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Marine Investigation Report MIR-26-32

Collision Between National Oceanic and Atmospheric Administration Uncrewed Surface Vessel and Prestige 450 Flybridge Recreational Vessel

Lake Erie

6 miles east-southeast of Monroe, Michigan

August 10, 2024

Abstract: This report discusses the August 10, 2024, collision between a National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory (GLERL) uncrewed surface vessel (USV) and a 45-foot long recreational vessel on Lake Erie near Monroe, Michigan. Safety Issues identified in this report include the inadequate perceptibility of the GLERL USV, and the inadequate monitoring of the GLERL USV given the vessel's configuration, mode of operation, and level of autonomy. As part of its investigation, the National Transportation Safety Board makes six new safety recommendations to the US Coast Guard, the National Oceanic and Atmospheric Administration, and SeaTrac Systems, Inc.

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Acronyms and Abbreviations

Abbreviation	Name
AIS	automatic identification system
AL	autonomy levels
ASV	autonomous surface vessel
CFR	<i>Code of Federal Regulations</i>
COTP	Captain of the Port
CPA	closest point of approach
ESP	environmental sample processor
GLD	Great Lakes District
GLERL	Great Lakes Environmental Research Lab
IMO	International Maritime Organization
MASS	Maritime Autonomous Surface Ships
MASS Code	<i>International Code of Safety for Maritime Autonomous Surface Ships</i>
MSIB	Marine Safety Information Bulletin
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
NVIC	Navigation and Vessel Inspection Circular
PMEL	Pacific Marine Environmental Laboratory
TCPA	time to closest point of approach
USC	<i>United States Code</i>

Abbreviation	Name
UMS	uncrewed marine systems
USV	uncrewed surface vessel

Executive Summary

What Happened

On August 10, 2024, about 1912 local time, a National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Lab (GLERL) SeaTrac SP-48 uncrewed surface vessel (USV) and a privately owned 45-foot-long Prestige 450 Flybridge recreational vessel collided while underway in Lake Erie, 6 miles east-southeast of Monroe, Michigan. The USV became fouled in the recreational vessel's starboard propeller pod, and the two vessels were towed conjoined to a nearby marina and later separated. No pollution was reported. One minor injury was reported. The USV was considered a total constructive loss valued at an estimated \$186,000. Damage to the recreational vessel was estimated at \$100,000.

What We Found

GLERL operated the SeaTrac SP-48 USV in an area offshore frequented by recreational vessels. The vessel was about the size of a small recreational vessel (15.7 feet long) and designed with only about a foot of its hull visible once in the water. Given these conditions, it would have been difficult for operators of other vessels to perceive the USV. Additionally, the USV likely could not be perceived by recreational vessels via electronic means, such as radar or an automatic identification system, nor did it have auditory means to signal its presence to other vessels. We found that, given the USV's area of operation, the vessel's visual, electronic, and auditory perceptibility were inadequate. Had GLERL tested the USV's perceptibility to operators of other vessels typically in the USV's area of operation, GLERL could have identified the USV's inadequate perceptibility and determined that the USV was a navigational hazard for surrounding vessel traffic.

At the time of the collision, there were no industry-wide perceptibility standards specific to USVs operating in US inland and territorial waters. We found that additional standards are necessary to enhance and ensure the perceptibility, collision avoidance capability, and navigational safety of USVs.

GLERL operated the USV in "adapted hold" mode, wherein the USV would automatically move back to set waypoints if it drifted outside a 150-foot radius set by the pilot. When the vessel was in adapted hold mode, the pilot passively monitored the vessel. We found that this configuration and operation of the USV without active monitoring left the USV without a proper lookout. Combined with the USV's

inadequate perceptibility, the lack of proper lookout rendered the USV vulnerable to collision in the area where it was operating.

When the USV was in adapted hold mode, GLERL passively monitored the vessel, relying on the USV to automatically maintain the waypoints set by the pilot. The USV could not calculate decisions regarding navigation or operational action and thus could not take appropriate action to avoid a collision. We found that, given the USV's low level of autonomy in adapted hold mode, GLERL's monitoring of the USV was not sufficient to safely operate it in an area offshore frequented by recreational vessels.

We determined that the probable cause of the collision between the NOAA GLERL USV and recreational vessel was the inadequate perceptibility of the USV to nearby vessels, given the operating area and conditions, and the lack of active monitoring given the vessel's configuration, mode of operation, and level of autonomy, which left the USV without a proper lookout to avoid a collision.

What We Recommended

We issued five recommendations to enhance the perceptibility of USVs. We recommended SeaTrac, the manufacturer of the GLERL USV, modify the design of its model SP-48 USVs to further enhance their perceptibility as practicable given the nature of the USV's work and area of operation. We also recommended that NOAA revise its internal policies contained within its "Uncrewed Marine Systems Manual" to ensure its USVs are perceptible, and to incorporate a requirement for testing USVs to ensure each USV is adequately perceptible to operators of other vessels typically in the USV's area of operation. We further recommended that the US Coast Guard develop and promulgate a national framework of perceptibility, collision avoidance capability, and navigational safety standards for USVs and incorporate these standards into regulations.

Finally, we recommended that NOAA require its USVs be monitored at a level commensurate with the USV's actual level of autonomy, factoring the vessel's area and mode of operation.

1 Factual Information

1.1 Event Sequence

1.1.1 Synopsis

On August 10, 2024, about 1912 local time, a National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Lab (GLERL) SeaTrac SP-48 uncrewed surface vessel (USV) and a privately owned 45-foot-long Prestige 450 Flybridge recreational vessel collided while underway in Lake Erie, 6 miles east-southeast of Monroe, Michigan (see figure 1).¹ The USV became fouled in the recreational vessel's starboard propeller pod, and the two vessels were towed conjoined to a nearby marina and later separated. No pollution was reported. One minor injury was reported. The USV was considered a total constructive loss valued at an estimated \$186,000. Damage to the recreational vessel was estimated at \$100,000.



Figure 1. Left to right: Prestige 450 Flybridge recreational vessel and NOAA USV underway before the collision. (Sources: Recreational vessel owner [left] and NOAA [right])

¹ (a) In this report, all times are eastern daylight time, and all miles are statute miles. (b) Visit [nts.gov](https://www.nts.gov) to find additional information in the [public docket](#) for this NTSB investigation (case no. DCA24PM057). Use the [CAROL Query](#) to search investigations. (c) The NTSB investigated this casualty in accordance with [Title 49 Code of Federal Regulations \(CFR\) 850.15\(b\)\(2\)](#), which requires the NTSB to conduct an investigation of any casualty involving a public vessel and a nonpublic vessel resulting in at least \$75,000 in damages and/or one fatality. In this casualty, the GLERL USV was a public vessel, and the Prestige 450 Flybridge recreational vessel was a nonpublic vessel.

1.1.2 Event Narrative

On August 9, 2024, GLERL's 15.7-foot-long SeaTrac SP-48 USV was operating in Lake Erie.² The USV was located at what GLERL staff referred to as the "WE08" site—a position that GLERL used for sample collection—in Lake Erie, about 2.6 miles off Valencia Beach, Michigan.³ The USV housed a scientific payload in the form of a miniaturized third-generation environmental sample processor (ESP) capable of collecting water samples, testing the samples, and sending the data to the user in near real time.⁴ GLERL used this data to monitor harmful algal bloom microcystin toxins in western Lake Erie. The ESP had been used in the USV's missions since 2022.⁵

Throughout the day, the SeaTrac SP-48 USV was remotely controlled by a number of GLERL employees serving as a "pilot," from either the GLERL facility in Ann Arbor, Michigan, or the pilot's personal residence, depending on the day of the week and time of day.⁶ Pilot rotations were split into 4-hour shifts (for example, midnight to 0400, 0400 to 0800, or 0800 to 1200), which the pilots signed up for.

The vessel had three operational modes—manual, mission, and hold—which established operating parameters and logic behaviors for the vessel. GLERL also operated the USV using mission mode to achieve a hold pattern, referred to in this

² GLERL conducts research on "the dynamic environments and ecosystems of the Great Lakes and coastal regions to provide information for resource use and management decisions that lead to safe and sustainable ecosystems, ecosystem services, and human communities." See [NOAA Great Lakes Environmental Research Laboratory](#).

³ The "WE08" site was the name GLERL staff gave to the position where the WLE08 buoy was typically deployed.

⁴ The ESP could be configured to sample either by command—typically sent by one of the scientists managing the ESP, not the pilot—or based on a pre-programmed time. Mission logistics, including the ESP sampling schedule, were coordinated between the pilot and ESP controller.

⁵ Monitoring began in 2017 using earlier-generation environmental sample processors, which remained stationary after being deployed. See [ESP: NOAA Great Lakes Environmental Research Laboratory—Ann Arbor, MI, USA](#).

⁶ The term "pilot" is synonymous with "remote operator" in this report, due to the unique vernacular adopted for USV operations. The pilots did not hold any specialized credentialing (Federal Aviation Administration or US Coast Guard) for USV operations.

report as “adapted hold” mode (see section 1.5 for more information about the USV’s appearance and operational modes).⁷

About 1143, the USV pilot remotely initiated a mission, prompting the vessel to travel 2.3 miles to a collection site 0.3 miles off Valencia Beach. The sample collection was initiated via the ESP when the vessel arrived on site at 1356.

About 1538, the sampling was complete. The pilot initiated another mission, and the vessel transited back to the WE08 site. After the USV arrived at the site at 1620, the pilot set the vessel to adapted hold mode. In adapted hold mode, the pilot created a mission with multiple waypoints at the same location, selected each waypoint’s behavioral type as “hold,” and set a timeframe for each “hold” waypoint to keep the USV within a fixed area. While the USV was in adapted hold mode, the pilot monitored the system using the manufacturer’s human machine interface, or “dashboard” (see section 1.5.1).

The USV remained in adapted hold mode within a 150-foot radius of the WE08 site on the evening of August 9 and throughout the day of August 10.⁸ The USV’s settings were such that when the USV drifted outside the 150-foot radius, it would automatically move back to the WE08 site location, where the pilot had set the USV’s hold position.⁹

According to the GLERL director at the time, the WE08 site was “the closest and safest location with existing GLERL assets in that location [near a second-generation ESP and its buoy marker—referred to in this report as the “NOAA buoy”], as well as a buoy [WLE08] noted in the charts.” The WLE08 buoy was not physically deployed at the WE08 site until August 13, 2024, and was not on station when the

⁷ The USV manufacturer’s data sheet for the USV listed the modes of operation as manual, supervised autonomy, and full autonomy (SeaTrac 2021) (see section 1.5.4). According to the SeaTrac cofounder, the USV was “uncrewed,” not “autonomous,” and instead referred to the modes as manual, mission, and hold, respectively. This report describes the modes of operation as the SeaTrac cofounder did.

⁸ The USV was scheduled to complete a follow-up mission on the morning of August 10. However, this mission was cancelled at 1000 because, according to the GLERL team, “winds would not allow for an effective science mission” until August 11.

⁹ The coordinates for the vessel to maintain at the WE08 site were 41°50.081’ N, 83°21.339’ W.

USV arrived at the site.¹⁰ GLERL staff were aware that the WLE08 buoy was not on station at the time.

The NOAA buoy marked the location of the second generation ESP. The yellow, cylindrical foam buoy was about 15 inches in diameter, with about 1 foot of foam above the waterline. The NOAA buoy was equipped with a yellow light with a 4-second flash pattern, and a 7-foot fiberglass pole with an orange flag (18 by 18 inches) mounted on top. The buoy also had an antenna to transmit environmental data to the shore station. According to a GLERL contractor, who had served as a research vessel captain for GLERL for 8 seasons, the NOAA buoy marker was not used as a center point for the USV's hold location due to the risk of the USV and buoy getting "snagged."

When the pilot set the USV to adapted hold mode at 1620, the USV was about 275 yards from the NOAA buoy (see figure 2).

¹⁰ The buoy was on station from June 2 to October 11, 2023, and present while GLERL conducted its 2023 deployment.

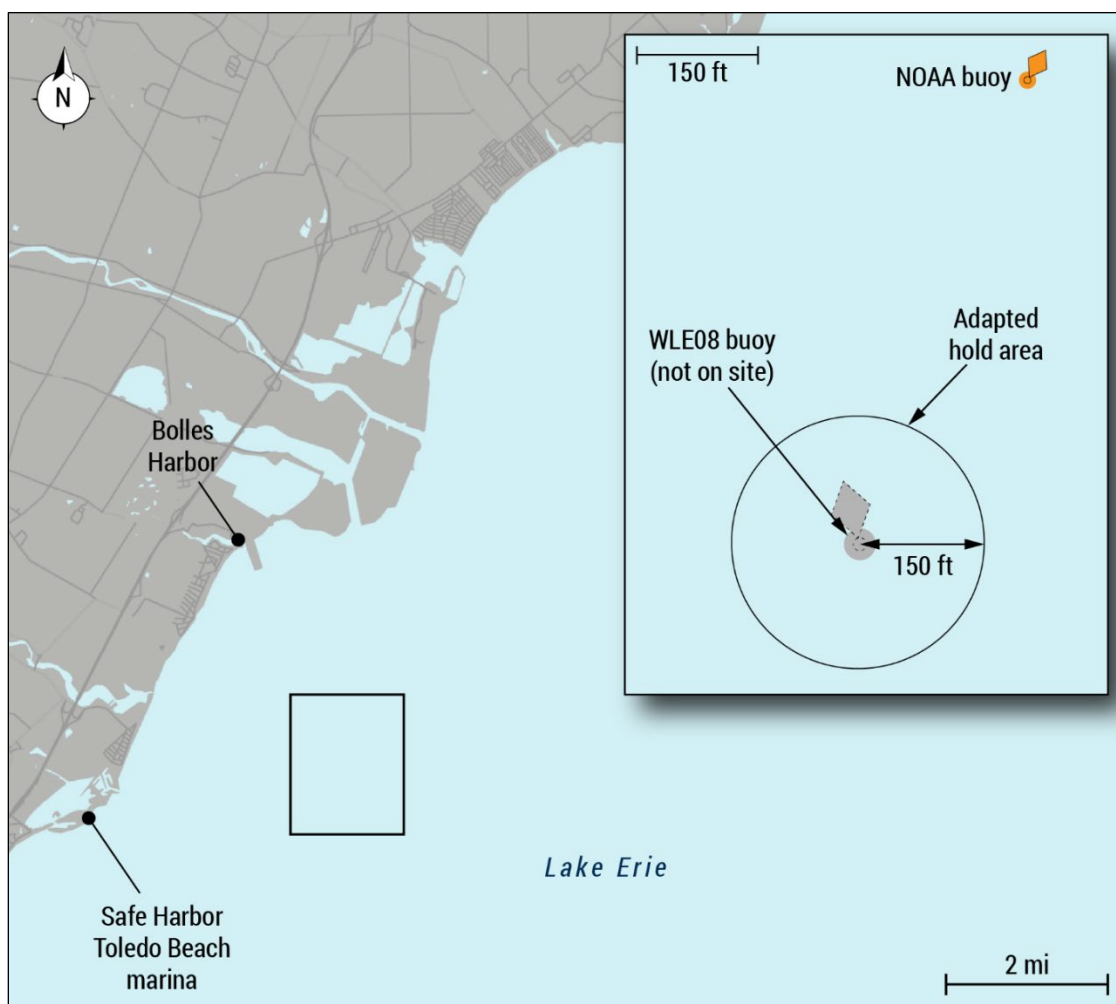


Figure 2. Approximate WLE08 buoy and NOAA buoy locations relative to adapted hold area. (Background source: Google Maps)

Meanwhile, on the afternoon of August 10, the owner of a 45-foot-long Prestige 450 Flybridge recreational vessel was preparing to depart Safe Harbor Toledo Beach marina in LaSalle, Michigan, with one passenger (his nephew) to “enjoy the day” on the water. The Prestige 450 Flybridge’s propulsion and steering were provided by two 435-hp engines that each drove forward-facing propellers mounted on an azimuthing pod underneath the hull.¹¹ The vessel was also outfitted with a bow thruster.

¹¹ The Volvo Penta inboard performance system aboard the recreational vessel used forward-facing, twin counter-rotating propellers in steerable azimuthing pods, which, according to the manufacturer, significantly improve a boat’s efficiency, speed, handling, and onboard space compared to traditional shaft-driven inboards. Each pod could spin 360° and provided variable thrust in any direction, eliminating the need for a rudder.

About 1800, the owner/operator got the recreational vessel underway with his nephew aboard. From the vessel's conning station, or cockpit (located on the starboard side interior), he maneuvered the recreational vessel toward Toledo Harbor Lighthouse and the Toledo Harbor Entrance Channel, testing the functionality of the vessel's autopilot and overall performance while transiting. The operator recalled that waves were "strong enough that going with the waves, [he] deployed [his] full trims [tabs] down to see if [he] could soften the waves."

While underway, the operator observed a freight vessel underway inbound in the channel. The operator maneuvered the vessel in the direction of the freight vessel, then idled the vessel to watch the vessel's transit inbound.

After observing the freight vessel, the Prestige 450 Flybridge operator continued underway. The operator initially headed west toward Bolles Harbor and Monroe Harbor but then decided to return to Safe Harbor Toledo Beach marina. He altered the vessel's course to port so that it was on a heading directly to the marina and operated the vessel using hand steering (rather than autopilot, as he had done on the outbound transit).

About 1912, the Prestige 450 Flybridge was on a southwest heading, about 240°, at a speed of about 25 mph when it struck an object. The operator told investigators that there were no other vessels, buoys, or objects in the immediate vicinity of the vessel at this time, and "there was nothing there that we would have hit" (see figure 3).¹²

¹² The NOAA contractor who had served as a research vessel captain for GLERL told investigators that the GLERL science staff overseeing the ESP operations were having issues with the equipment due to prevailing environmental and waterway conditions at the time (see sections 1.6 and 1.7). The GLERL science staff requested that the GLERL USV conduct a check of the buoy marker to confirm if it had been hit or if there was a damaged antenna. The GLERL USV pilot team declined the request due to the risk of entanglement with the buoy.

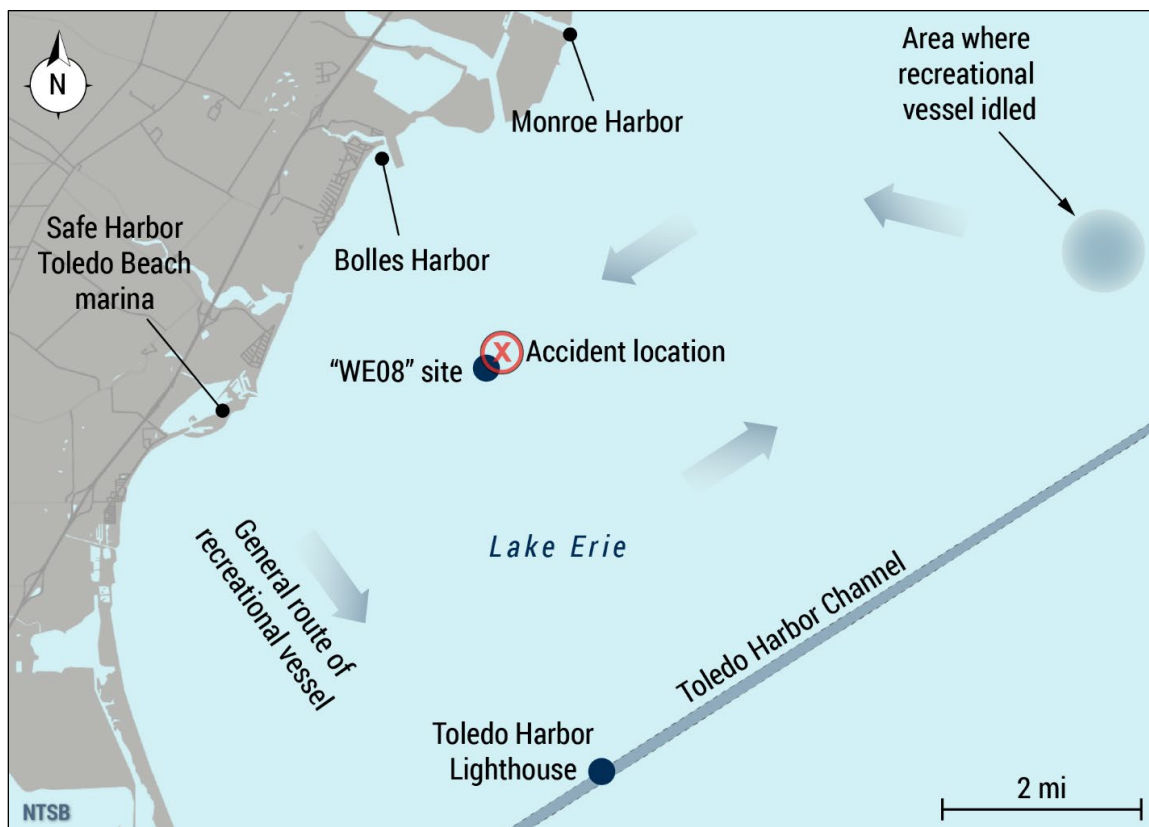


Figure 3. Location of WE08 site and where the recreational vessel operator idled to observe a freight vessel in the Toledo Harbor Channel. The casualty location, near WE08 station, is marked with a circled X. (Background source: Google Maps)

One of the recreational vessel's two propeller pods abruptly stopped, and the other propeller pod continued at the same throttle demand (rpm) before impact. The vessel rapidly heeled, and this abrupt motion threw the operator from the conning station to the deck near the centerline of the vessel. The operator pulled himself up, grabbed the helm, and reached for the throttles immediately. He successfully positioned both throttles in the stop position, then contacted a towing service for assistance.

The operator and passenger immediately checked for flooding, but they did not find water coming into the vessel. While assessing the vessel and looking for the cause of the impact, the passenger found "something" in the water and called the operator over to take a look. The operator recalled, "It was a two-foot square panel of solar panels." The object had fouled the recreational vessel's starboard propeller pod, so the operator was "unable to move" the vessel. The operator discovered the object was a vessel and realized the recreational vessel had collided with another vessel (see figure 4). He immediately called the US Coast Guard to report the incident.



Figure 4. Prestige 450 Flybridge and GLERL USV conjoined after the collision. (Source: NOAA)

About 1946, the GLERL lead engineer, who was serving as the pilot of the USV at the time (1600 to 2000 shift from his personal residence), received a phone call from Coast Guard Sector Detroit inquiring about the deployment status of the “yellow autonomous vessel.” The lead engineer confirmed the vessel was deployed and provided the last known coordinates, the same coordinates as the hold position at the WE08 site. Given this information, the Coast Guard confirmed that the recreational vessel and GLERL’s USV were involved in an “incident.” (GLERL staff were unaware the USV had been involved in an incident before this time.)

By this time, the towing service the Prestige 450 Flybridge operator had called was on scene assisting the recreational vessel. While the towing service was on scene, the Prestige 450 Flybridge operator and towing service staff determined the vessel would not be able to safely transit to the operator’s slip at Safe Harbor Toledo Beach marina. According to the operator, “the [USV] was strongly attached under [the] hull,” and they “were unsure if it could clear [the] harbor entrance depth.” Instead, the conjoined vessels were towed to Coast Guard Station Toledo that night to be separated.

The following day, on August 11, a towing service towed the conjoined vessels from Coast Guard Station Toledo to Safe Harbor Toledo Beach marina at the request of the Prestige 450 Flybridge's operator. The conjoined vessels were taken to a dock at the Safe Harbor Toledo Beach marina (not the recreational vessel operator's slip). The towing service notified the GLERL lead engineer that they planned to haul the vessels out of the water at 1100 on August 12.

On August 12, GLERL staff and the Prestige 450 Flybridge operator were joined by members of the LaSalle Michigan Fire Department, the Monroe County Sheriff, Safe Harbor Toledo Beach staff, US Customs and Border Protection, and two vessel towing services to separate the USV and recreational vessel (see figure 5). About 1030, separation of the conjoined vessels began. The scientific payload on board the USV was recovered and returned to the GLERL laboratory. All remaining pieces of the USV were recovered by 1600.



Figure 5. Recreational vessel and GLERL USV hauled out of the water, with the USV split into two large pieces and fouled in the recreational vessel's starboard pod. (Source: Monroe County Sheriff)

1.2 Injuries

The Prestige 450 Flybridge operator reported a minor injury to his foot resulting from the collision. Table 1 shows the injuries sustained in the collision.

Table 1. Injuries sustained in the collision.¹³

Type of Injury	GLERL USV	Prestige 450 Flybridge	Total
Fatal	0	0	0
Serious	0	0	0
Minor	0	1	1
None	0	0	0

1.3 Damage

As a result of the collision, the USV's fiberglass hull was split into two pieces (the forward and aft hull sections remained), and the wiring for the vessel's systems was compromised (see figure 6). The ESP on board was not damaged. The USV was declared a constructive total loss valued at an estimated \$186,000.



Figure 6. Left to right: GLERL USV after the collision, showing about half of the vessel with its broken fiberglass hull and remaining solar panels intact, and the internal structure of the USV, showing the structural area for scientific equipment and vessel system electrical infrastructure.

The Prestige 450 Flybridge suffered structural damage to both of its propeller pods and fiberglass hull (see figure 7). The starboard pod had to be rebuilt; the port

¹³ The NTSB uses the International Civil Aviation Organization injury criteria in all of its casualty reports, regardless of transportation mode. A serious injury is a non-fatal injury that requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone; causes severe hemorrhages, nerve, muscle, or tendon damage; involves any internal organ; or involves second- or third-degree burns, or any burn affecting more than 5% of the body surface. ([49 CFR 830.2](#)) A minor injury is any injury that does not meet the conditions for classification as a serious injury.

pod required repairs. The damages were estimated to cost about \$100,000, including salvage and insurance costs.



Figure 7. Left to right: Recreational vessel propeller pod damage viewed from the starboard side after the collision, and bow thruster with visible damage to the keel.

1.4 Vessel Information

1.4.1 Prestige 450 Flybridge

The privately owned Prestige 450 Flybridge recreational vessel was Michigan-registered and had a fiberglass (fiber-reinforced plastic) hull. The recreational vessel was purchased in 2013 by a private individual and moved to the Safe Harbor Toledo Beach marina 1 year later. The owner had operated the vessel in Lake Erie for the past 10 years.

The vessel was equipped with radar, a chart plotter, and VHF radio. The operator stated that on the day of the collision, he kept his radar dome “hinged,” which made it unavailable. He stated that when the radar dome was deployed, it inhibited his ability to maneuver his vessel to his covered dock slip, so he typically kept it hinged. The operator also stated that he did not use his vessel’s VHF radio or chart plotter while navigating on the day of the collision. The vessel was not equipped with an automatic identification system (AIS), nor was it required to be.

1.4.2 Uncrewed Surface Vessel

Built in 2021, the fiberglass and foam composite-hulled SeaTrac SP-48 USV was owned and operated by NOAA GLERL. SeaTrac Systems, Inc. designed and manufactured the vessel and developed its operational software.¹⁴

The USV had a yellow hull and main deck (see figure 8). The stern displayed the text “UNCREWED SURFACE VESSEL” in black lettering. Solar paneling covered most of the vessel’s surface area, aside from the centerline area, parts of the bow, stern, and freeboard area. According to the GLERL lead engineer, the vessel’s freeboard was about 1 foot.¹⁵ The USV was capable of transiting at a speed up to 5 knots.

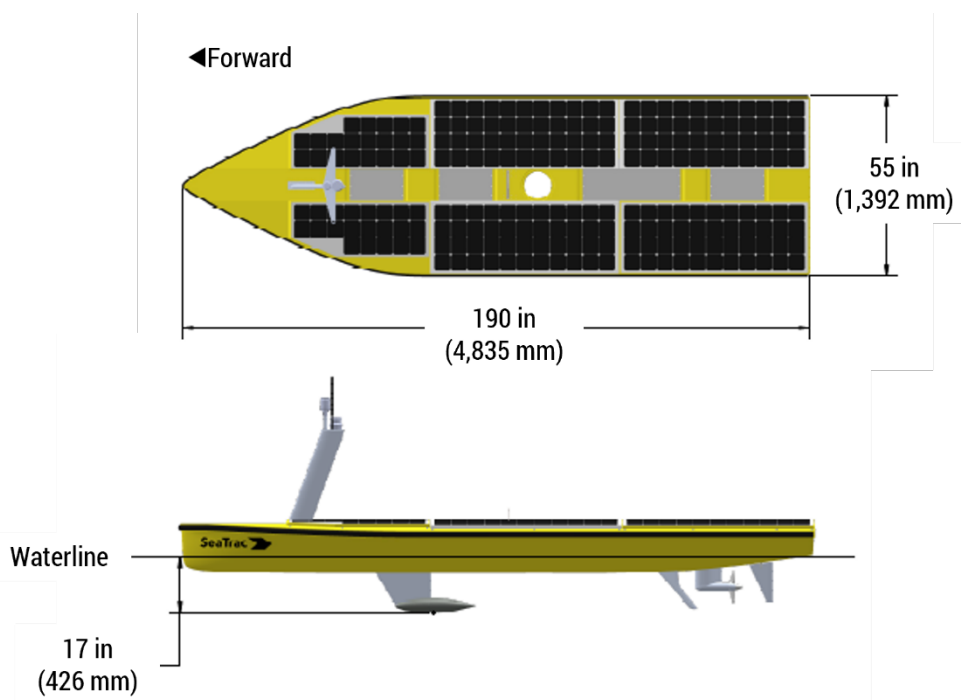


Figure 8. SeaTrac SP-48 overhead and profile view. Note: The drawing shows the vessel as built without GLERL’s modification to add the aft mast. (Background source: SeaTrac)

¹⁴ The SP-48 USV was the only type of vessel SeaTrac manufactured.

¹⁵ *Freeboard* is the vertical distance between the vessel's waterline and the highest watertight deck—in this case, to the deck mounting the solar panels on the USV.

The vessel had a forward mast structure, about 26 inches tall, which housed instrumentation and antennas (see figure 9).¹⁶ The highest antenna was about 17 inches above the mast, about 3.6 feet from the deck. A small yellow flag was also secured to the mast to increase visibility.¹⁷ The GLERL lead engineer estimated the flag was about 2.5 feet above the waterline. The mast also housed a combined lantern with red and green running lights and a white stern light.

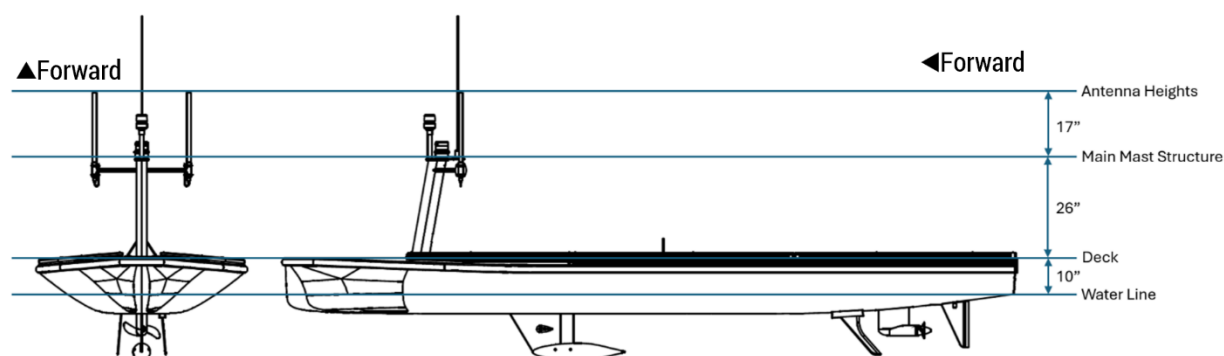


Figure 9. Forward view (looking aft) and profile view of USV. Note: The drawing shows the vessel as built without GLERL’s modification to add the aft mast. (Background source: SeaTrac)

A second mast, which housed an all-around white light, was installed aft on the vessel (see figure 10). This light was added by the GLERL lead engineer to aid surrounding craft operators in spotting the vessel and for lighting redundancy. The GLERL lead engineer estimated this second mast extended about 3 feet above the deck.

¹⁶ According to one of the SeaTrac co-founders, if the mast was taller, it would cast a larger shadow on the solar panels and start “to hurt the power [the vessel] can grab during the day.”

¹⁷ At the time of the casualty, there were no formal visibility requirements for USVs operating on waterways beyond what applied to a power-driven vessel.

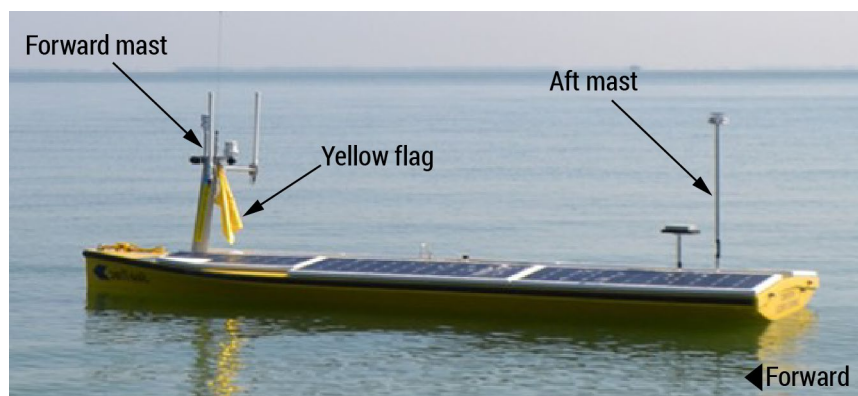


Figure 10. Profile view of USV showing forward and aft masts. (Background source: NOAA)

Propulsion was provided by a 1,000-watt brushless motor connected to a weedless propeller and powered by lithium-iron-phosphate, 6.75-kilowatt-hour batteries. The batteries were controlled by a battery management system.¹⁸ Deflector fins were fixed to the hull forward of the propeller to protect the propeller and rudder.

The USV was equipped with a Class B AIS device, which transmitted the vessel's position; unlike Class A devices, it did not transmit the navigational status of the vessel.¹⁹ According to SeaTrac, the USV's AIS device was powered on and set to transmit at the time of the collision.

GLERL staff did not know whether the USV would register a signature on another vessel's radar.

The USV was also equipped with a 360° camera system consisting of four cameras, used to visually monitor the USV's environment. By default, the cameras live-streamed footage to the human machine interface when they were in use (see section 1.5.1). The pilot had the option to turn on video saving, which would

¹⁸ A *battery management system* is a computer system designed to ensure efficient and safe operation of the electrical battery system. It typically manages the voltage, current, and temperature of each battery cell aboard, as well as the charging and discharging.

¹⁹ An AIS is a maritime navigation safety communications system that provides vessel information automatically to appropriately equipped shore stations, other ships, and aircraft; automatically receives such information from similarly fitted ships; monitors and tracks ships; and exchanges data with shore-based facilities. AIS Class B transmitters were developed to provide the safety and navigation benefits of AIS to smaller vessels with lower cost and simpler installations when compared to AIS Class A. AIS Class B transponders have lower power output (maximum range of 8-10 miles to nearby vessels, and transmissions are often not received by AIS satellites that provide global vessel tracking), are less expensive, and transmit a vessel's position less frequently than an AIS Class A transponder.

store video to the hard drive. If the allocated space filled, the system would overwrite the oldest footage. At the time of the collision, GLERL did not have the cameras or video saving turned on.

1.4.3 Vessel Particulars

Table 2 shows the vessel particulars for the GLERL USV and Prestige 450 Flybridge recreational vessel.

Table 2. Vessel Particulars

Vessel	GLERL USV	Prestige 450 Flybridge
NTSB Vessel Group	Specialty/Other (Uncrewed surface vessel)	Yacht/Boat (Recreational vessel)
Owner/Operator	NOAA GLERL (Government)	Private owner (Private)
Flag	N/A	United States
Port of registry	N/A	Michigan
Year built	2021	2014
Official number		MC6109TK
IMO number	N/A	N/A
Classification society	N/A	N/A
Length (overall)	15.9 ft (4.8 m)	45.0 ft (13.7 m)
Breadth (max.)	4.6 ft (1.4 m)	14.0 ft (4.3 m)
Draft (casualty)	1.4 ft (0.4 m)	3.5 ft (1.1 m) est.
Tonnage	N/A	N/A
Engine power; manufacturer	1 × 1,000 W brushless motor	2 × 435 hp (324 kW) Volvo/Penta IPS 600

1.5 Uncrewed Surface Vessel Operations

1.5.1 Human Machine Interface

The USV pilot controlled the vessel remotely using its human machine interface software, or “dashboard” (see figure 11).²⁰

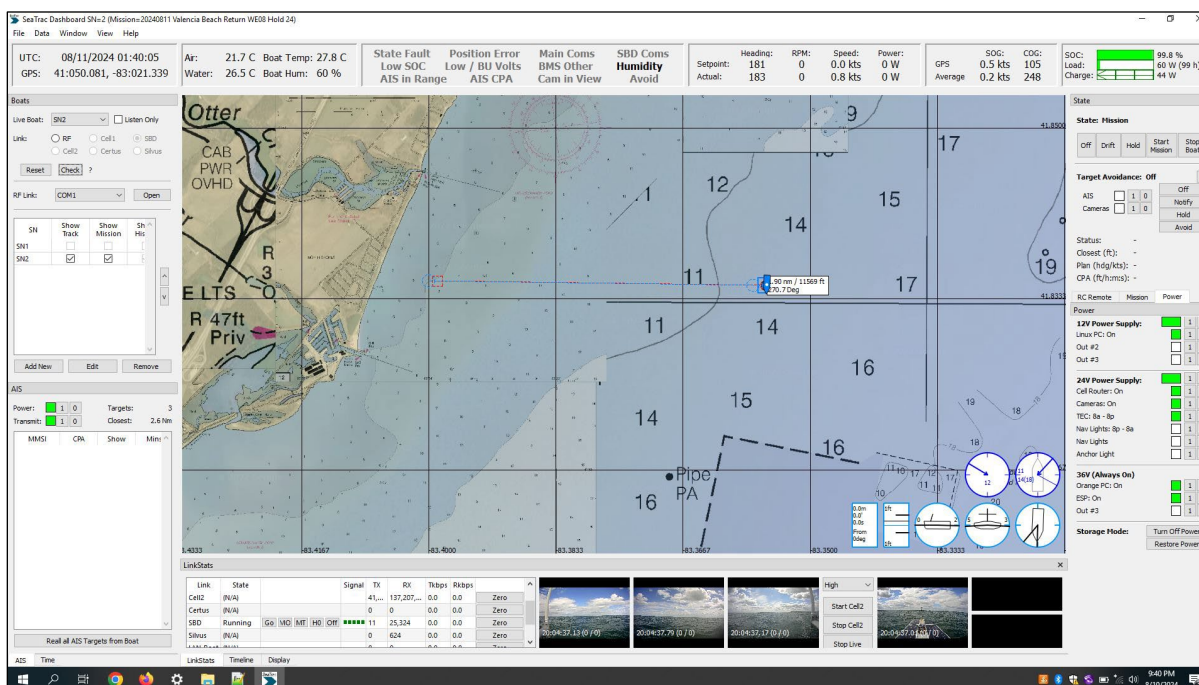


Figure 11. GLERL USV dashboard, or human machine interface, showing the vessel in mission mode. (Source: GLERL)

Using the dashboard, the USV pilot could remotely control the USV's operational mode and view its systems and performance. The dashboard displayed a navigational chart showing the USV's location, as well as other AIS targets near the USV. The pilot could zoom in or out on the dashboard; zooming in would focus on the USV, while zooming out would show surrounding AIS targets. According to the GLERL lead engineer, USV pilots typically kept the dashboard open at all times during their shifts, completing scheduled checks of all systems every 20-30 minutes via the dashboard to verify the vessel's position and heading, the condition of the batteries and solar panels, and that no errors had been reported.

²⁰ The only time the USV was not controlled by the dashboard was during launch and recovery, when GLERL staff used a remote control pack to control the vessel.

The dashboard could also show views from the four cameras installed on the USV when the cameras were on. According to the GLERL lead engineer, the cameras would be turned on “occasionally” to check the condition of the vessel or its surroundings, if the pilot identified something of interest on the dashboard, or if the vessel had to be manually moved. The lead engineer stated that GLERL’s primary concerns with operating the cameras continuously for extended periods of time were:

- the cellular provider “throttling data transmission due to high data usage [which] ... would result in delayed communications between the USV and the pilot,” and
- conserving battery power.

1.5.2 Operational Modes

SeaTrac’s software for the USV allowed it to be operated in three modes: manual, mission, or hold.

In manual mode, the pilot actively controlled the vessel’s heading and speed remotely by inputting the demands using the dashboard. The GLERL lead engineer told investigators that the USV’s cameras were typically turned on when the USV was piloted in manual mode.

In mission mode, the pilot created a mission consisting of a series of waypoints and the desired speed for mission execution to direct the USV. The pilot then sent the mission to the USV and pressed the “Start Mission” button on the dashboard to initiate the mission. A new mission could not be initiated while a mission was underway; instead, the pilot would have to place the vessel in hold mode, send a new mission, and then start the new mission. While the vessel was in mission mode, the pilot actively monitored it using the dashboard.

When in hold mode, the USV powered down and used propulsion and steering as necessary to remain within a defined location: the boundaries of the inner circle of two concentric circles. The pilot designated the center point as well as the radius of the two concentric circles on the dashboard. While operating in this mode, the USV would drift while the wind and waves acted on it. If the vessel reached the boundary of the outer circle, it would engage the navigation system, return to the

inner circle, disengage the navigation system, and resume drifting. The pilot set the speed the vessel would use to return to the inner circle.²¹

During an earlier mission, GLERL staff discovered that when the USV's mode was set to hold, the USV would "struggle to manage returning to the inner circle," and "after several hours the USV would throw a state fault error and start drifting [outside of the defined circles]." GLERL staff determined that the use of hold mode to remain in one position for hours at a time was not reliable and instead adapted their use of mission mode to mimic the hold state (referred to in this report as "adapted hold" mode). To do so, they created a mission with multiple waypoints at the same location, selected each waypoint's type as "hold," and set a timeframe for each "hold" waypoint. The USV would then arrive at the waypoint, and its propulsion and steering would stop.

Once the USV drifted outside of the outer circle radius set by the pilot for the "hold," the USV would automatically maneuver to the inner circle as if it were in hold mode (see figure 12). After the specified hold time elapsed, the USV would advance to the next waypoint (at the same location) and repeat the pattern. This pattern would repeat until the USV had advanced through all waypoints, a new mission was started, or the mission was manually stopped and restarted.

²¹ Speed setpoint corresponds to an engine rpm on the USV. It does not account or compensate for structural impediments (drag) or environmental conditions (wind/current/seas) acting on the vessel.

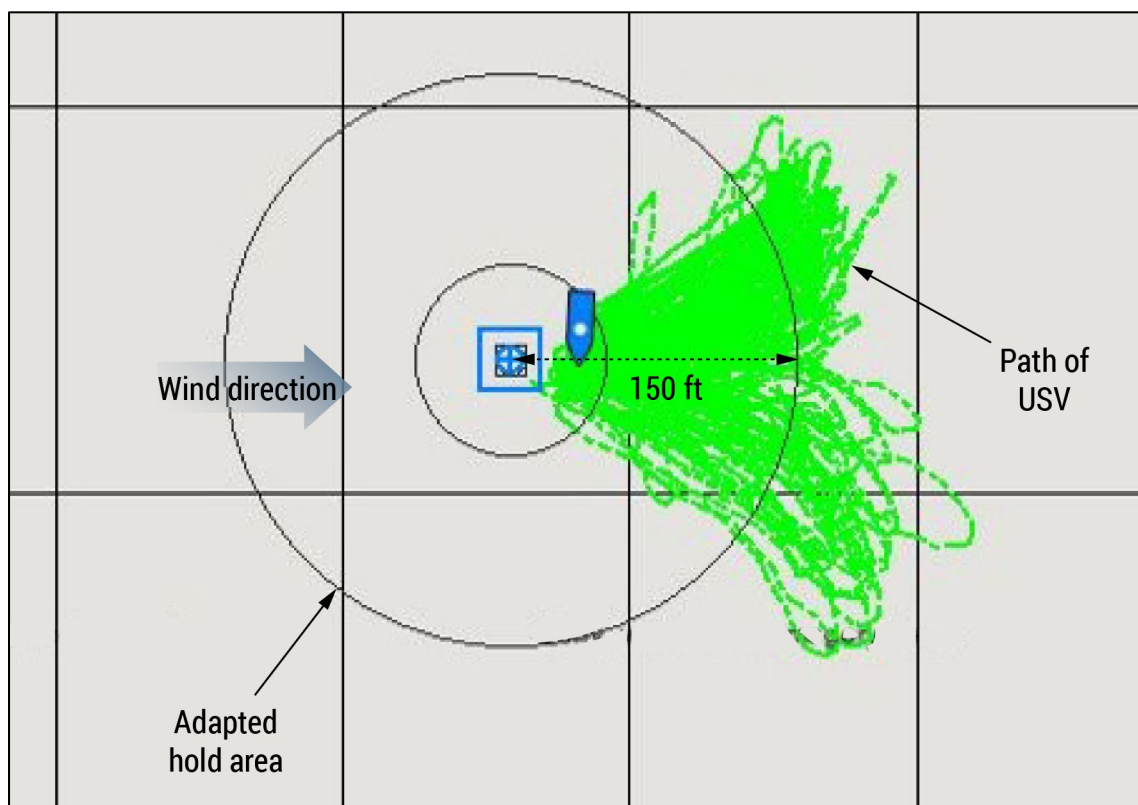


Figure 12. USV dashboard showing the vessel in adapted hold mode on the day of the casualty, including the center point, inner circle, and outer circle set by the pilot. The green marks indicate the vessel's past position. (Background source: GLERL)

At the time of the collision, the USV was in adapted hold mode, and the vessel's cameras were off. For each "hold" waypoint, the radius of the hold position outer circle was 150 feet, and the speed setpoint was 3 knots, as it had been for the mission all week. The lead engineer, who was piloting the USV at the time, stated, "Typically, it was really only going somewhere around 2 and 2.5 knots."

When the vessel was in either hold mode or adapted hold mode, a GLERL pilot passively monitored its condition using the dashboard and automatic vessel status alert email and text notifications. GLERL's lead engineer told investigators that it typically took about 1–5 minutes (and up to 10 minutes) to activate the vessel and get it underway on a mission from a hold waypoint while in adapted hold mode, depending on the primary communication method: cellular or satellite. According to the manufacturer, SeaTrac, this process could be executed in as little as 5 seconds up to a minute.

1.5.3 Traffic Notification and Collision Avoidance

The USV's software included AIS vessel detection, which alerted the pilot when other vessels transmitting AIS were nearby. To use this function, the USV pilot set alert parameters based on a nearby vessel's closest point of approach (CPA) and time to closest point of approach (TCPA). If a nearby vessel was transmitting AIS and its CPA and/or TCPA met the parameters, the USV pilot received a status alert notification that provided the AIS information for the vessel in range.²² The USV would not maneuver away from another nearby vessel without human intervention. The traffic monitoring range was 0.25 miles and 30 minutes at the time of the collision.

The USV manufacturer's data sheet also stated that the vessel had "automated collision avoidance" (SeaTrac Systems, Inc. 2021). The Inland Navigation Rules are collision avoidance regulations that mariners must abide by while transiting navigable inland waters in the United States, including when a vessel should stand on or give way when the risk of collision exists.²³ SeaTrac SP-48 USVs did not factor in the Inland Rules when executing avoidance maneuvers.

The manufacturer told investigators that the collision avoidance system was a new feature and remained under testing. This feature was not activated at the time of the collision; GLERL staff had it turned off. The manufacturer further stated, "Our guidance to NOAA and all the other customers is, look, when you pilot this boat, you're sitting and piloting it," and piloting a USV was "a 24/7 operation."

The GLERL lead engineer stated that before the casualty, GLERL had conducted testing of the USV's collision avoidance capability. During the testing, a USV pilot remotely operated the USV from aboard another nearby GLERL vessel. The pilot started the USV on a pre-programmed mission, such as transiting to the WE08 site, and observed it from the cameras on the dashboard. A second NOAA vessel then executed a series of maneuvers close to the USV.²⁴ On the dashboard, the USV operator could see the targets that the USV identified during each maneuver and observe whether the USV deviated from the mission course to increase the space

²² The manufacturer described this function using CPA-logic. AIS B does not transmit CPA/TCPA data.

²³ See [Inland Rules](#).

²⁴ These maneuvers included: crossing the USV bow perpendicularly from port and starboard, overtaking the USV from port and starboard and crossing the bow, crossing the USV stern from port and starboard, heading directly for the side of the USV from port and starboard, and heading directly for the USV's bow.

between the USV and the other NOAA vessel. GLERL staff observed the USV repeatedly maneuvering away from the other NOAA vessel without human intervention.

1.5.4 Level of Autonomy

According to the manufacturer's data sheet for the USV, the vessel offered manual, "supervised autonomy," or "full autonomy" operational options (SeaTrac Systems, Inc. 2021). Supervised autonomy was described as "man in the loop," while full autonomy was "programmed missions" (SeaTrac Systems, Inc. 2019).²⁵

In 2024, GLERL staff completed an Autonomous Vessel Information Request form to be submitted to the Coast Guard Sector Detroit, to provide notice of two separate deployments planned in July and August 2024 (see section 1.5.6).²⁶ The form listed seven autonomy levels (AL) from AL 0 to AL 6 and asked the operator to identify the level of autonomy that the vessel would operate at. When GLERL staff completed the form for the USV, they selected AL 4 (see table 3). They also noted that the USV "can and will be operated at a level of AL 0 for launch and recovery in and around marinas and/or launch sites."

Table 3. Autonomy levels adapted from Lloyd's Register. (Source: Coast Guard)²⁷

Autonomy level	Description	Operator Role
AL 0	Manual steering. Steering controls or set points for course, etc. are operated manually.	The operator is on board or performs remote control via radio link.
AL 1	Decision-support on board. Automatic steering of course and speed in accordance with the references and route plan given. The course and speed are measured by sensors on board.	The operator inserts the route in the form of "waypoints" and the desired speed. The operator monitors and changes the course and speed, if necessary.
AL 2	On-board or shore-based decision support. Steering of route through a sequence of desired positions. The route is calculated so as to observe a wanted plan. An external system is capable of uploading a new route plan.	Monitoring operation and surroundings. Changing course and speed if a situation necessitates this. Proposals for interventions can be given by algorithms.

²⁵ *Man-in-the-loop*, also referred to as *human-in-the-loop*, is a type of system design wherein a human operator is integrated into the system's control process such that the system requires human interaction.

²⁶ In the Great Lakes area, Coast Guard Sector Detroit conducted risk assessments of autonomous vessel operations using the Autonomous Vessel Information Request form.

²⁷ In the absence of national definitions for levels of autonomy, Coast Guard Sector Detroit used Lloyd's Register's levels of autonomy defined in this table.

Autonomy level	Description	Operator Role
AL 3	Execution with human being who monitors and approves. Navigation decisions are proposed by the system based on sensor information from the vessel and its surroundings.	Monitoring the system's function and approving actions before they are executed.
AL 4	Execution with human being who monitors and can intervene. Decisions on navigation and operational actions are calculated by the system which executes what has been calculated according to the operator's approval.	An operator monitors the system's functioning and intervenes if considered necessary. Monitoring can be shore-based.
AL 5	Monitored autonomy. Overall decisions on navigation and operation are calculated by the system. The consequences and risks are countered insofar as possible. Sensors detect relevant elements in the surroundings and the system interprets the situation. The system calculates its own actions and performs these. The operator is contacted in case of uncertainty about the interpretation of the situation.	The system executes the actions calculated by itself. The operator is contacted unless the system is very certain of its interpretation of the surroundings and of its own condition and of the thus calculated actions. Overall goals have been determined by an operator. Monitoring may be shore-based.
AL 6	Full autonomy. Overall decisions on navigation and operation are calculated by the system. Consequences and risks are calculated. The system acts based on its analyses and calculations of its own capability and the surroundings' reaction. Knowledge about the surroundings and previous and typical events are included at a "machine intelligent" level.	The system makes its own decisions and decides on its own actions. Calculations of own capability and prediction of surrounding traffic's expected reaction. The operator is involved in decisions if the system is uncertain. Overall goals may have been established.

1.5.5 Operator Training

In 2021, after GLERL received the vessel, the USV manufacturer provided USV training for GLERL staff. The training included instruction on the operation of the USV software and system maintenance, as well as presentations and a review of hardware and integrated sensors, maintenance, software, and operations. According to the manufacturer, the training was “strictly limited to the functions of the boat” and did not include guidance on navigation rules applicable to the USV.

1.5.6 Mission Awareness

1.5.6.1 Communication with the Coast Guard

The GLERL lead engineer submitted the Autonomous Vessel Information Request form to Coast Guard Sector Detroit on June 26, 2024, to provide notice of

two separate deployments planned in July and August 2024. GLERL followed this protocol in the 2 years prior, as well as for deployments in 2022 and 2023. The lead engineer stated that he received no email correspondence from the Coast Guard in response to these email notices; he did not recall whether he had attempted to follow up with the Coast Guard by phone. The Coast Guard did not publish a notification of the GLERL USV's operation, nor did they have a policy requiring its publication.

1.5.6.2 Communication to Public

GLERL provided the NTSB with a history of communications work regarding SeaTrac deployments beginning in 2022. A factsheet containing information about the USV operations, which included a map of the areas of operation and the anticipated date range of the operation, was distributed through a variety of local channels as well as social media posts in the prior years of operation (2022 and 2023).²⁸

GLERL staff gave a presentation to yacht club members at the North Cape Yacht Club, co-located at the Safe Harbor Toledo Beach marina, regarding the USV's 2024 deployment and provided marina staff with a one-page flyer. (The club members were also customers and/or dock owners at Safe Harbor Toledo Beach marina.) Flyers were also provided to Ohio Sea Grant via email for distribution to local charter captains and other recreational users.²⁹

The recreational vessel operator stated that he typically checked the bulletin board near his dock slip at Safe Harbor Toledo Beach marina and read a local newsletter as well as boating magazines, but he had not seen anything that mentioned the USV's deployment in the Toledo Beach area.

1.6 Environmental Conditions

According to the National Weather Service, at the time of the collision, the sustained wind speed was 18 knots, from the west, with gusts to 23 knots. Visibility

²⁸ Local channels included the Safe Harbor Toledo Beach marina, Toledo Beach Yacht Club, Ohio Sea Grant, and the Charter Captains Conference.

²⁹ Ohio Sea Grant is part of the Ohio State University College of Food, Agricultural, and Environmental Sciences. The organization researches and collaborates with Great Lakes communities to perform outreach regarding, environmental and economic issues involving Lake Erie (see <https://ohioseagrant.osu.edu/>).

was 8 miles, and skies had broken clouds.³⁰ The air temperature was 72°F. Sunset was at 2039.

According to the operator of the Prestige 450 Flybridge, the sun was off to his right side at the time of the collision. He was unable to recall the sky conditions; however, he reported that his transition eyeglasses were at a medium tint as he steered the vessel from the cockpit area. He stated that the collision occurred about an hour before sunset, so the light conditions were not as bright as they would have been in the middle of the day. The operator told investigators, "The difficulty, obvious, was the waves [surrounding the USV]. You can't see anything that low to the water with the color of the water."

1.7 Waterway Information

The collision occurred in Lake Erie, about 6 miles east-southeast of Monroe, Michigan (see figure 13). Lake Erie measures about 241 miles from east to west and 57 miles from north to south. At the time of the collision, the wave height was reported as 3 feet from the west. The waterway depth at the collision location was about 16 feet.

³⁰ Broken clouds are clouds that cover between 60% and 90% of the sky. See [the National Weather Service's Full Weather Glossary](#).



Figure 13. Area where the collision between uncrewed surface vessel and recreational vessel occurred, as indicated by a circled X. (Background source: Google Maps)

The GLERL lead engineer stated that the usual traffic in the USV's location was sailboats, with larger recreational vessels traveling at speeds of 10-20 knots. He told investigators that, at the USV's location at the time of the collision, it was not out of the ordinary for someone to be traveling at a high rate of speed in a power-driven vessel.

NOAA also employed a contractor, who had served as a research vessel captain for GLERL for 8 seasons at the time of the collision. He was familiar with the operational area and stated that the location where the USV was located was not heavily traveled, but larger recreational vessels would take that route. Regarding the Prestige 450 Flybridge operator, the contractor stated, "I don't see any reason why he wouldn't be at full cruising speed out there."

1.8 Personnel Information

The operator of the Prestige 450 Flybridge recreational vessel told investigators that he had operated boats for over 60 years and had owned and operated boats in the Monroe area for about 20 years. He had completed a Michigan State Boating Safety course, initially in 1995, and had earned a training certificate from the United States Power Squadrons in 1989.³¹ He completed the Michigan State Boating Safety course again with his children and friends in more recent years.

The GLERL USV pilot at the time of the collision had operated the USV during the 2 years before the collision in the same area of operation. He completed a Boating Skills and Seamanship course with the US Coast Guard Auxiliary and a Boating Safety course with the Michigan Department of Natural Resources.³² He had also attended the USV manufacturer-provided training on the functions of the USV in 2021.

1.9 Industry Overview

1.9.1 Population

USVs are used by various entities, including government agencies such as NOAA or the Coast Guard, to perform varying missions in the Great Lakes region. For example, in 2026, the Coast Guard announced that between May and October, GLD would be deploying autonomous sail drones “to monitor the Great Lakes, gather critical weather data for emergency response planning, track illicit activity, and keep maritime borders safe” (Lauofo 2026).

According to NOAA, as of the publication of this report, NOAA organizations operate seven USVs. Three of these are SeaTrac SP-48 USVs; one is operated in the Great Lakes region, and two are operated in the Pacific Northwest by NOAA’s Pacific

³¹ The United States Power Squadrons, also known as America’s Boating Club, is a non-profit educational organization that provides classes in boat handling, navigation, boating rules and regulations, marine electronics, and boat maintenance (see [Boating Education & Safety Courses | America’s Boating Club](#)).

³² The US Coast Guard Auxiliary’s mission is to promote and improve recreational boating safety; provide trained crews and facilities to augment the Coast Guard; and support Coast Guard operational, administrative, and logistical requirements. See [US Coast Guard Auxiliary](#).

Marine Environmental Laboratory (PMEL).³³ PMEL's USVs have been modified to include a large wing structure on the stern. According to a PMEL representative, this structure "adds height and makes the vehicle more visible on the water." PMEL also added a radar reflector to its USVs "to improve safety and visibility," as well as a yellow independent flashing light. The light has a visibility range of about 2 miles and is set to flash 1 second on and 5 seconds off during night operations. GLERL's other USV has not been modified and is designed similarly to the GLERL USV involved in the collision. According to NOAA staff, NOAA plans to operate PMEL's USV in the Bering Sea in 2027 and 2028.

SeaTrac told investigators that the company had sold 25 SP-48 USVs as of June 2026.

1.9.2 Uncrewed Surface Vessel Policy, Guidance, and Standards

1.9.2.1 Coast Guard

At the time of the collision, the Coast Guard did not have regulations for uncrewed or autonomous surface vessels in any operating areas within the United States. The Coast Guard did have regulations for automated systems on vessels, which stated:

- Coast Guard acceptance of automated systems to replace specific personnel or to reduce overall crew requirements is predicated upon the capabilities of the system, the system's demonstrated and continuing reliability, and a planned maintenance program that ensures continued safe operation of the vessel.
- The OCMI [Officer in Charge, Marine Inspection] considers the capabilities of an automated system in establishing initial manning levels; however, until the system is proven reliable, a manning level adequate to operate in a continuously attended mode will be specified on a vessel's COI [certificate of inspection]. It remains the responsibility

³³ (a) Two USVs were manufactured by DriX, and two by EchoBoat. (b) The Pacific Marine Environmental Laboratory is a federal laboratory under NOAA that "makes critical observations and conducts groundbreaking research to advance our knowledge of the global ocean and its interactions with the earth, atmosphere, ecosystems, and climate." See ["About PMEL \[Pacific Marine Environmental Laboratory\]"](#).

of the vessel's Master to determine when a continuous watch is necessary.³⁴

Coast Guard CG-CVC [Office of Commercial Vessel Compliance] Policy Letter 22-01, "Guidelines for Human-Supervised Testing of Remote Controlled and Autonomous Systems on Vessels," provided guidance for Captains of the Port and Officers in Charge, Marine Inspection, to engage with the maritime industry "to ensure that testing of remote and autonomous vessel systems meets applicable laws and regulations" (US Coast Guard 2021).³⁵

When the collision occurred, the Coast Guard was in the process of drafting formal policies for the use of uncrewed and autonomous vessels. A Coast Guard Navigation and Vessel Inspection Circular (NVIC), "Best Practices for Maritime Autonomous Surface Ships and Unmanned Maritime Systems," was drafted in September of 2020, and a Coast Guard Commandant Instruction, "Autonomous and Remote Controlled Vessel Activities," had been in draft stages since July 2021.³⁶ According to the Coast Guard, the NVIC and Commandant Instruction sought to establish definitions, an operational framework, a risk mitigation framework, and roles and responsibilities, among other items, to safely integrate uncrewed vessels into operational waterways. As of the publication of this report, these documents have not been published.

1.9.2.2 National Oceanic and Atmospheric Administration

NOAA's Uncrewed Systems Operations Center director told investigators that at the time of the collision, there were no agency-wide policies for "Uncrewed Marine

³⁴ See [46 CFR Section 15.715](#). These regulations were promulgated in 1987. Additional regulations relating to requirements for periodically unattended machinery plants were promulgated in 1988. See [46 CFR Section 62.50-30](#).

³⁵ (a) The Coast Guard's Office of Commercial Vessel Compliance "develops and maintains policy and standards for the prevention activities of the Coast Guard to achieve Marine Safety, Security, and Stewardship mission success." See [Commercial Vessel Compliance](#). (b) CG-CVC Policy Letter 22-01 was initially signed on [February 16, 2022](#), and was set to expire on January 1, 2024. The Coast Guard published a revised CG-CVC Policy Letter 22-01 on [April 30, 2024](#); this letter was set to expire "in two years, unless cancelled or suspended."

³⁶ According to the Coast Guard, NVICs provide "detailed guidance about the enforcement or compliance with a certain [sic] Federal marine safety regulations and Coast Guard marine safety programs. While NVIC's [sic] are non-directive, meaning that they do not have the force of law, they are important 'tools' for complying with the law." See [Navigation and Vessel Inspection Circulars: Background Information](#). A Commandant Instruction is "an enterprise-wide policy that incorporates laws, strategy, executive policy guidance, and other program direction for organization implementation." See [Commandant Instructions](#).

Systems” and “each operator is still in the position of creating their own policies.” He further stated that an administrative order to authorize the creation of overarching NOAA policies had been drafted and remained under consideration (see section 1.10.2).

1.9.2.3 International Maritime Organization

In 2021, the International Maritime Organization (IMO) completed a regulatory scoping exercise on maritime autonomous surface ships to “assess existing IMO instruments to see how they might apply to ships that utilize varying degrees of automation.”³⁷ As part of the exercise, the IMO identified four degrees of autonomy for vessels:

- Degree one: Ships with automated processes and decision support.
- Degree two: Remotely controlled ships with seafarers on board.
- Degree three: Remotely controlled ships without seafarers on board.
- Degree four: Fully autonomous ships.

In 2022, IMO created a working group, the “MSC-LEG-FAL Joint Working Group on Maritime Autonomous Surface Ships (MASS),” to develop a regulatory framework for autonomous shipping.³⁸ In May 2026, IMO adopted the non-mandatory *International Code of Safety for Maritime Autonomous Surface Ships* (MASS Code).³⁹ The MASS Code took effect in July 2026 and “introduces new requirements for the design, approval and operation of [crewless or remote-operated] ships, including in key areas such as navigation, connectivity, remote operations, fire safety, and search and rescue” (IMO n.d.). IMO plans to begin

³⁷ (a) IMO is the global standard-setting authority for the safety, security, and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is universally adopted and implemented. IMO measures cover all aspects of international shipping, including ship design, construction, equipment, manning, operation, and disposal. (b) See <https://www.imo.org/en/mediacentre/hottopics/pages/autonomous-shipping.aspx>.

³⁸ MSC stands for Maritime Safety Committee, LEG stands for Legal Committee, and FAL stands for Facilitation Committee. All three are committees of IMO.

³⁹ The MASS Code as adopted applies to cargo vessels covered under the *International Convention for the Safety of Life at Sea*, Chapter 1. While it is non-mandatory, IMO member states have the opportunity to test its use until it becomes mandatory.

development of a mandatory MASS Code in 2028, aiming to adopt the code by July 1, 2030.⁴⁰

1.10 Postcasualty Actions

1.10.1 Coast Guard

On August 23, 2024, 13 days after the collision, , Coast Guard Great Lakes District (GLD) published Marine Safety Information Bulletin (MSIB) 003-24, "Autonomous Unmanned Watercraft on the Great Lakes" (US Coast Guard 2024a). The MSIB:

- informed readers of the operation of autonomous uncrewed vessels on the Great Lakes;
- suggested precautions for mariners navigating the area; and
- provided links to Coast Guard resources to stay informed of research vessel deployment and operations and a list of common identifiers—including flashing white or yellow lights, specific markings, and radar reflector and/or AIS—"to aid mariners in sighting and avoidance" of autonomous unmanned watercraft.

On November 7, 2024, the Coast Guard published MSIB 24-008, "Uncrewed Marine Craft and Autonomous Marine System Technology," to bring awareness to autonomous uncrewed marine crafts and systems operating in the northeast waters (US Coast Guard 2024b).⁴¹ The MSIB stated that the systems' "increasing presence and diversity of form, shape, and function introduce significant layers of complexity to the maritime environment" and provided examples of vessels, including the GLERL USV (see figure 14). The MSIB listed the expected precautions that all mariners, vessel owners, and operators "must consider while planning an outing or transit." The bulletin recommended that owners and operators of autonomous craft engage early

⁴⁰ The United States is a member country of IMO. The Coast Guard is the head of the delegation representing the United States at IMO.

⁴¹ MSIB 24-008 was included in the Local Notice to Mariners and was posted on the Coast Guard's [Homeport site](#) as well as Coast Guard district social media.

with the Coast Guard when planning operations and ensure autonomous vessels include “appropriate marking” to help mariners see and avoid them.⁴²



Figure 14. The GLERL USV pictured (top right) along with two other vessels in an MSIB.
(Source: Coast Guard)

In August 2025, as a result of the Coast Guard’s investigation of this casualty, the Coast Guard GLD issued two safety recommendations:

- Recommend GLD create a regional policy for ASV [autonomous surface vessel] operations to standardize how autonomous vessel operations are to be reported to the Captain of the Port (COTP) and what type of broadcasts and/or notices are to be sent out; as well as defining required operating parameters (like national policy drafts that are not finalized) [see section 1.9.2].
- The Great Lakes District Inspection and Investigations Branch understands WWM [Office of Waterways Management] has policy in draft form. We still recommend that Coast Guard Headquarters develop comprehensive national policy and/or guidance for ASV operations to standardize the reporting processes to COTPs. The policy should provide the types of broadcasts and notices to be issued to mariners and vessels as well as the required or recommended operating

⁴² According to the MSIB, common identifiers of autonomous, uncrewed vessels include: a flashing all around yellow light, a radar reflector, retro-reflective markings, visual markings identifying the craft as “UNCREWED,” a bright yellow or orange paint scheme with a specific point of contact and domestic phone number, and/or an AIS system that transmits “uncrewed” in the vessel name.

parameters for ASVs. This policy should include considerations and recommendations for collision avoidance and navigational safety with the goal of establishing a unified national framework. A framework that will ensure consistency across regions and promote the safe integration of ASVs into complex Maritime Transportation System environments.

According to the Coast Guard, as of the publication of this report, these recommendations are still being processed and no formal policies have been adopted as a result of these recommendations.

On June 1, 2026, the Coast Guard Assistant Commandant for Prevention Policy issued Work Instruction 5P-WI-002, "Oversight of Unmanned, Autonomous and Remote-Control Operations" (US Coast Guard 2026).⁴³ The work instruction provides guidance to District Commanders, COTPs, and Officers in Charge, Marine Inspection, for "evaluating operations involving unmanned, autonomous or remote-controlled maritime technologies within the Marine Transportation System (MTS)." The work instruction discusses the operation of unmanned systems, procedures for remote and autonomous systems on inspected vessels, and stakeholder engagement to communicate unmanned systems operations. However, the work instruction explicitly states that it is not applicable to:

- Small unmanned maritime systems owned, operated, or chartered by NOAA, or
- Public vessels.

The work instruction exempted these vessels because the National Defense Authorization Act for Fiscal Year 2026 exempts small uncrewed vessels operated by NOAA from:

Any vessel inspection, design, operations, navigation, credentialing, or training requirement, law, or regulation that ... will harm real-time operational extreme weather oceanographic and atmospheric data collection and predictions.⁴⁴

⁴³ Coast Guard work instructions are not regulation or law; they provide guidance to assist industry, mariners, the public, and the Coast Guard in applying statutory and regulatory requirements.

⁴⁴ (a) See [Pub. L 119-60](#). (b) According to the Coast Guard work instruction, this restriction "does not limit the authority of the Secretary of the department in which the Coast Guard is operating ... if there is an immediate safety or security concern regarding small uncrewed maritime systems."

1.10.2 National Oceanic and Atmospheric Administration

As a result of the collision, NOAA issued administrative order NAO 212-19, “NOAA Uncrewed Marine Systems,” effective January 16, 2025 (NOAA 2025a).⁴⁵ The order’s purpose was to prescribe “the policy and responsibilities for the management and utilization of ‘Uncrewed Marine Systems’ [UMS] to support NOAA programs.”

To fulfill the requirements of the administrative order, in February 2025, NOAA produced a manual, titled “NOAA Uncrewed Marine Systems Manual,” which provided agency requirements for the operation of USVs (NOAA 2025b). Among the guidance included in the manual was the requirement to “equip NOAA UMS in such a manner as to minimize risk of collision,” including “the appropriate use of lights, sounds, markings, and electronic signals to ensure that NOAA UMS can be detected, identified, and avoided.” The manual stated that NOAA UMS should have, among other things:

- “high visibility coloration”;
- radar reflectors, other reflective markings, and markings that identify the vessel as “UNCREWED”; and
- sound-producing and listening devices “that mimic the requirements for providing and monitoring audible alerts/warnings under COLREGs.”⁴⁶

The manual also states that USV operators should complete available training on the appropriate UMS platform as well as additional training “to ensure familiarity with the COLREGS, collision avoidance, and general maritime practice as appropriate for operations.” The manual further requires staff to conduct a risk assessment before operating a NOAA UMS, including consideration of weather and oceanographic

⁴⁵ NOAA defines “Uncrewed Marine Systems” as “remotely operated or autonomous craft that can function without an onboard human presence, and that may include associated components such as control and communications.”

⁴⁶ “COLREGS” refers to the *Convention on the International Regulations for Preventing Collisions at Sea, 1972*, which provide “rules of the road” for vessels operating at sea or in navigable waterways. See [Convention on the International Regulations for Preventing Collisions at Sea, 1972 \(COLREGs\)](#). In the United States, the Inland Navigation Rules (commonly known as the Inland Rules), govern collision regulations for US inland waterways, including the Great Lakes. The Inland Rules were formalized in 1980 and first effective in 1981. The Inland Rules became effective for the Great Lakes in 1983. With the exception of Annex V to the Inland Rules, the 72 COLREGS and Inland Rules are similar in content and format.

conditions and “circumstances with respect to the operating area, including visibility conditions, vessel traffic likely to be encountered, compliance with regulations as appropriate to the operation, and abnormal procedures.”

1.10.3 SeaTrac

As a result of the collision, SeaTrac now provides an optional reflection kit, with a “passive radar reflector” and reflecting tape, for this model of USV.⁴⁷ For new models, SeaTrac modified the combined lantern on the masthead (the forward masthead on the GLERL USV) so that it was capable of flashing white all around. In addition, the vessel’s AIS antenna and supporting electrical systems were changed to improve reception and transmission ranges.

⁴⁷ The manufacturer stated that the reflection kit was optional because some customers do not want the vessel to be visible due to the nature of their operations.

2 Analysis

2.1 Introduction

On August 10, 2024, about 1912 local time, a GLERL SeaTrac SP-48 USV and a privately owned 45-foot-long Prestige 450 Flybridge recreational vessel collided while underway in Lake Erie, 6 miles east-southeast of Monroe, Michigan. The USV became fouled in the recreational vessel's starboard propeller pod, and the two vessels were towed conjoined to a nearby marina and later separated. No pollution was reported. One minor injury was reported. The USV was considered a total constructive loss valued at an estimated \$186,000. Damage to the recreational vessel was estimated at \$100,000.

This analysis evaluates the following safety issues:

- Inadequate perceptibility of the GLERL USV (section 2.2.1)
- Inadequate monitoring of the GLERL USV given the vessel's configuration, mode of operation, and level of autonomy (section 2.2.2)

Having completed a comprehensive review of the circumstances that led to the casualty, the investigation excluded the following as casual factors:

- *Mechanical equipment or electrical system failure.* The GLERL USV was operated by various pilots throughout the day of the collision, and none of the pilots reported any issues with the USV. NOAA did not report previously experiencing issues with the USV's mechanical equipment or electrical systems. Similarly, the owner of the Prestige 450 Flybridge recreational vessel did not report any issues with the vessel's mechanical equipment or electrical systems.
- *USV human machine interface ("dashboard") connectivity.* None of the pilots that operated the GLERL USV on the day of the collision reported any issues with the USV dashboard. Additionally, a screenshot of the dashboard taken by a pilot when notified of the collision did not show any system errors or anomalies.

Thus, the NTSB concludes that none of the following were factors in this casualty: (1) mechanical equipment or electrical system failure or (2) USV human machine interface ("dashboard") connectivity.

2.2 Uncrewed Surface Vessel Perceptibility and Operation

USVs in use around the world today are typically designed or adapted to perform specialized tasks. These tasks can include clean up and disaster response; short-distance cargo hauling; short-distance passenger transport; or scientific observation, like the GLERL USV (GAO 2024). These vessels operate in areas frequented by other types of vessels, from small recreational vessels to larger commercial ships. Remote operators control USVs by programming them to perform specific actions/maneuvers and, in some cases, to make decisions with minimal human input (NOAA 2022).

Like other vessels, USVs are subject to collision regulations. In the United States, the Inland Navigation Rules (commonly known as the Inland Rules), govern collision regulations for US inland waterways, including the Great Lakes.

To avoid a collision between two vessels, the vessels' operators must be able to perceive each other—visually (by sight), electronically (via radar, AIS, or other navigational system), sound, or a combination thereof. Additionally, when a collision is imminent, the two vessels must maneuver promptly to avoid the collision, so far as practicable.⁴⁸ The Inland Rules define expectations for collision avoidance, including when a vessel should stand on or give way when the risk of collision exists.

2.2.1 Perceptibility of Uncrewed Surface Vessels

At the time of the collision, GLERL's SeaTrac SP-48 USV was operating near Toledo Beach in "adapted hold" mode, meaning that it was set to stay within a circle with a 150-foot radius (essentially, controlled drifting). If the vessel drifted beyond this circle, it would automatically move back within the boundaries of an inner circle based on coordinates set by the USV pilot. While the USV was in adapted hold mode,

⁴⁸ Inland rule 8, "Action to Avoid Collision" requires: (a) Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship. (b) Any alteration of course or speed to avoid collision shall, if the circumstances of the case admit, be large enough to be readily apparent to another vessel observing visually or by radar; a succession of small alterations of course or speed should be avoided. (c) If there is sufficient sea room, alteration of course alone may be the most effective action to avoid a close-quarters situation provided that it is made in good time, is substantial and does not result in another close quarters situation. (d) Action taken to avoid collision with another vessel shall be such as to result in passing at a safe distance. The effectiveness of the action shall be carefully checked until the other vessel is finally past and clear. (e) If necessary to avoid collision or allow more time to assess the situation, a vessel shall slacken her speed or take all way off by stopping or reversing her means of propulsion.

it was considered underway in accordance with the Inland Rules because it was not at anchor, made fast to the shore, or aground.⁴⁹

While the USV was underway near the WE08 site, the recreational vessel owner was transiting back to Safe Harbor Toledo Beach on a southwest heading at cruising speed (about 25 mph). Having owned and operated vessels in the Monroe area for over 20 years, the operator had a thorough understanding of the area and was navigating his vessel visually. Although the sun was positioned at a low angle in the western sky off the starboard side of the vessel, the operator told investigators that the sun was not impairing his vision. He stated there was about 2–3 miles of visibility.

With an overall length of 15.7 feet, the USV had a similar length to a small-sized recreational vessel such as a kayak, canoe, rowboat, or powered skiff. The USV had a yellow hull, meant to help make it more visible to other vessel operators. However, due to the vessel's design, only about 1 foot of freeboard was visible. Additionally, most of the main deck was covered with solar paneling, which was dark in color, thus obscuring the vessel's yellow coloring and making it blend in with the surrounding water. At the time of the collision, waves were 3 feet, which would have intermittently obscured the USV's hull as it dropped through the troughs of the waves and made it difficult to discern the USV in the water (figure 15 shows the vessel underway in similar wave conditions). Further, most of the USV's hull appeared dark yellow when viewed from the side, as the vessel's design cast a shadow on the hull.



Figure 15. Portside view of the GLERL USV while underway. (Source: SeaTrac)

⁴⁹ See [Rule 3 of the Inland Navigation Rules](#) (Title 33 *CFR* section 83.03)

Given the distance was about 2.5 miles from the western shore, recreational vessels operating in the same area as the GLERL USV would likely not expect to encounter smaller vessels with low freeboard and without tall masts, such as canoes, kayaks, rowboats, and powered skiffs. Additionally, it was about an hour before sunset, when operators of these smaller vessels are not typically offshore. The USV's size and general appearance made it inconspicuous and difficult to visually perceive as the recreational vessel operator approached it while underway at cruising speed.

Mid- to large-sized recreational vessels are frequently equipped with radar, as was the case with the recreational vessel involved in the collision. The recreational vessel's radar was not in use at the time of the collision. However, even if the operator had been using it, the USV likely would not have been visible on radar given the USV's small size, fiberglass hull, and lack of radar reflector—a device designed to help vessels become more visible on the radar display of other vessels (the USV was not required to have a radar reflector).

The USV was equipped with AIS Class B, which provides safety and navigation benefits by providing the USV's position to other vessels. Like the AIS Class A typically found on large ocean-going vessels, AIS Class B can augment a navigational watch by providing dynamic vessel data in real time, allowing for the verification of surrounding traffic information used in collision avoidance decision-making. According to SeaTrac, the USV's AIS was powered on and set to transmit at the time of the collision.

Large ocean-going and Great Lakes commercial vessels are equipped with Class A AIS and transit shipping routes. Due to the shallow depth in the area, these vessels typically would not operate where the GLERL USV was underway at the time of the collision. In contrast, most recreational vessels propelled only by a motor—including the recreational vessel involved in the collision—are not equipped with AIS (Class A or Class B), nor are they required to be, and thus would not be able to identify the USV using AIS. Therefore, it is unlikely that the USV would be perceived electronically by the vessel traffic typically in the area.

The USV also had no auditory means to signal its presence to other vessels. Its weedless propeller was driven by a battery-powered electric motor that made

minimal noise, and the vessel did not have any other sound signaling device, as required by the Inland Rules.⁵⁰

Because the operator of the recreational vessel could not easily perceive the GLERL USV, he could not act appropriately to avoid the collision. The NTSB concludes that, given GLERL's operation of the SeaTrac SP-48 USV in an area offshore frequented by recreational vessels, the USV's visual, electronic, and auditory perceptibility were inadequate.

SeaTrac told investigators that the company had sold 25 model SP-48 USVs (like the GLERL USV) as of June 2026. As a result of the collision, SeaTrac modified its SP-48 USVs so that the combined lantern on the masthead was capable of flashing white all around and to improve the reception and transmission ranges of the AIS antenna and supporting electrical systems. Additionally, SeaTrac added an optional reflection kit, which included a "passive radar reflector" and reflecting tape. However, these modifications would not have prevented the collision or enhanced the USV's visual or auditory perceptibility. Although a flashing all around light could have drawn the attention of a recreational vessel operator, the ability to see it would have depended on environmental conditions. The daylight conditions at the time of the collision could have made a flashing light difficult to discern from background clutter such as the shoreline, especially combined with the weather conditions—choppy waves from the 18-knot winds—causing the vessel to be in motion. Further, because recreational vessels operating in inland waters or near shore, like the Prestige 450 Flybridge, do not typically have AIS, and the Prestige 450 Flybridge was not using radar at the time of the collision, the USV's AIS antenna and the optional radar reflector would not have been effective. Therefore, additional measures are needed to improve the perceptibility of SeaTrac SP-48 USVs. The NTSB recommends that SeaTrac modify the design of the SP-48 uncrewed surface vessel to further enhance its perceptibility as practicable given the nature of the USV's work and area of operation.

As a result of the collision, NOAA issued Administrative Order NAO 212-19 and, in accordance with the order, produced its "Uncrewed Marine Systems Manual," which provides agency requirements for the operation of USVs. Among the policies included in the manual was the requirement to "equip NOAA UMS in such a manner

⁵⁰ Rule 33 requires that any vessel "less than 12 meters in length shall not be obliged to carry the sound signaling appliances prescribed in paragraph (a) of this Rule but if she does not, she shall be provided with some other means of making an efficient sound." Paragraph (a) states that a "whistle" means "any sound signaling appliance capable of producing the prescribed blasts and which complies with specifications in Annex II" of the Rules. See [Inland Navigation Rules](#).

as to minimize risk of collision,” including “the appropriate use of lights, sounds, markings, and electronic signals to ensure that NOAA UMS can be detected, identified, and avoided.” The manual stated that NOAA UMS should be highly visible, with radar reflectors or other reflective markings as well as markings identifying the vessel as uncrewed. The manual also requires sound-producing and listening devices “that mimic the requirements for providing and monitoring audible alerts/warnings.”

Some of the markings, equipment, or technology listed in the UMS may have improved the perceptibility of the GLERL SeaTrac SP-48. For example, a sound-producing device could have been used to alert nearby vessels to the USV’s presence. Others, such as the high visibility coloration and markings identifying the vessel as “uncrewed,” were included for the GLERL USV. It was bright yellow and marked “UNCREWED SURFACE VESSEL” on its stern. However, even with this coloration and marking, the USV was not perceptible to the Prestige 450 Flybridge operator in the time leading up to the collision.

The UMS manual required staff to conduct “an assessment of the risks associated with the use and/or operation of a NOAA UMS prior to such use or operation.” This included consideration of “circumstances with respect to the operating area.” However, a risk assessment may not have identified that the GLERL SeaTrac SP-48 was not easily perceptible to other vessel operators, such as the Prestige 450 Flybridge operator, in the area where it was underway in adapted hold mode.

GLERL did not conduct testing of the SeaTrac SP-48 to determine its perceptibility in the area near the WE08 site before regularly operating it there, nor was there any requirement to do so in GLERL or NOAA guidance or in regulations. The navigation tools the USV was equipped with, such as AIS, were intended to help make it more perceptible to other vessels. However, GLERL staff were unaware of how vessels that typically operated in the area would, or whether they could, perceive the USV. For example, GLERL did not know whether the SeaTrac SP-48 would register a signature on another vessel’s radar.

Knowledge of a vessel’s perceptibility is key to understanding how it must be operated in order to mitigate the risk of collision. If a vessel operator cannot perceive another vessel, the operator cannot recognize the risk of collision and take action to avoid it. Therefore, the NTSB concludes that had GLERL tested the SeaTrac SP-48’s perceptibility to operators of other vessels typically in the USV’s area of operation, GLERL could have identified the USV’s inadequate perceptibility and determined that the USV was a navigational hazard for surrounding vessel traffic.

As of the publication of this report, NOAA organizations operate seven other USVs, including three SeaTrac SP-48 USVs. USVs used by NOAA organizations are commonly adapted to perform a variety of specialized tasks, and NOAA organizations may operate other types or models of USVs in the future. Therefore, the NTSB recommends that NOAA revise its “Uncrewed Marine Systems Manual” to ensure all USVs are perceptible to vessel traffic given the vessel’s area of operation. The NTSB further recommends that NOAA incorporate into its “Uncrewed Marine Systems Manual” a requirement for testing of USVs it operates to ensure adequate perceptibility to operators of other vessels typically in the USV’s area of operation.

At the time of the collision, USVs in the same type of service as the GLERL SeaTrac SP-48 were typically outfitted to meet perceptibility standards based on their size, propulsion type, and area of operation. For a power-driven vessel the size of the GLERL USV, the Inland Rules required an all-around white light and side lights, or a combined lantern—like the GLERL USV had.⁵¹ However, there were no rules in the Inland Rules specific to USVs. Additionally, there were no industry-wide perceptibility standards specific to USVs operating in US inland and territorial waters. Coast Guard regulations focused solely on Coast Guard acceptance of automated systems and requirements for periodically unattended machinery plants, not uncrewed surface vessels. The Coast Guard had limited guidance related to testing of “remote and autonomous vessel systems,” but it was for Coast Guard personnel, not USV operators.

As a result of the collision, the Coast Guard GLD issued two safety recommendations to create regional and national policies and/or guidance for “autonomous surface vessels.” As of the publication of this report, the Coast Guard is still processing these recommendations, and no formal policies have been adopted as a result of these recommendations. The Coast Guard also released an MSIB to provide awareness of the operation of USVs on the Great Lakes. The MSIBs included a list of common identifiers of USVs to aid Great Lakes commercial and recreational mariners in sighting and avoiding USVs. However, MSIBs are guidance and thus not mandatory.

In June 2026, the Coast Guard issued a work instruction providing guidance related to the operation of unmanned systems, procedures for remote and autonomous systems on inspected vessels, and stakeholder engagement to communicate unmanned systems operations. However, the work instruction is not applicable to NOAA vessels like the GLERL USV because the National Defense

⁵¹ See [Rule 23 of the Inland Rules](#) (33 CFR section 83.23).

Authorization Act for Fiscal Year 2026 exempts small uncrewed vessels operated by NOAA from:

Any vessel inspection, design, operations, navigation, credentialing, or training requirement, law, or regulation that ... will harm real-time operational extreme weather oceanographic and atmospheric data collection and predictions.⁵²

Additionally, the work instruction does not provide specific standards regarding the perceptibility of USVs.

As USVs become more commonplace in US waterways, it is critical for the Coast Guard to begin to set standards and policies for these vessels. Therefore, the NTSB concludes that additional standards are necessary to enhance and ensure the perceptibility, collision avoidance capability, and navigational safety of USVs. The NTSB recommends that the Coast Guard develop and promulgate a national framework of perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels. The NTSB also recommends that the Coast Guard incorporate perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels into regulations.

2.2.2 Operation of Great Lakes Environmental Research Laboratory Uncrewed Surface Vessel

On the day of the collision, the GLERL USV was operating in adapted hold mode in an area where it was common for recreational vessel traffic to transit at a high rate of speed. A GLERL pilot passively monitored the USV by periodically checking the dashboard and having automatic status alert notifications (emails and texts) set to monitor the vessel.

When the USV was in adapted hold mode, it could detect other vessels using its AIS detection feature. However, the AIS detection feature would not prompt the vessel to maneuver autonomously to avoid a collision. Instead, if the USV detected another vessel transmitting AIS nearby and within a range defined by the USV pilot, the pilot would be notified via email or text. The pilot then had to activate the vessel and maneuver it from its hold waypoint.

Since most recreational vessels are not equipped with AIS, any recreational vessels operating in the area and approaching the USV—including the Prestige 450

⁵² See [Pub. L 119-60](#).

Flybridge—would not have triggered the USV's AIS detection feature and notified the pilot. Additionally, if a vessel did trigger the AIS detection feature and notify the pilot, it would have taken the pilot about 1–5 minutes (and up to 10 minutes) to activate and maneuver the vessel. As nearby vessels converge on a position, particularly with a high rate of closure, vessel operators must have the capability to take timely, positive action. Depending on the rate of closure between two vessels, even 1 minute can be critical in a collision avoidance situation.

When in use, the USV's four cameras gave the pilot (remote operator) a 360° view of the waterway surrounding the vessel, including any approaching vessels. Although GLERL had also tested the cameras' collision avoidance software, the cameras were not used for traffic monitoring and collision avoidance like the AIS detection feature, but rather for overall monitoring of the navigational environment as the pilot found necessary. To prevent high data usage and conserve battery power, the cameras were only turned on occasionally, and at the time of the casualty, they were off.

Given the vessel's limited autonomous capability and the time needed to get the USV underway to avoid a potential collision, maintaining an active lookout was critical. A proper lookout is essential in determining the risk of collision for both traditionally crewed vessels and uncrewed or autonomous vessels. A proper lookout means effectively using all available resources, including visual scanning, radars, AIS, and sound, to increase situation awareness. According to the USV manufacturer, piloting a USV was "a 24/7 operation." However, when the USV was in adapted hold mode, GLERL pilots did not actively monitor the vessel. Instead, they periodically checked the dashboard and had automatic status alert notifications set to monitor the vessel. Without a proper lookout, the vessel had no means to identify approaching vessels and then act to maneuver the USV. Further, the USV pilot and GLERL were unaware the USV was involved in a collision until over 30 minutes after the collision.

When a vessel approaches another vessel, its operator makes assumptions about how the other vessel will operate and how each vessel should maneuver to avoid collision based on the Inland Rules. Because the GLERL USV relied on set waypoints in adapted hold mode, it was not capable of maneuvering on its own in accordance with the Inland Rules and thus in a way another vessel's operator would expect it to as the operator approached. The USV was, effectively, a hazard to navigation for other vessels transiting in the area.⁵³ Therefore, the NTSB concludes

⁵³ According to [33 CFR Part 64](#), *hazard to navigation* means "an obstruction, usually sunken, that presents sufficient danger to navigation so as to require expeditious, affirmative action such as marking, removal, or redefinition of a designated waterway to provide for navigational safety."

that GLERL's configuration and operation of the SeaTrac SP-48 USV in "adapted hold" mode without active monitoring left the USV without a proper lookout, which, combined with the USV's inadequate perceptibility, rendered the USV vulnerable to collision in the area in which it was operating.

On the Autonomous Vessel Information Request form submitted to the Coast Guard in 2024, GLERL indicated the SeaTrac SP-48 USV was designed with a level of autonomy such that the vessel's "decisions on navigation and operational actions are calculated by the system which executes what has been calculated according to the operator's approval" (see section 1.5.4). However, while in adapted hold mode, the USV could not calculate decisions regarding navigation or operational action. Instead, while the GLERL USV was underway in adapted hold mode, a GLERL pilot remotely monitored its condition, relying on the vessel to automatically maintain a series of waypoints set by the pilot.

If a vessel cannot effectively maneuver to avoid a potential collision in accordance with the Inland Rules, it is critical that the vessel's operator carefully consider the vessel's area and mode of operation, accounting for typical vessel traffic and waterway and environmental conditions, to mitigate the risk of a collision. Regardless of a vessel's presumed level of autonomy, an operator is responsible for ensuring it is safe to operate in a chosen area and ensuring an adequate level of active monitoring is maintained. The NTSB concludes that given the SeaTrac SP-48 USV's low level of autonomy in adapted hold mode, GLERL's monitoring of the vessel was not sufficient to safely operate it in an area offshore frequented by recreational vessels.

The "NOAA Unmanned Marine Systems Manual," developed as a result of the collision, requires NOAA's USV operators to conduct an assessment of risks associated with the operation of a USV, including consideration of weather and environmental conditions, anticipated failure modes, and vessel traffic. However, the manual does not require operators to determine the level of active monitoring of a USV based on its level of autonomy in each mode of operation. Therefore, the NTSB recommends that NOAA require its USVs to be monitored at a level commensurate with the USV's actual level of autonomy, factoring the vessel's area and mode of operation.

3 Conclusions

3.1 Findings

1. None of the following were factors in this casualty: (1) mechanical equipment or electrical system failure or (2) uncrewed surface vessel human machine interface (“dashboard”) connectivity.
2. Given the Great Lakes Environmental Research Laboratory’s operation of the SeaTrac SP-48 uncrewed surface vessel in an area offshore frequented by recreational vessels, the uncrewed surface vessel’s visual, electronic, and auditory perceptibility were inadequate.
3. Had the Great Lakes Environmental Research Laboratory (GLERL) tested the SeaTrac SP-48’s perceptibility to operators of other vessels typically in the uncrewed surface vessel’s (USV) area of operation, GLERL could have identified the USV’s inadequate perceptibility and determined that the USV was a navigational hazard for surrounding vessel traffic.
4. Additional standards are necessary to enhance and ensure the perceptibility, collision avoidance capability, and navigational safety of uncrewed surface vessels.
5. The Great Lakes Environmental Research Laboratory’s configuration and operation of the SeaTrac SP-48 uncrewed surface vessel (USV) in “adapted hold” mode without active monitoring left the USV without a proper lookout, which, combined with the USV’s inadequate perceptibility, rendered the USV vulnerable to collision in the area in which it was operating.
6. Given the SeaTrac SP-48 uncrewed surface vessel’s low level of autonomy in adapted hold mode, the Great Lakes Environmental Research Laboratory’s monitoring of the vessel was not sufficient to safely operate it in an area offshore frequented by recreational vessels.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory uncrewed surface vessel (USV) and recreational vessel was the inadequate perceptibility of the USV to nearby vessels, given the operating area and conditions, and the lack of active monitoring given the vessel’s configuration, mode of operation, and level of autonomy, which left the USV without a proper lookout to avoid a collision.

4 Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations.

To the US Coast Guard:

Develop and promulgate a national framework of perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels. (M-26-03)

Incorporate perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels into regulations. (M-26-04)

To the National Oceanic and Atmospheric Administration:

Revise your “Uncrewed Marine Systems Manual” to ensure all uncrewed surface vessels are perceptible to vessel traffic given the vessel’s area of operation. (M-26-05)

Incorporate into your “Uncrewed Marine Systems Manual” a requirement for testing of uncrewed surface vessels you operate to ensure adequate perceptibility to operators of other vessels typically in the uncrewed surface vessel’s area of operation. (M-26-06)

Require your uncrewed surface vessels to be monitored at a level commensurate with the uncrewed surface vessel’s actual level of autonomy, factoring the vessel’s area and mode of operation. (M-26-07)

To SeaTrac Systems, Inc.:

Modify the design of the SP-48 uncrewed surface vessel to further enhance its perceptibility as practicable given the nature of the uncrewed surface vessel’s work and area of operation. (M-26-08)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER L. HOMENDY

Chairwoman

MICHAEL GRAHAM

Vice Chairman

THOMAS CHAPMAN

Member

JOHN DELEEuw

Member

Report Date: October 7, 2026

Appendixes

Appendix A: Investigation

The US Coast Guard was the lead federal agency in this safety investigation. The National Transportation Safety Board (NTSB) learned of this casualty from the Coast Guard on August 10, 2024, and an NTSB marine accident investigator arrived on scene in Ann Arbor, Michigan, and La Salle, Michigan, on August 13, 2024.

While on scene, the NTSB participated with the Coast Guard in joint interviews of the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory (GLERL) staff involved in the project. Investigators also examined both vessels, gathered documentation, and retrieved physical evidence relevant to the casualty. After conducting on scene activities, the NTSB participated with the Coast Guard in joint interviews conducted virtually with a research vessel captain contracted by GLERL, the SeaTrac founders and director, the Prestige 450 Flybridge recreational vessel operator, and the National Oceanic and Atmospheric Administration's Director of Uncrewed Systems Operation Center.

The Coast Guard, GLERL, and SeaTrac Systems, Inc. were parties to the investigation.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code (USC)* 1117(b) requires the following information on the recommendations in this report.

For each recommendation—

(1) a brief summary of the Board’s collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board’s use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the US Coast Guard

M-26-03

Develop and promulgate a national framework of perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1, Perceptibility of Uncrewed Surface Vessels. Information supporting (b)(1) can be found on pages 36–42; (b)(2) can be found on pages 26–30; and (b)(3) can be found on pages 30–34.

M-26-04

Incorporate perceptibility, collision avoidance capability, and navigational safety standards for uncrewed surface vessels into regulations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1, Perceptibility of Uncrewed Surface Vessels. Information supporting (b)(1) can be found on pages 36–42; (b)(2) can be found on pages 26–30; and (b)(3) can be found on pages 30–34.

To the National Oceanic and Atmospheric Administration

M-26-05

Revise your “Uncrewed Marine Systems Manual” to ensure all uncrewed surface vessels are perceptible to vessel traffic given the vessel’s area of operation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1, Perceptibility of Uncrewed Surface Vessels. Information supporting (b)(1) can be found on pages 36-42; (b)(2) can be found on pages 26-30; and (b)(3) can be found on pages 30-34.

M-26-06

Incorporate into your “Uncrewed Marine Systems Manual” a requirement for testing of uncrewed surface vessels you operate to ensure adequate perceptibility to operators of other vessels typically in the uncrewed surface vessel’s area of operation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1, Perceptibility of Uncrewed Surface Vessels. Information supporting (b)(1) can be found on pages 36-42; (b)(2) can be found on pages 26-30; and (b)(3) can be found on pages 30-34.

M-26-07

Require your uncrewed surface vessels to be monitored at a level commensurate with the uncrewed surface vessel’s actual level of autonomy, factoring the vessel’s area and mode of operation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.2, Operation of Great Lakes Environmental Research Laboratory Uncrewed Surface Vessel. Information supporting (b)(1) can be found on pages 42-44; (b)(2) can be found on pages 26-30; and (b)(3) can be found on pages 30-34.

To SeaTrac Systems, Inc.

M-26-08

Modify the design of the SP-48 uncrewed surface vessel to further enhance its perceptibility as practicable given the nature of the uncrewed surface vessel’s work and area of operation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1, Perceptibility of Uncrewed Surface Vessels. Information

supporting (b)(1) can be found on pages 36-42; (b)(2) can be found on pages 26-30; and (b)(3) can be found on pages 30-34.

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Casualty Summary

NTSB Casualty Category	Collision
Location	Lake Erie, about 6 miles east-southeast of Monroe, Michigan 41°50.08' N, 083°21.33' W
Date	August 10, 2024
Time	1912 eastern daylight time (coordinated universal time –4 hours)
Injuries	1 minor
Property damage	\$286,000 est. (\$186,000 uncrewed surface vessel; \$100,000 recreational vessel)
Environmental damage	None
Persons on board	None (uncrewed surface vessel), 2 (recreational vessel)

NTSB investigators worked closely with our counterparts from **Coast Guard Marine Safety Unit Toledo** throughout this investigation.

The NTSB is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in the other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)).

For more detailed background information on this report, visit the [NTSB Case Analysis and Reporting Online \(CAROL\) website](#) and search for NTSB accident ID DCA24PM057. Recent publications are available in their entirety on the [NTSB website](#). Other information about available publications also may be obtained from the website or by contacting –

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