRIPTION: The R/V *MARTIN* is a Response Boat Small 25 ft* (RBS25) vessel built by Safe Boat International (Safe Boat International, Bremerton, Washington; *https://safeboats.com/*) (Figure 1). This vessel was a US Coast Guard patrol vessel that was decommissioned in 2009 and acquired by ERDC-CHL shortly thereafter. The RBS25 is a surface vessel with a beam width of 8.5 ft and an operational weight of 9,710 lb. This vessel can be transported on the highways without any special permits and shipped via sea or air. The vessel is powered by two gasoline 225 Honda outboards, for a total of 450 hp and a top speed of 48 kn. A 100 gal. fuel tank with foam bottom gives this vessel a max range of 170 nautical miles at 30 kn. The structure of the vessel is aluminum with a 100% reinforced foam-collar system.

Figure 1. US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL), Research Vessel (R/V) *MARTIN*.

SEMIAUTONOMOUS SYSTEM: The SM300 by SMR was designed for open-ocean operations. The principal users of the system are cargo ships and other marine transportation companies. SMR manufactures two systems, one being the SM200 that is a teleoperated system, which is remote control only and does not have object detection and object avoidance (OD/OA) capabilities. The other is the SM300 that is the complete package that has OD/OA, waypoints navigation, and collaboration following modes (Figure 2). The OD/OA mode within the SM300 enables the vessel automatically to detect and avoid obstacles in the planned path. The waypoint navigation mode

* For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–347, respectively. *https://www. govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf*.

enables the user to create point to point navigation parameters. The collaborative following mode enables the user to set a vessel offset for the semiautonomous vessel to follow the leader vessel, which creates a force multiplier during survey operations. The SM300 requires data inputs such as GPS position, rudder position, throttle, navigations chart, and a radar. It also utilizes available Electronic Navigation Charts (ENCs) and Inland Electronic Navigation Charts (IENCs) for mission planning. The ENCs and IENCs meta data layer for sail lines, depths, and structures is used as additional parameters for safe operations. During initial sea trials, the SM300's source code was modified for testing at Eagle Lake, Mississippi. The danger-zone code line was set to *false* as that function is to prevent the vessel from operating in shallow depths and outside sail line areas.

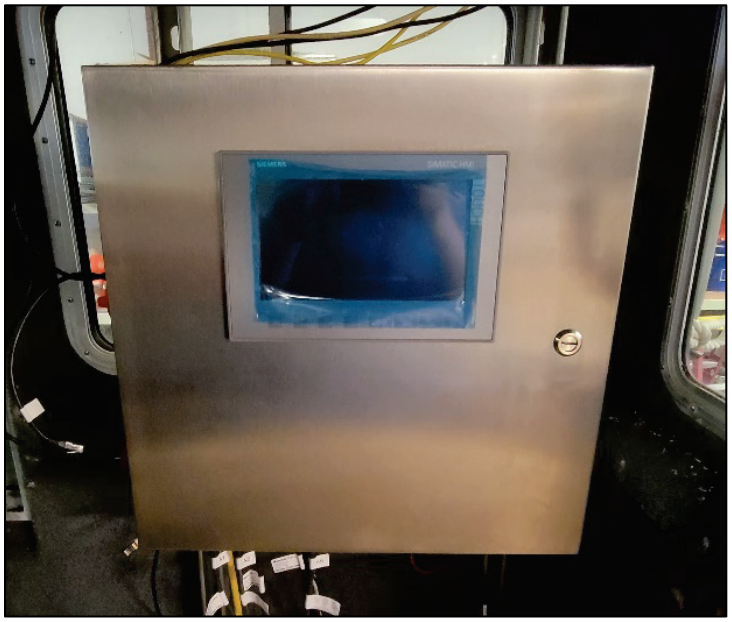

Figure 2. Sea Machines SM300.

UPGRADES BEFORE SM300 INSTALLATION: The R/V *MARTIN* required some vessel upgrades to the operational side before the SM300 could be installed. The SM300 controls the vessel operations with programmable logic controllers (PLCs) through the transmission of digital signals. However, due to the age of the vessel, many key components were operated manually, such as the throttle controls and the no-assisted steering. These components were updated and the marine electronics replaced to make them compatible with the SM300 controls.

The first upgrade was the throttle controls for the outboard motors; these older outboards were operated by a manual cable system unlike newer models that are all electronic fly-by-wire (FBW) interface systems. The FBW system controls the inputs transmitted to the processing computer to determine the electrical signal provided for actuators to function properly. A SeaStar Solutions (SeaStar Solutions, Litchfield, Illinois) i7800 mechanical cable to electronic actuator throttle system was installed (Figure 3). This was the most economical solution in comparison to purchasing new outboard motors, but there is the possibility of failure of the actuator cable. All the vessel mechanical and electrical components should be inspected and checked at the beginning of each operation.

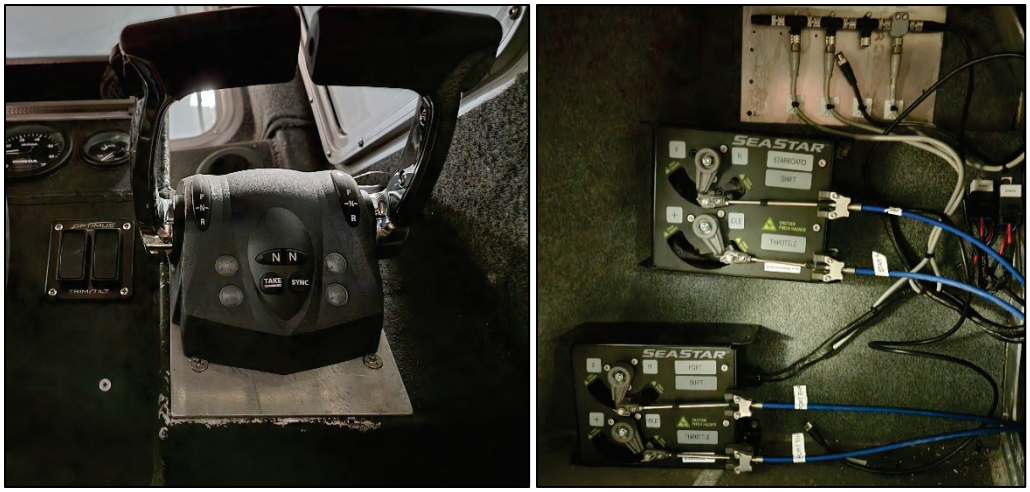

Figure 3. SeaStar Solutions i7800.

The second upgrade was to the steering system because it did not have an electric hydraulic motor but had a manual hydraulically assisted steering system. For the SM300 to operate uncrewed, a Simrad (Simrad Yachting, Apalachicola, Florida; *https://www.simrad-yachting.com/*) auto pilot hydraulic reversible pump with a Maxon (Maxon, Switzerland; *www.maxongroup.com*) electronic motor controller was added to interface with the SM300's PLC (Figure 4). To account for the rudder angle position, a SeaStar Solutions Smart stick was installed on the steering linkage to provide rudder angle feedback data to the SM300 (Figure 5).

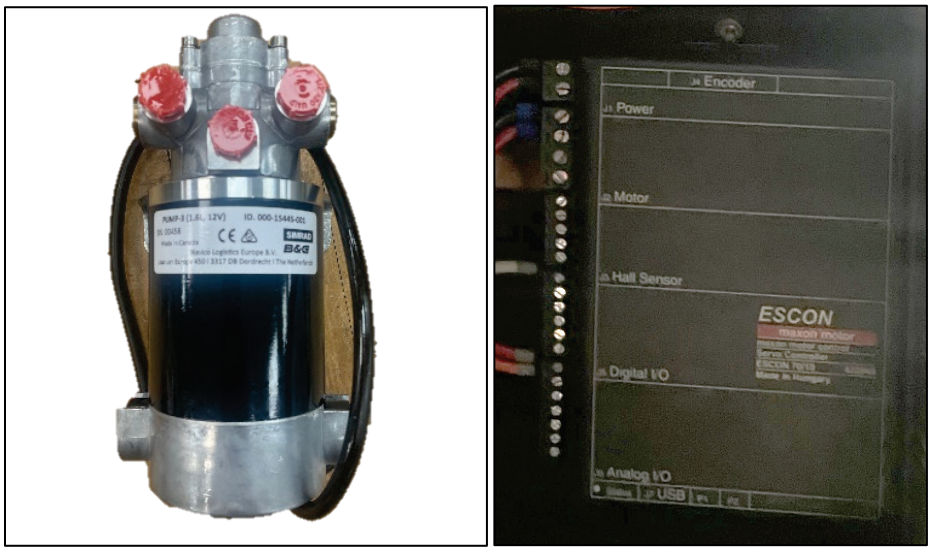

Figure 4. Simrad hydraulic pump and Maxon motor controller.

Figure 5. SeaStar Solutions Smart Stick.

POSITIONING AND OBJECT DETECTION SYSTEM: The SM300 uses the positioning and object detection data from a Furuno (Furuno, Nishinomiya, Hyogo, Japan; *https://www.furuno.com/en/*) DRS4D-NX radar, TZTL12F multifunctional touch processor and Applanix (Trimble Applanix, Richmond Hill, Canada; *https://www.applanix.com/*) Wave Master II Inertial Measurement Unit (IMU)/GPS unit. The SM300 utilized the position and heading from an Applanix Wave Master II IMU/GPS. To stay in compliance with any future DoD GPS equipment regulations, SMR modified the SM300 to accept the positioning messages from a Trimble/Applanix GPS system string at 5 Hz to better handle river currents and eddies instead of the standard 1 Hz rate that is suitable for open-ocean environments. The GPS data collected are captured from the National Electrical Manufacturers Association 2000 backbone, this is the data interface between all the Furuno equipment on board the vessel (Figure 6).

The SM300 currently utilizes the onboard radar for OD/OA. The Furuno radar creates an automatic radar plotting aid target that provides the trajectory of a moving object. This target information is ingested into the SM300's AI/ML algorithm for determining the safest path around the object. During sea trials, the radar captures objects within 0.5 nautical miles of the vessel; these objects included channel buoys, banks, and medium-sized vessels. There is also an automatic identification system (AIS); this adds a secondary layer to the OD/OA function. An AIS is typically installed on commercial vessels to track their position and heading; each vessel is assigned its own nine-digit number called Maritime Mobile Service Identities (MMSI). The R/V *MARTIN*'s MMSI is ignored by the SM300 so that the vessel would not attempt to run away from itself.

A third layer of OD/OA is being added to the SM300 in fiscal year 2023 (FY23) and FY24. This layer will utilize a camera-based OD/OA system with a computer vision algorithm that will identify any known objects in view and determine the vessel's path to avoid the obstacle. Since the current model used for the system is for open-ocean environments, ERDC will collect 500,000 images in FY23 and early FY24 to begin the riverine image database. SMR will be classifying the images and creating the riverine model. Once complete, the model would be installed on the SM300 by the field team from Sea Machines. ERDC will use Eagle Lake as a controlled testing location for the newly updated OD/OA algorithm. Some example objects that will be used are smaller 8 in. buoys, wood logs, 8 ft johnboat, etc. Once the capability is confirmed, further tests will be conducted in different riverine environments.

Figure 6. Furuno display and radar.

COMMUNICATIONS: The user can control, plan, and observe everything on the vessel through a cellular network modem. A Cradlepoint (Cradlepoint, Boise, Idaho; *https://cradlepoint.com/*) 4G cellular modem was installed for remote users from anywhere in the world. There are some limitations to this method such as 4G cellular coverage in remote areas. The system can utilize an Iridium service, but due to cost, this was not tested. An Ubiquiti (Ubiquiti, New York, New York; *https://www.ui.com/*) internet protocol radio is used for the vessel-to-vessel communication for collaborative following mode. The vessel does have a secured radio connection for operating and transferring data. This radio system is the MPU5 by Persistent Systems (Persistent Systems, New York, New York; *https://www.persistentsystems.com/*), which is a 256-bit encryption radio that is capable of streaming four 4K videos. The MPU5 is the same system used by armed forces.

SM300 USER INTERFACE: A user interface (UI) is operated for the command and control of the SM300 (Figure 7). The UI allows the user to switch on or off any onboard devices that are connected to the relay control box (Figure 8). The user can create the survey mission with embedded tools in the UI or create the survey mission with HYPACK (HYPACK, A Xylem Brand, Middletown, Connecticut; *https://www.hypack.com/*) planned-lines editor. Currently, the ingestion of a HYPACK line will allow the survey software to start and stop the survey automatically. All missions are saved on board so they may be repeated easily and efficiently. The UI also displays the onboard cameras for the remote user's situational awareness. Upgrades to UI are planned for FY23, including the use of go/no-go boundaries.

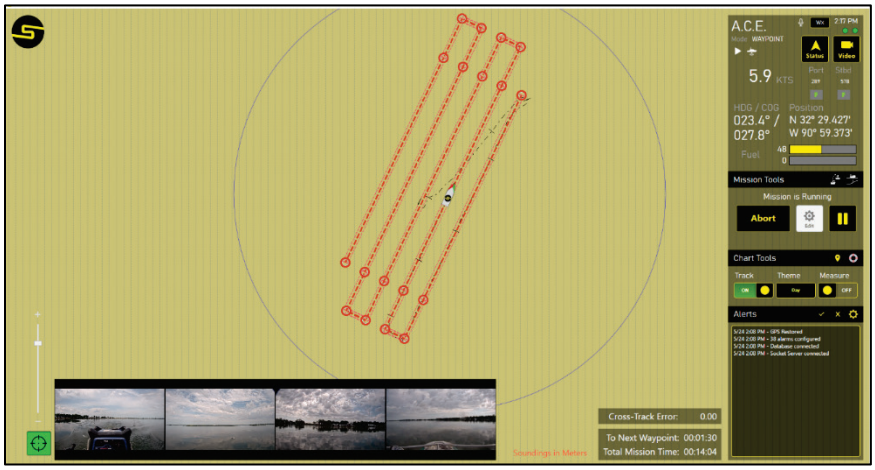

Figure 7. SM300 user interface (UI).

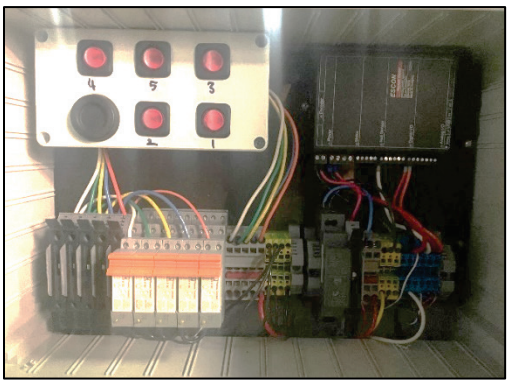

Figure 8. Relay control box.

The SM300 system has the capability to conduct collaborative following, which consists of a mothership, or crewed vessel, and child ship, or uncrewed vessel. The user sets the operational parameters in the UI for the child ship to follow the mothership. To date, this feature was only tested at a survey speed of 7 knots (Figure 9). This feature may increase productivity for survey missions by extending the coverage while reducing the time required to conduct a mission, by having multiple vessels that are controlled by one survey team.

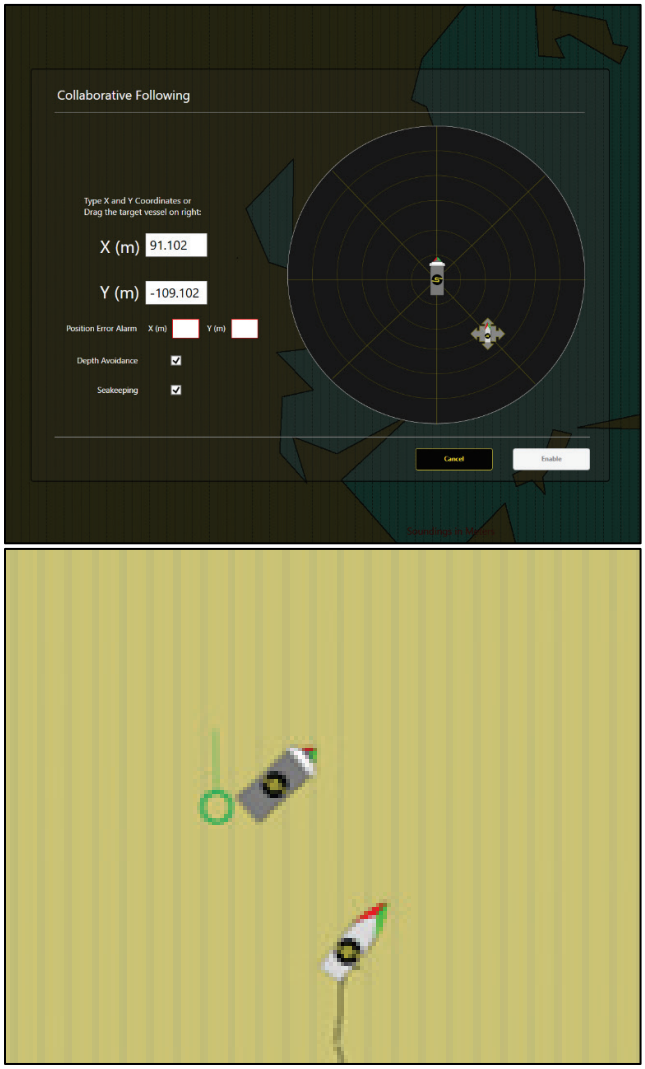

Figure 9. Collaborative mode.

CONCLUSION: This Coastal and Hydraulics Engineering technical note (CHETN) details the Field Data Collection and Analysis Branch's efforts to develop a semiautonomous vessel for data collection in the riverine environment. A semiautonomous vessel would expand the current surveying capability within USACE. This advancement, once fully operational, will increase the efficiency of current methods for collecting bathymetric data within USACE. An additional benefit of this system would be a reduction in operator fatigue during extended collection durations or rough-sea states. Upcoming capabilities demonstrations are planned at various USACE districts to build the end-user comfort levels towards uncrewed systems. Moving forward, the Field Data Collection and Analysis Branch team intends to use the semiautonomous vessel during survey

mission to document the efficiency and capability of the system. Additionally, this vessel would be an ideal platform to test and evaluate newer technologies and operating procedures.

ADDITIONAL INFORMATION: This CHETN was prepared by Mr. David A. Nguyen, research civil engineer, ERDC-CHL, Vicksburg, Mississippi. The study was funded by the USACE Navigation Systems Research Program. Questions about this CHETN can be addressed to Mr. David A. Nguyen at 601-634-3403 or *David.A.Nguyen@usace.army.mil*.

This CHETN should be cited as follows:

> Nguyen, David A. 2023. *Uncrewed Survey-Vessel Conversion*. ERDC/CHL CHETN-IV-131. Vicksburg, MS: US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.