National Transportation Safety Board
Office of Marine Safety
Washington, DC 20594

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NAUTICAL OPERATIONS

Group Chair's Factual Report
25 March 2025

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A ACCIDENT

Location: North Atlantic Ocean
Date: June 18, 2023
Time: 1047 Newfoundland daylight time
1317 coordinated universal time (UTC)
Manned submersible: *Titan*

B NAUTICAL OPERATIONS GROUP

Group Chair / IIC — Mr. Marcel L. Muise
National Transportation Safety Board
Washington, DC

Party Coordinator — Mr. Jason Neubauer
U.S. Coast Guard
Washington, DC

C SUMMARY[1]

Figure 1. Submersible Titan on platform in 2022, aboard the surface tender Horizon Arctic. (Source: Garry Comber)

[1] "For the purposes of this document; submersible, submarine, and sub have no difference in meaning.

D DETAILS OF THE INVESTIGATION

1.0 Background

On June 18, 2023, about 1740 eastern daylight time, the US Coast Guard was notified that the 21-foot-long submersible *Titan* had not returned to the Canadian general cargo vessel *Polar Prince*, which was on station about 900 nautical miles east of Cape Cod, Massachusetts. The *Titan* had submerged at 0905 earlier that day with five persons on board and was scheduled to surface in the afternoon after viewing the wreckage of the *Titanic*, but the *Polar Prince* lost contact with the submersible about one hour and 45 minutes into its voyage. On June 22, about 1500, the Coast Guard announced that the *Titan's* tail cone and additional debris had been found. All five persons on board are presumed dead.

1.1 Early events

OceanGate LLC was formed in October 2009 with a vision to provide submersibles for charter, anywhere in the world, with no dedicated surface tender.[2] At the time most submersibles had dedicated surface tenders with high fuel costs and whose size was driven by the size of a crane needed to launch a submersible. OceanGate intended to offer submersibles that could fit in standard containers and used a vessel of opportunity.

The original CEO and co-founder, testified the original intention was not to build a submersible, let alone a carbon fiber one. OceanGate acquired *Antipodes* in 2009, an ABS-classed, steel hull with a rated depth to 300 m in order to learn submersible operations. They operated *Antipodes* on expeditions in Puget Sound, Monterrey Bay, and the Catalina Islands. Manufacturers at the time could not meet their specific requirements and they realized they needed to manufacture their own vehicles.

In 2013, OceanGate began the process of designing and building their own submersible. The original CEO with a background in business start-ups, left the company and the remaining co-founder, an engineer by training, became CEO.

The company then acquired the 500 m capable *Lula 500*. The submersible was brought from the Azores to Florida and was stripped to just the steel hull. The engine was also removed. Only the viewport, the steel hull, and the conning tower with hatch remained classed by ABS. The vessel, renamed *Cyclops,* was then used as a prototype for the *Titan* program.

All three terms are used interchangeably to describe any self-propelled vessel carrying passengers and crew which is designed to operate on the surface, submerge, operate submerged, surface and remain afloat."

[2] For the purpose of this report surface tender refers to a surface vessel, chase vessel, or shore-based facility providing support to submersible.

The University of Washington's Applied Physics Lab (APL-UW) had some experience in submersibles from the DeepGlider program. They were enlisted to design the mechanical and electrical systems that were installed aboard *Cyclops* and used as proof of concept for *Cyclops II,* renamed *Titan* in the autumn of 2017. APL-UW's design responsibility shifted to OceanGate's in house engineering department in March 2016 when they hired a Director of Engineering.

1.2 Construction

Carbon fiber. OceanGate chose to use a carbon fiber hull, which according to the CEO would be "better in compression than tension" and was lighter requiring less buoyancy. He reiterated his confidence in the material in a 2018 exit interview of the Director of Operations. "…the Navy has been against it, and the orthodoxy of the submersible world have been against it, and they talk about capricious failure modes, and they talked about porosity, and they talk about all these little things. And the world is coming around to understand that, in fact, carbon fiber is perfect for pressure vessels. It's the only material for pressure vessels… It doesn't require extra buoyancy."[3]

Another carbon fiber submersible, what would later be the *DeepFlight Challenger*, was built for the late adventure explorer, Steve Fossett. That hull was built by Hawkes Ocean Technologies and the carbon fiber hull laid up by Spencer Composites. It developed a leak at the hull and dome mating surface. The CEOs of Hawkes Ocean Technologies and OceanGate were introduced to each other. OceanGate also hired Spencer Composites for *Titan's* hull although it is unknown how much experience and innovation of the *DeepFlight Challenger* was used in the design and construction of *Titan*.

Carbon fiber is a high strength, light weight material. It reduces the need for syntactic foam for buoyancy, allows launching with a smaller davit or crane, and increases the size of the hull for more occupants. External pressure, however, acts perpendicular to the carbon fibers and it will fail catastrophically when loaded beyond limits. It has no plasticity and no well-established yield point. Stress and strain are linear up to a failure point.

Common failure modes of carbon fiber hulls include delamination (separation of the carbon fiber plies), fatigue damage from repeated pressure cycles, hidden cracks, localized over-loading, debonding (stands coming out of the epoxy matrix due to failure of adhesion), fiber breakage (manufacturing defects, high stress, impact loads), matrix cracking (cracks in the epoxy from fatigue). The hull needed to be protected by a coating or covering from impact damage and prolonged UV exposure which would damage the epoxy resin. Salt-water intrusion can also cause delamination if there are voids in the carbon fiber.

[3] Lockridge, David, interview by Stockton Rush, January 19, 2018, 33.

Titan's carbon fiber hull was also cylindrical. Industry leaders testified that spherical hulls are best, if not ubiquitous, at depths below 1000 m. The hoop stress in such hulls is half that of a cylindrical hull such as *Titan*'s

The first hull. The CEO stated that they told Spencer Composites that they originally wanted a vehicle rated for 6000 m with a safety factor of 2.5 and a 4.5-inch thick hull. According to the former director of engineering, the as-built 5-inch thick hull provided a safety factor of 2.25. *Titan's* first hull was laid up by Spencer Composites in 2018..

Excess carbon fiber was trimmed from each end of the hull and titanium rings glued on it. The aft dome was bolted on to the aft ring and never removed. The forward dome had 18 bolts but was primarily held on by sea pressure. According to the former director of engineering, an O-Ring was added to the forward ring which mated with the hinged forward dome although the CEO stated it was unnecessary due to the metal to metal seal under high-pressure. In an exit interview of the director of marine operations in 2018, the CEO stated that the weakest link was the titanium dome. He was very concerned with someone being hit, injured, or both by the dome.

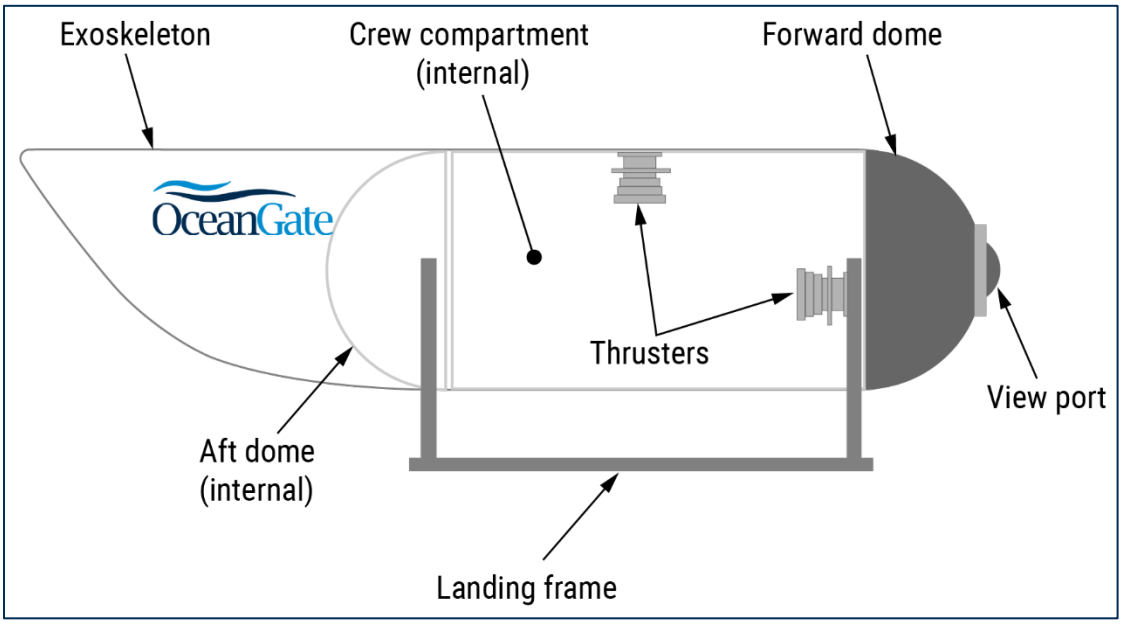

Figure 2. Profile view of Titan (scale approximate).

Testing and sea trials. OceanGate could not carry out ultrasonic testing (UT) of the scale model due to a coating Spencer Composites had applied on the outside. They considered UT of the final hull at Boeing but to do so would have required building a unique jig to stand the hull on end to test something this large and this thick. According to a former director of marine operations, the CEO put large confidence in the real time monitoring (RTM) system, justifying a decision not to UT the hull. RTM included both acoustic emissions (AE) sensors and strain gauges. According to the former director of engineering, the schedule and budget did not allow for this. OceanGate and Boeing did test an end piece that had been cut off the

scale model and left uncoated. The test found what was thought to be a delamination consistent with what was later found in the first full-size hull.

OceanGate sent *Titan's* first hull to Great Abaco Island in The Bahamas for sea trials in 2018 through April 2019. The Bahamas were chosen as they could reach 4000 m depths close to shore – just a day trip. The first test dive was unmanned with the vehicle suspended from a line. The CEO personally test dove the submersible, alone on subsequent dives, until about December 2018, when he took additional crew. All reported cracking sounds.

OceanGate planned to take *Titan* to the *Titanic* site in 2019 until the submersible was hit by lightning in 2018 which required a rebuild of all the electronics. The vehicle was sitting on a wooden deck flatbed trailer, turned off, with no lightning protection when it was struck. OceanGate had already booked clients for *Titanic* trips for the 2019 summer expedition.

The former director of engineering wrote two reports documenting concerns. "We were diving it after the lightning strike not knowing that there was any damage inside."[4] He also pushed for additional dives to analyze more acoustic data and establish a baseline for the RTM system.

A guest who participated in the last dive to depth on April 17, 2019, testified that he heard heard a loud bang. This same guest built and operated his own submersibles. In an email to the CEO the following day, he concluded there was "an area of the hill that is breaking down/ getting spongy." He further opined that the proposed 2 to 7 additional test dives were too few and shared that he had done 50 dives in his first submersible, *C-bug,* before carrying passengers.

On May 13, 2019, following a test dive, one of the dive pilots noticed a hairline fracture in the hull, inside the clevis of the forward titanium ring. The COO described it as half-inch deep. At this point the submersible had had about 12 dives below 2,500 m. The former director of engineering, who also refused to dive, himself, in the vehicle because he didn't trust Operations Department crews, then left the company in July 2019.

The new COO, who had previously consulted as a project manager, was hired in April 2019. Planning for the 2019 expedition was well underway at the time. The surface tender, the offshore supply vessel (OSV) *Havila Harmony*, had cancelled according to the director of administration.[5] The OSV operator had offered another vessel which did not meet OceanGate's needs and clients were notified of the cancelled expedition. A mission specialist testified that they were told the *Titanic* expedition was cancelled due to the surface tender cancelling and because OceanGate had to build a new hull.

The hull was shipped to Everett, Washington, thence to the Deep Ocean Test Facility (DOTF) in Annapolis, Maryland, then operated by Northrup Grumman in October 2019. The hull was condemned following this testing and a planned 2020 expedition to *Titanic* was postponed. A new Director of Engineering was promoted

[4] Nissen, Antonio, interview by U.S. Coast Guard Marine Board of Investigation, August 9, 2023, 57.
[5] *Havila Harmony,* IMO No. 9343596 was a Norwegian flagged, 93-meter-long offshore supply vessel. The ship was later reflagged in Brazil and renamed *Parcel Dos Meros*.

and a new COO took on the role of organizing external help including NASA and the DOTF.

NASA, Electroimpact, and the second hull. OceanGate engaged NASA, through their business development program, to build a second carbon fiber hull. NASA had no expertise in submersibles but they did have an interest in carbon fiber structures. OceanGate selected Toray's carbon fiber after considering 3M and Hexel. 300 pounds of carbon fiber were delivered to NASA in March 2020 and was stowed in cold storage. The Marshall Space Flight Center, however, shut down during the COVID pandemic. Following COVID however NASA returned the material and approximately $124,000 of the $148,874 paid by OceanGate.

A scale model of the second hull was tested at UW's Oceanography Lab on July 26, 2020. This model included active strain gauges and AE sensors. The hull imploded at a 2,800 m equivalent pressure with an "ear splitting bang" according to the then director of engineering. On August 20, a second model was tested. They stopped the final test when it was clear the model was going to fail. These models were not multi-cured as the final hull was.[6]

Electroimpact of Mukilteo, Washington, was then contracted to construct the second full size hull. The mandrel used to build the first hull was reused. The completed *Titan*, with titanium rings and domes, and with the legs attached, was delivered to OceanGate on February 9, 2021. The hull underwent testing at DOTF and in Puget Sound. Once outfitted with tail, interior, and exterior equipment, OceanGate shipped the submersible and platform to Newfoundland for the 2021 expedition to *Titanic*.

1.3 Outfitting

A removable fiberglass insert held all the interior systems including oxygen tanks, deck, and control systems. This allowed for minimal contact with the inside surface of the carbon fiber hull itself. Some systems were upgraded for the second hull, including a different variable ballast system, drop weight motor actuators, navigation systems, compass, thruster pods with motor controllers, a different interior, and rewritten software.

A coating was applied to the outside of both hulls for impact protection and as a water barrier. The coating reportedly started to peel in the sun in The Bahamas on the first hull. The former director of engineering conceded that a concern was the "rhino liner doesn't work and some water gets in there and it freezes and they it starts to create, you know, voids."

1.3.1 Ballast

There were three ballast systems. There four drop weights per side with 25 to 30 pounds of steel shard each in a bag. These were operated by electric motors with

[6] Multi-cure involves curing each layer of the hull separate as they are added, vice the whole hull at once.

an emergency 28-volt lithium battery backup. Additionally, squibs would automatically release the ballast after 24 hours in the water forcing the submersible to the surface.

There was also a variable ballast system consisting of air bags supplied by high pressure air tank in the external tail. The crew could also drop the legs or the carriage. The drop weight motors and variable ballast could also be manually operated.

1.3.2 Propulsion

There were two horizontal and two vertical reversible 1002HL Hexscreen, oil filled, 150 V, 12 hp thrusters. (Lewis, p. 9). The make and model thrusters used for *Cyclops* were not available for *Titan*. As a result, *Titan's* control system was different.

1.3.3 Viewport

The original acrylic window was manufactured by Hydrospace and came with documentation certifying it to 1000 meters. Acrylic is used because, among other things, it is not brittle. The CEO and the former director of engineering stated that they were confident crews would know of any imminent failure due to acrylic's tendency to "craze" beforehand. A replacement manufactured by Heinz Fritz was in place on the accident voyage.

1.3.4 Electrical

Titan had three battery systems. Under the deck and internal to the submersible was a 24 V system through 6 V cells. Two 150 V batteries were installed externally in the tail solely for thruster power. There was also an emergency backup battery connected to the drop weight motors.

Internal to the submersible behind a bulkhead in the aft dome were three CPU's. The topmost was the "Control" CPU that ran the thrusters and using a Linux operating system. This CPU also logged data such as hull temperature and vacuum pressure. The was a media PC using Microsoft Windows and running other application such as the sonars and cameras. The third was the "logger" PC, also using Linux, and logging the AE and strain gauges.

The pilot ran the thrusters and drop weights using a game controller which communicated with control software. The submersible carried an extra controller and batteries. There was no other way to control thrusters without the game controller. On the pilot's display were several screens with tabs for hull sensors, acoustic and strain gauges, and battery management system. There was enough thruster battery power to maneuver to the LARS after four hours of thrusters use on the sea floor. On one occasion in 2022, *Titan* had to be towed to the LARS when battery power had run out.

1.3.5 Monitoring

The RTM system originally consisted of nine AE sensors and 18 strain gauges. The system was intended to detect elevated noise in the carbon fiber as strands failed, leading to a possible hull failure. OceanGate believed the system would allow the crew to abort a dive before the hull failed. The system gave the pilot go/no-go data. The CEO also claimed "…every other sub out there is unsafe. They should have strain gauges at every location on a steel sub."

Each sensor's data was displayed as a bar graph showing the level of acoustic activity. A "hit" was a burst of acoustic energy over 5000 acoustic-to-digital (A/D) units on a maximum scale of 32,000. Pre-programmed levels would trigger a green, yellow, or red indicator to the pilot. Pilots were to abort dives following a red alarm, indicating a possible imminent failure of the hull. After each dive a software engineer would graph the data from the acoustics system, but not the strain gauges.

There were eight acoustic sensors and 16 strain sensors on the final version of *Titan*.. The sensors were evenly distributed on the inside of the carbon fiber hull though none of the hull was accessible for visual inspection due to the interior fiberglass sleeve and the exterior polyurethane coating.

The system would not detect pre-existing anomalies. According to the former director of engineering, he insisted he alone would set the go/no-go thresholds although the CEO wanted control of that.

The data from the original 2018 dives in the Bahamas was flawed according to the director of engineering. The first good baseline data was when the first hull was tested in the DOTF. From the AE and the strain data, it appeared the hull would fail at about 2,800 m.

The same make and model sensors were used in the second *Titan* hull. One group of sensors became inoperative and the director of engineering suspected they were bumped while installing the submersible's insert. He suggested that the insert be removed to which the CEO declined citing there was no time. These sensors were still inoperative on the accident voyage.

AE is not commonly used in submersibles according to ABS.

1.3.6 Communications

Communications between the surface tender and submersible was done with acoustic underwater telephone. Communications checks would happen every 10 to 15 minutes. *Titan* had used a Sonardyne system on earlier expeditions which did not function well at depths less than 70 meters. Thruster noise would also interfere with communications including position data and text messages. They had also used a Kongsberg system which *Arctic Horizon* was outfitted with, but which *Polar Prince* was not. Kongsberg worked better near the surface according to the electrical engineer.

Horizon Arctic's Kongsberg acoustic system could track the submersible during the 2021 and 2022 expeditions. There was also a Teledyne transducer deployed from a small boat for use up to 1000 m. It was not rated beyond 1000m and staff then

switched to the Sonardyne system. OceanGate also rented a ship mounted transceiver. Kongsberg beacon was rented.

In 2023, OceanGate switched to an EvoLogics system for communications. This included transponders on the submersible and transducers suspended from the surface tender. There was also an EvoLogics transponder that could be deployed on the seabed for *Titan* to navigate without instruction from the surface tender although the bottom transponder was never used.

OceanGate manned a station on the bridge of the surface tender they called "the pit". This was in the chart room aboard *Polar Prince*. EvoLogics also had remote access to the data.

Titan was also outfitted with VHF radio and an Iridium satellite beacon to help find the submersible when it surfaced.

1.3.7 Launch and Recovery System (LARS)

OceanGate developed a floodable barge style LARS for *Cyclops* and for *Titan*, similar to one used by the University of Hawai'i for *Pisces IV* and *Pisces V*. . Divers opened valves to flood the barge, sinking it to 9.1 meters (30 feet). Divers would then release the submersible allowing it to thrust away.

The submersible landed on the submerged LARS at the end of a dive and was locked down by divers. Air stored in tanks on the LARS deck would displace the ballast water and the LARS surfaced with the submersible, in an advertised two minutes.

The LARS could be split in half for highway transport. According to the former director of engineering, towing *Titan* on the LARS in seas was not a problem. The LARS was towed in eight-foot seas in The Bahamas according to him.

The LARS relieved them from having a dedicated surface tender, saving costs. Launching from a platform negated the need for a ship mounted crane certified for manriding. Without a crane however, such as when towed by *Polar Prince,* there was no secondary means to recover *Titan* had the LARS sunk or otherwise become inoperable.

Submersibles are treated independently from the surface tenders by classification societies. Rules for launch systems, like cargo gear, are not mandatory but are available should an owner seek certification.

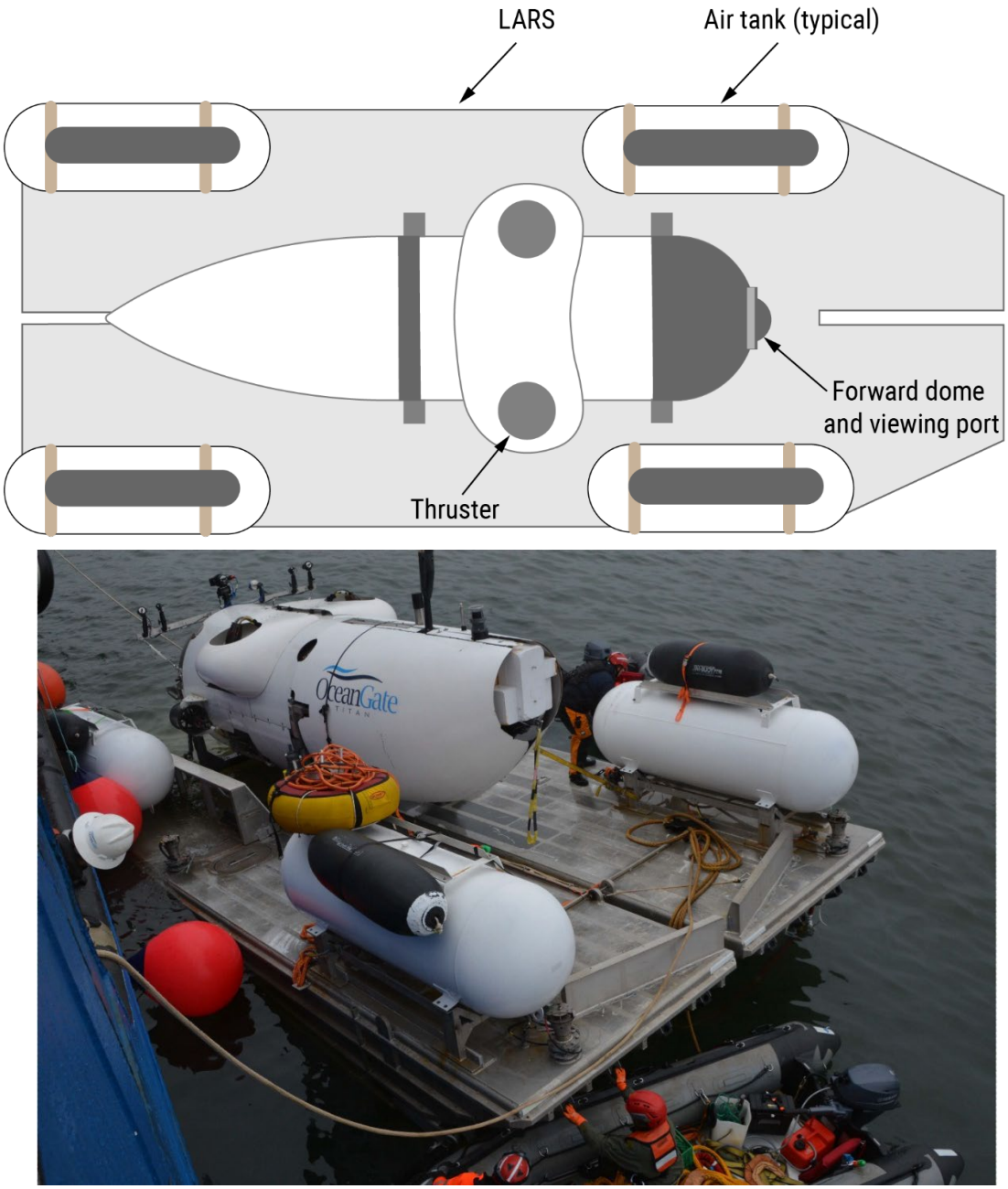

Figure 3. From top: Top-down view of *Titan* on LARS (scale approximate), and *Titan* secured on partially submerged LARS (*Titan's* forward dome is not secured on the submersible). (Source [bottom]: Coast Guard)

1.4 *Titan* operations

An OceanGate expedition was made up of one or more missions, or trips, to a dive site. A mission was made up of one or more dives. Mission specialists paid $250,000 for the opportunity to go on a mission in 2023, which included eight days aboard the ship and one dive. (The original cost was $109,000 in 2021). Local

contractors for photography, diving, and small boat operations, among others, would join the OceanGate staff on missions.

Prior to a mission, according to the Operations Manager, equipment was checked to include cameras, lights, thrusters, et cetera. Boats were inflated and fueled, compressors were conveniently staged, and spare equipment secured for sea. A dive brief would be held about 24 hours ahead of a dive and a "risk index" calculated.

Additional pre-dive checks were completed the morning of a dive. Upon boarding the LARS, a 3-person team had to open the dome using an Air Caster, called the dome dolly by the crew, and loosen the bolts.

The 6,000-pound titanium dome, with view port, was moved into position. There was an O-ring on the dome's face where it sealed with the submersible. This ring was protected by a plate while people boarded, and the dome team leader would inspect it for nicks and tears and wipe it clean but not necessarily replace it on every dive. There were four bolts that OceanGate determined were critical and were secured first followed by the others. The process took 11 to 35 minutes depending on crew experience. The dome team lead on the day of the accident confirmed that he had checked the torque on the bolts himself. A vacuum would be pulled on the submersible's interior, equivalent to an 800 m altitude.

On those expeditions using *Horizon Arctic,* in 2021 and 2022, the platform would be launched via a stern ramp off the deck. Otherwise, crew would be transferred via small boat. The mission director on the bridge of the surface tender would check with each station to ensure that checklists were complete. A five-minute planned hold, known as a "stopski" would occur to slow the forward motion of the operation. Everyone was to review their checklists for missed items, there was no talking amongst the players, and reflect on what they were about to do.

The platform pilot, in a dinghy, would then sink the platform until it was suspended by buoys. The submersible's pilot would then request permission to leave the platform and they would thrust off. If there was a problem with the vehicle, the platform would return to the surface with it. Otherwise, the submersible would continue on its way and the platform would surface to recharge the air tanks.

The submersible would establish communications and start its descent at about 30 meters per minute.. As the vessel approached the seabed, which at the *Titanic* site was 3880 m, the vehicle would slow its descent by dropping weights and becoming close to neutral buoyant. The submersible crew would conduct bottom checks to ensure everything was still working. The surface tender would then vector the submersible pilot to the *Titanic*.

Dives to the *Titanic* would take about eight hours including two and half hours to descend, three at the wreck, and two and a half to ascend. Crews in small boats would meet the submersible on the surface which then would thrust to and land on the submerged platform. Specific to operations with *Horizon Arctic,* the LARS with submersible would be winched onboard the OSV where the dome would be opened. Otherwise, the dome would be opened on the floating LARS, the crew exit, and board waiting small boats.

According to the operations manager there was never a time when *Titan* used emergency equipment such as releasing the legs and according to the director of administration, there were never any injuries.

1.5 Previous expeditions

2021. The 2021 expedition began on June 24. *Titan* was carried aboard the Canadian flagged OSV *Horizon Arctic* which was outfitted with a ramp with rollers off her stern. Each mission took two and half days to the wreck, three or four days on scene, and another two and half days' return. (*Horizon Arctic* could make the passage in a day and half but would cost more in fuel burn.) The expedition lasted six weeks, concluding on August 6. OceanGate then shipped *Titan* to Everett, Washington, for the winter.

Figure 4. Launching *Titan* and the LARS via stern ramp from *Arctic Horizon*. (Source: Garry Comber)

Former employees testified that the ramp configuration was hard on the vehicle as the ship pitched and heaved. The LARS would also seesaw on the ramp where it met the deck of the ship, slamming down on the deck if not carefully recovered. On the June 30, 2021 dive, the LARS came down on the deck with enough force that the bolts holding the forward dome sheared. The dome slid down and fetched up on a fitting without falling overboard, with occupants still in the now open submersible, though no one was injured. . On July 3, the next dive after the dome incident, OceanGate decided to put in all 18 bolts despite it taking longer to get the crew out on recovery. On another recovery there was a issue with the rollers on the ramp and the LARS had to be towed to St. John's.

2022. The 2022 expedition began June 12, again using *Horizon Arctic* as a surface tender. The expedition included five missions. On June 20, *Titan* explored *Titanic's* stern section, taking longer than normal on the sea bottom, and surfaced to

find rough seas. *Titan's* batteries died before landing on the LARS and there was no other way to recover the submersible nor for occupants to egress. The pilot was unable to thrust and divers were unable to lock the vessel in on the LARS due to the seas. *Titan* stayed on the surface overnight with crew onboard and was recovered in the morning.

On a July 9 dive, the drop weight motor mechanism failed and the crew had to use a hydraulic backup to drop weights. On July 15, a loud bang was heard inside the submersible and by the small boat crew on the surface as *Titan* ascended. The CEO described a sound like "a slap of the ruler on the table." Mission specialists both in the sub and on *Horizon Arctic* were told the bang was thought to be the *Titan's* fuselage shifting in the carriage. On a July 23 dive, the pilot (the COO on this occasion) heard something similar and the RTM system logged double the amount of AE hits.

The expedition ended on July 25 with seven successful dives to *Titanic*. Manned submersibles are normally kept in controlled conditions such as a hangar where they are not exposed and where personnel can work on them in clean environment.. *Titan,* however, was stowed in St. John's following the 2022 expedition. It was left on the pier, outside, covered with a tarp, until February 2023. OceanGate then moved *Titan* to an inside bay dedicated for Remotely Operated Vehicles (ROVs) at Memorial University's Marine Institute (MI).

2.0 Events

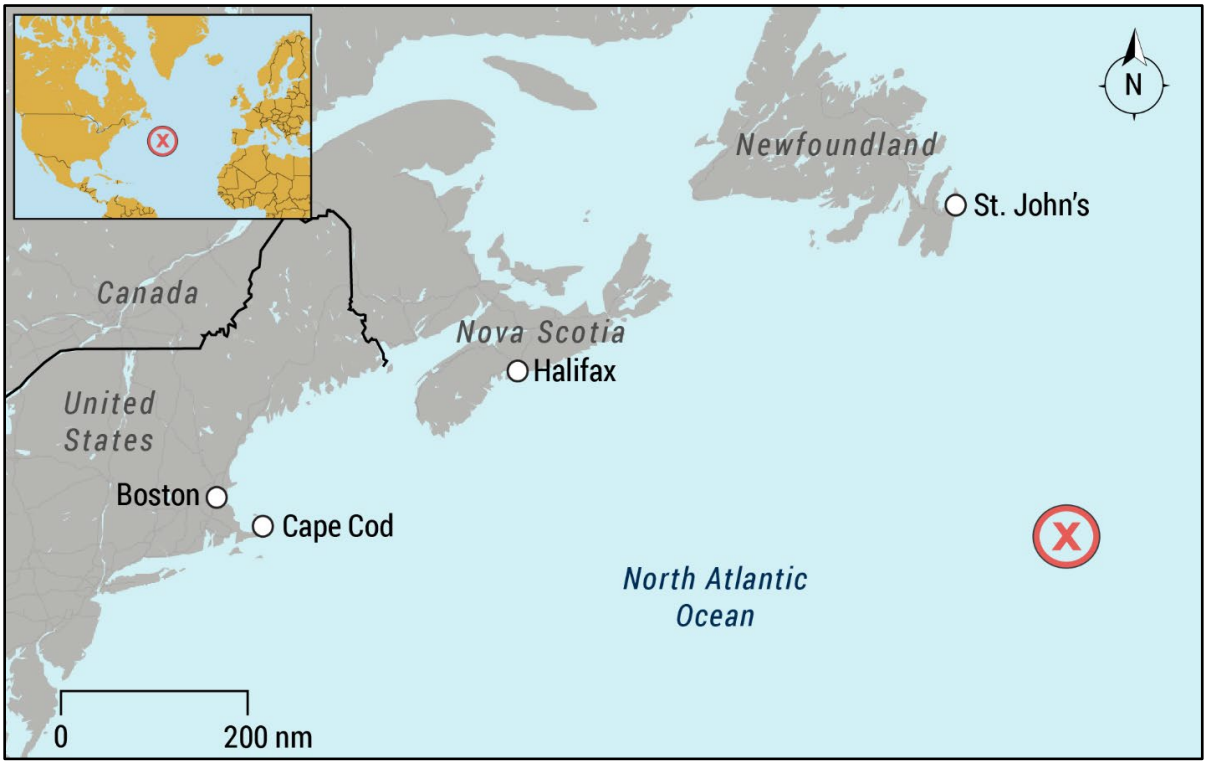

Figure 5. Area where the Titan hull failure occurred, as indicated by a circled X. (Background source: Google Maps)

2.1 2023 Expedition and accident voyage

2.1.1 Early 2023 missions

OceanGate personnel arrived in Newfoundland about a month before the 2023 expedition. *Titan* was in a "service bay" at MI. The submersible was moved to MI's Holyrood facility where it was installed on the LARS for the expedition. A small boat towed the LARS with *Titan* to Long Pond where they met *Polar Prince*.

The early start was due to *Polar Prince's* availability and due to the CEO's daughter's scheduled August wedding. *Horizon Arctic,* a large anchor handling and supply vessel, was available and affordable in previous years due to a downturn in the oil and gas industry. By 2023, post-COVID, demand for the vessel had returned and it became cost prohibitive. Horizon Marine offered OceanGate the *Polar Prince,* a former Canadian Coast Guard icebreaker, to replace *Horizon Arctic*.

Table 1. Horizon Maritime vessels.

Vessel	*Horizon Arctic*	*Polar Prince*
Type	Offshore supply vessel	Cargo, General (Cargo ship)
Owner/Operator	Horizon Maritime Services Ltd (Commercial)	Horizon Maritime Services Ltd (Commercial)
Flag	Canada	Canada
Port of registry	St. John's, Canada	St. John's, Canada
Year built	2016	1959
IMO number	9732838	5329566
Classification society	DNV	DNV
Length (overall)	307.0 ft (93.6 m)	220.4 ft (67.2 m)
Breadth (max.)	78.72 ft (24.0 m)	48.0 ft (14.6 m)
Draft	25.6 ft (7.8m)	15.4 ft (4.7 m)
Tonnage	8,143 GT ITC	2,062 GT ITC
Engine power; manufacturer	12,000 kW 2 x Bergen B32:40V12A	3820 kW Diesel Electric 4 x Fairbanks Morse 8-38D8-1/8

OceanGate staff described the 2023 expedition as much colder with rain and much higher seas. Procedure called for at least 1 km visibility and early missions of the expedition experienced challenging fog.[7] A contract diver testified that weather was not good on any of the 2023 missions.

By 2023 most of the engineering department had left the company. The second director of engineering, was replaced by an engineer with a software and electrical background, not composites. According to the former director of engineering, "[The CEO's] target was never to have an engineering group… he wanted somebody to build the toy for him; and then he could do what he wanted with it."

Crews also had to load personnel and tools in dinghies to reach the LARS, which was now towed behind *Polar Prince*. It was also more difficult to do maintenance on the vehicle since one would have to arrange for a dinghy, a crane driver, and boat crew to get to the LARS. The riskiest part of the operations though, according to the director of administration was transferring mission specialists from *Polar Prince* to the small boat, then to the platform. Closing the dome became a 23 to 25 minute operation on the moving platform.

Mission 1. Mission 1 did not have mission specialists onboard. This allowed OceanGate to integrate the newly contracted *Polar Prince* and crew and test procedures, given that *Titan* would be towed behind *Polar Prince* rather than launched from the deck. OceanGate hoped to get three dives in each mission. *Titan* was not able to launch on Missions 1 through 4 due to either weather or technical difficulties with the LARS. The *Polar Prince* captain stated, in written responses to investigators, that the LARS would list to starboard on Missions 1 through 3 after 12 hours. OceanGate personnel would visit the LARS by small boat and correct the problem. There were also technical difficulties with the external cameras.

Mission 2. *Polar Prince* left St. John's for Mission 2, their first to *Titanic* of this expedition on May 20. The LARS with *Titan* attached made a shallow dive without people onboard on May 22. This was the first dive logged in 2023 and the only one on Mission 2.

Normally the LARS was trimmed by the stern while towed. On May 23, 30 miles southwest of the *Titanic* site, the tow trimmed forward (instead of by the stern, as was typical) which OceanGate attributed to a "ghost fishing net" caught on the tow line causing it to trim forward. The vessels had to shelter in Witless Bay and wait on weather on May 27 before returning to St. John's May 28. *Titan* lost a fairing in high seas and the blanks on the bottom of the hull, where penetrations let water in to sink the vessel came loose. The crew found the platform listing and divers had to effect repairs.

[7] See the NTSB *Meteorology Group Factual Report* for additional metocean data.

Figure 6. Left to right: Operational mishaps during the 2023 expedition showing the aft starboard corner and aft end of the LARS tipped downward.

Mission 3. The vessels left St. John's again on May 29, and proceeded to St. Mary's Bay, sheltering there overnight and conducting one test dive with five people to a depth of 10 m. They arrived over the *Titanic* wreck on June 3, conducting another shallow test dive on June 5th, also with five people.

Mission 4. *Titan* departed St. John's on June 7 and diverted southwest toward Nova Scotia rather than the *Titanic* site. On June 8, the tow rope became entangled in *Polar Prince's* propeller shaft and had to be repaired by divers. They planned a dive at Gully Canyon before learning it was a protected area. Consequently, they tried a dive elsewhere on the shelf. There was an issue with a valve in the variable ballast system however and the dive was scrubbed with only *Titan's* bow releasing from the LARS. The platform listed severely, with *Titan* still attached, and with 5 people onboard. The submersible was repeatedly slammed down on the LARS by wave action before divers could secured it.

Polar Prince and *Titan* then returned to St. John's, arriving on June 15.

2.1.2 Mission 5

Polar Prince, with the LARS and *Titan* in tow, left St. John's about 0900 on June 16. The ship arrived at *Titanic* about 0400 on June 18. The weather was improved

over the previous 2023 missions with southwest force 4 winds, 3 m seas, and 5 mile visibility.[8]

Checks began at 0400. Crew and mission specialists were ferried to the LARS once thruster checks were complete. . *Titan's* complement included the CEO as pilot, a *Titanic* expedition guide who had been on all the missions, and three mission specialists.

A communications and tracking team was located on the bridge including the CEO's spouse, the mission director, a software engineer (who was also on the dome closing team), and an electronics technician (ET). The team maintained communications and coordinated the various dinghies, the platform, and *Titan*. The teams did communication checks and monitored *Titan's* depth and status. According to the ET, *Titan* did not report any alarms or distress. (The RTM system was not relayed automatically to the surface).

This was the first time *Titan* had launched off the LARS during the 2023 expedition. This was also the deepest dive carried out with the new EvoLogics communications system. A mission specialist helping out with the dome team testified there were no issues launching on time, and that the *Titan* crew were "smiling and excited." The LARS crew and divers stayed with the dinghy until *Titan* reached a depth of 1000 m, returning to *Polar Prince* after recovering the LARS and recharging the low pressure air tanks .

Routine communications between *Titan* and the surface were logged until 107:27 when telemetry from *Titan* stopped.

Titan was outfitted with 35 lb drop weights. and the last message received was that they were dropping weights. This was standard practice to slow the rate of descent as they approached the seabed. By practice, there should also have been a later message confirming the drop. The last ping was at 1047:32 from a depth of 3346.28 m in position 41° 44.06' N, 049° 56.54'W per EvoLogics data.

2.2 Search and rescue (SAR)

2.2.1 Initial response

OceanGate staff aboard *Polar Prince* first assumed there was an issue with the acoustic communications equipment. Procedures required the *Titan* crew to abandon the dive and surface 45 minutes after a loss of communications. The mission director therefore calculated that, following procedure, and given the ascent rate and last known depth, that *Titan* should surface about 1500. OceanGate staff continuously attempted to establish communications in the mean time.

When *Titan* did not surface as expected, *Polar Prince* contacted JRCC Halifax at 1855, then RCC Boston for assistance at 1910.[9]

[8] See the NTSB *Meteorology Specialist's Factual Report*, for additional metocean data and discussion.
[9] A Rescue Coordination Center (RCC) coordinates search and rescue within a search and rescue region (SRR). A Joint Rescue Coordination Center (JRCC) works both aeronautical and maritime cases.

OceanGate's "Project Execution Plan" listed Pelagic Research Services, Phoenix International, Canyon Offshore, Oceaneering International Inc. and the National Oceanic and Atmospheric Administration (NOAA) as "potential rescue ROV operators." The OceanGate Director of Logistics and Quality Assurance, who was the only other qualified submersible pilot at the time and was aboard *Polar Prince,* reached out directly to Pelagic's CEO in the evening of June 18. . Pelagic started immediately preparing their 6000 m capable *Odysseus* ROV. Magellan had also worked with OceanGate previously and was familiar with the site. Their ROV however was in the United Kingdom (UK) at the time.

Titanic rests within RCC Boston's internationally agreed search and rescue region (SRR). The U.S. Coast Guard did not monitor activity at *Titanic* though, nor were they aware of OceanGate's "Project Execution Plan". After learning of the incident, they issued a SafetyNET Hydrolant message at 2124 seeking assistance from vessels in the vicinity to keep a lookout for a 21 foot white hull overdue submarine.

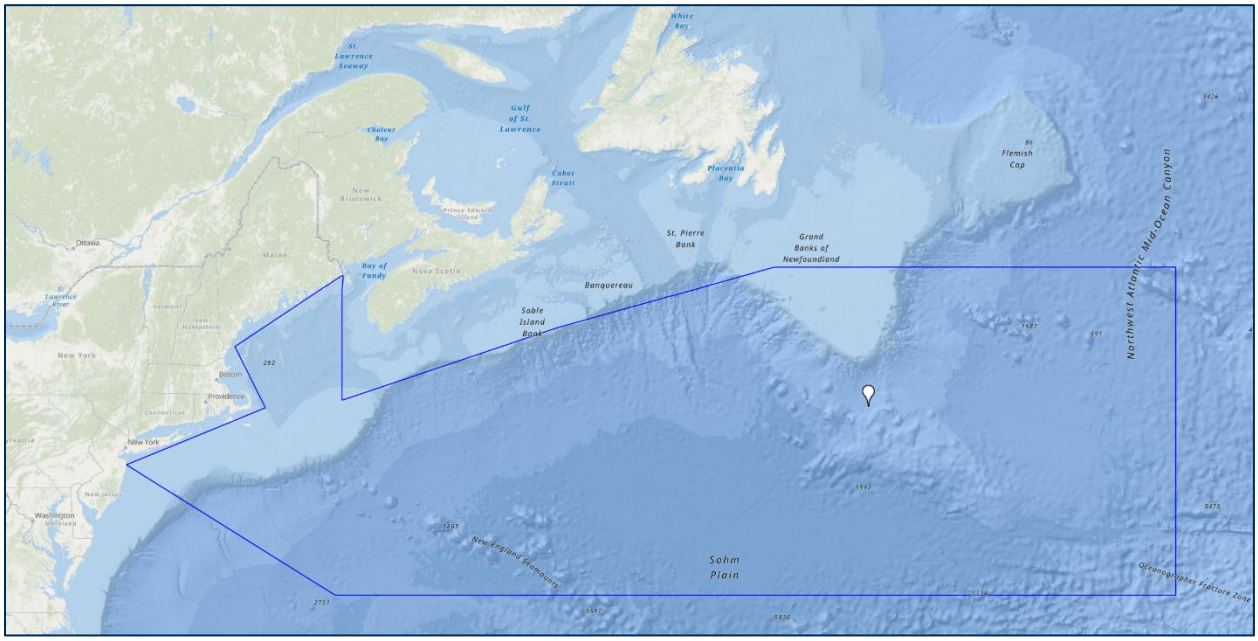

Figure 7. PLACEHOLDER chart of RCC Boston's SRR. (Source: IMO, Background: ESRI)

2.2.2 Air search

RCC Boston requested a C-130 Hercules to conduct an overflight, one of which (CG 2013) happened to be in Newfoundland, assigned to the International Ice Patrol (IIP). They conducted the first air search on the evening of June 18. A second Elizabeth City-based C-130 (CG 2015) conducted the first daylight search on June 19. Over four days, U.S. Coast Guard, RCAF, and New York Air National Guard conducted multiple searches for the submersible. These included Canadian Forces Poseidon and Aurora aircraft, with underwater detection (sonobuoy) capabilities.

Although Exxon Canada offered offshore oil helicopters to aid in the search, the closest oil platforms were too distant to be tasked. The IIP, whose mission is to track icebergs, also used available satellite imagery to assist in the search.

2.2.3 Surface search

RCC Boston provided *Polar Prince* a search pattern at 2203 on June 18 which the ship declined to use, preferring to concentrate on listening for subsea communications should *Titan* be on the seabed or suspended in the water column. Vessels searched the surface for four days including the Canadian Coast Guard Ship (CCGS) *John Cabot* and the Spanish fishing vessel *Vizconde de Eza,* both of which were sonar equipped, along with the CCGS Kopit Hopson and the OSV *Atlantic Merlin*. *John Cabot* was also assigned as On Scene Coordinator. The U.S. Coast Guard buoy tender *Sycamore* was diverted from Greenland while the CCGS *Terry Fox* and *Teleost* ferried medics, U.S. Navy, and U.S. Coast Guard subject matter experts to the scene.

SAR coordinators also located a mobile decompression chamber and arranged to have it loaded aboard the Royal Canadian Navy's *Glace Bay*.

2.2.4 Underwater detection and knocking

RCC Boston learned at 1132 on June 19 that a naval unit had detected an anomaly "consistent with sudden loss of pressurization of a hull" and corresponding with the time of lost communications with *Titan*. Almost concurrently, SAR Controllers received reports of noise consistent with knocking, detected by the sonar buoys deployed by the first Poseidon.. At 1342 *Polar Prince* reported they had also detected sounds consistent with knocking.

At 1417 on June 19, an Aurora again reported sounds of knocking about 3600 m east-southeast of the search datum. By 1750 they had narrowed the location to a 500 m radius around 41° 44.46'N 049° 55.48'W.. *John Cabot* searched the area and sounds were detected until June 22. OceanGate staff in Washington state attempted to isolate the reports of banging that would come every half hour however it was not possible to plot and isolate the various search vessels from the noise.

2.2.5 Remote Operated Vehicles

RCC Boston established a multi-agency, multi-national, Incident Management Team to coordinate all of the resources, prioritize objectives, interpret all data, and to plan ROV operations. A U.S. Coast Guard officer from the team testified that "…no one agency, and not even a single country had all the assets that we needed, and frankly, it took a collaboration between the public sector and private sector…" The Undersea Rescue in San Diego, International Submarine Escape and Rescue Liaison Office (ISMERLO), US Navy, and Canadian Coast Guard coordinated to locate available ROVs.

The ocean was 3880 m deep at the site. The cable ship *Deep Energy,* responding to an ISMERLO request, was the first on scene with an ROV in 34 hours about 1500, on June 20.

Key OceanGate personnel moved from *Polar Prince* to *Deep Energy* which had two 3000 m capable ROVs. They deployed one ROV to its maximum cable length of 3000 m. They then drove it to the end of its umbilical beyond its rated depth, in an effort to reach the seabed, almost another 2000 m. The ROV was destroyed in the process. They then used the second ROV for sonar scanning.

On the morning of June 19, OceanGate contacted the U.S. Air Force's RCC for help transporting Pelagic's *Odysseus* ROV from Buffalo, New York, not previously discussed for in their emergency plan. The U.S. Air Force Reserve's, Ohio based, 910th Air Wing flew *Odysseus* on a C-130 to Newfoundland. Meanwhile,. *Horizon Arctic* had responded from St. John's about 2100 on June 18, but returned to port before reaching the accident site about 2100 on June 19. The OSV was then quickly modified to carry and launch the ROV. *Odysseus* was loaded aboard *Horizon Arctic* in St. John's and the two departed about 0500 on June 21. U.S. Coast Guard SAR personnel testified it would normally take two weeks to get an ROV in the air, an OSV outfitted, and crew assembled.

The French research vessel *Atalante* responded from mid-ocean carrying the 6000 m capable ROV, *Victor 6000*. A 100-member ROV crew flew to Newfoundland and was ferried by the Canadian Coast Guard's *Ann Harvey* where they rendezvoused with the research vessel early on June 22.

Both *Atalante* and *Horizon Arctic* were in position over the site on the morning of June 22. These were the first ROVs on scene that could reach the sea floor. *Odysseus* located debris from *Titan* at 0810, 500 m from *Titanic*'s bow, including the tail cone and both titanium domes. The wreckage was found close to where the sub was last tracked to.

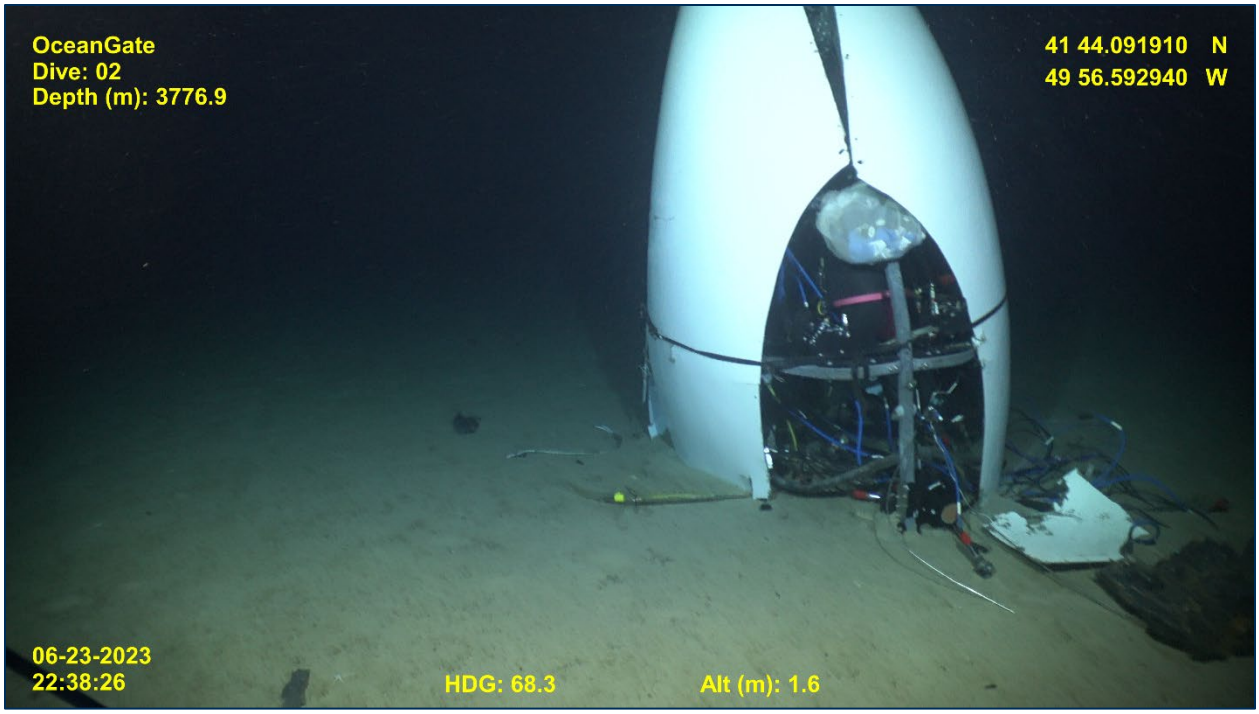

Figure 8. *Titan*'s avulsed tail cone and exoskeleton on the seabed. (Source: Pelagic)

2.2.6 Others

Table 2. Search and rescue resources assigned (Source: U.S. Coast Guard)

Resource	Description	Role
106th Rescue Wing	New York based Air National Guard SAR unit	Provided C-130 for air search
910th Air Wing	Ohio based Air Force airlift unit	Ferried ROV *Odysseus* to Newfoundland
CCGS *Anne Harvey*	Canadian Coast Guard buoy tender	Ferried French ROV team, Canadian Forces medical personnel, and embarked helicopter
Atalante	Research vessel	6000m ROV equipped
Atlantic King Fisher	OSV	Loaded FADOSS 6000 m capable heave compensated lifting package
Atlantic Merlin	OSV	Transported ROV package for Skandi Vinland
Deep Energy	Cable ship	Deployed the first ROV at the scene, a Schilling Robotics 3000 m Working Class ROV
HMCS *Glace Bay*	RCN coastal defence vessel	Transported mobile decompression chamber

Horizon Arctic	OSV	Embarked Phoenix's 6000m *Odysseus* ROV
CCGS *John Cabot*	Offshore fisheries science vessel	Sonar equipped on scene coordinator,
CCGS *Kopit Hopson*	Icebreaking buoy tender	Surface search
Royal Canadian Air Force	CP-140 Auruoa and P-8A Poseidon patrol aircraft	Air and sub-surface search
Skandi Vinland	Cable ship	On scene ROV
USCGC *Sycamore*	USCG buoy tender	Transported wreckage
CCGS *Teleost*	Fisheries research vessel	Ferried USCG SERT to the scene
CCGS *Terry Fox*	Icebreaker	Ferried medics that missed Anne Harvey. Ferried USN SME.
Vizconde de Eza	Research vessel	Sonar capable

3.0 Additional information

3.1 Other submersibles

OceanGate subs. *Antipodes* was built in 1973 as a diver lock-out submersible by Perry Submarine Builders and named *PC-1501*. It was classed by ABS. The vehicle was converted to a 5-person submersible, between 1995 and 1997 with the diver lockout compartment removed and the vehicle renamed *XPC-15*. It was sold in 1999, renamed *Antipodes,* and operated in New Zealand in the tourist and research industry. OceanGate purchased *Antipodes* in 2008. It had a steel hull, a rated depth of 305m (1000 feet) depth with a steel pressure hull.

In April 2010, OceanGate applied to have *Antipodes* inspected as a small passenger vessel and ORV. The Coast Guard inspected the vessel, witnessed test dives and training, and issued an ORV designation letter in 2010 for Puget Sound, Washington. The vessel also had a State of Washington registration.

In 2011, the Coast Guard allowed OceanGate to operate *Antipodes,* in Monterey, California as a recreation vessel and explained to them investors would be considered paying passengers which was not permitted for recreational vessels. *Antipodes* received an ORV designation in Miami as well, in 2012. Coast Guard inspectors in Miami denied a request for OceanGate to charge pilot trainees as they would then be considered paying passengers.

The Coast Guard in 2020 denied a request for *Antipodes* to be certified as a small passenger vessel citing, among other things, means of escape, separate control area, negative buoyancy is some modes, pressure boundary calculations, and missing

drawings. The vessel's ORV designation was renewed however in 2020 and again in 2022.

Lula 500 was originally built in the United Kingdom and classed by ABS. The Coast Guard issued an ORV designation letter for the renamed *Cyclops* in 2018 and again in 2020 and 2022.

Table 3. OceanGate submersibles

Submersible	Antipodes	*Cyclops*	Titan
Registration	WN 9815 NZ	WN 6745 SF	None
Length	4.0 m (13 feet)	6.7 m (22 feet)	6.7 m (22 feet)
Class	ABS	ABS	None
Beam	2.4 m (8 feet)	8.5 feet (2.6 m)	2.8 m (9.2 feet)
Hull	Steel	Steel	Carbon fiber with titanium domes
Rated depth	1,000 feet	1,700 feet	4000 m (13,124 feet)
Complement	5	5	5

Industry. In 2024, there were also nine known submersibles, excluding *Titan,* in the world that could reach a depth of 4000 m. There were 12 that could reach 1000 m, beyond which the US requires an export license.

Operator-owned and constructed submersibles have been successful. One such operator, operated unflagged and unclassed (although built to class standards), passenger carrying submersibles in Roatán for 21 years, in depths up to 915 m. A US-

based manufacturer delivered a 24-passenger 100 m vehicle for a client in Vietnam in 2022. The same manufacturer has delivered a 9-passenger submersible operated from a cruise ship.

3.2 Regulatory environment

3.2.1 IMO

The IMO published the *Guidelines for the design, construction, and operation of Passenger Submersible Craft (MSC/Circ. 981)* in 2001. These are voluntary guidelines unless made mandatory by the flag state, which the US has not. The guidelines discuss, among other things, survey intervals, training, and licensing. They also require design, construction, and maintenance meeting the requirements of a recognized organization, typically a class society. The document also requires compliance with the ISM Code. In addition to an operating manual, submersibles are to have a written emergency response plan by the guidelines. A 2004 circular clarified that viewports must also meet ASME PVHO standards or and equivalent level of safety.[10]

Flag administrations may issue a Safety Compliance Certificate for Passenger Submersible Craft for vessels meeting the requirements of the circular.

3.2.2 Flag states

United States. The application of most Coast Guard regulations is dependent on the service of a merchant vessel. US-flagged submersibles are regulated as either small passenger vessels, oceanographic research vessels, or recreational vessels per 46 CFR Subchapters T, U, or C, respectively. Small passenger vessels must additionally be inspected by the US Coast Guard. Vessels carrying six or less passengers for hire would not normally be inspected and issued a Certificate of Inspection, however the Passenger Vessel Safety Act of 1993 defined submersibles carrying just one passenger for hire as a small passenger vessel. There are therefore no US submersible uninspected passenger vessels.

US law define oceanographic research vessels (ORV) as those "employed only in oceanography or limnology, or both, or only in oceanographic or limnological research, including studies about the sea such as seismic, gravity meter, and magnetic exploration and other marine geophysical or geological surveys, atmospheric research, and biological research."[11] ORVs must meet the regulations in Subchapter U but are not inspected by the U.S. Coast Guard and are not issued a Certificate of Inspection. The U.S. Coast Guard does issue letters of designation to ORVs, valid for two years. ORVs may carry only researchers, owners, and crew. The Coast Guard Authorization Act of 2019 however eliminated age restrictions on who

[10] International Maritime Organizations. *Interpretation to the Guidelines for Design, Construction and Operation of Passenger Submersible Craft, MSC/Circ. 1138*. 2004

[11] See 46 U.S.C. §2101.

can do research, allowing ORVs to carry young students and still qualify for a letter of designation.

Recreational vessels are likewise not inspected by the U.S. Coast Guard. Self-propelled recreational vessels however must be state registered (or federally documented) and have a hull identification number (HIN.) The boating safety regulations in 33 Code of Federal Regulations (CFR) Subchapter S would also apply.

The Coast Guard published Navigation and Vessel Inspection Circular (NVIC) 5-93 following the first manned submersibles being certified as small passenger vessels in 1987. The NVIC provides guidance to inspectors and vessel owners on how to apply regulations to submersibles however, in itself, is not law. It does include both design and operational requirements. U.S. Coast Guard staff testified that they would consider proposals from industry meeting an equivalent level of safety.

The NVIC recommended restricting small passenger vessel operations to waters less than a submersible's "rated depth, or depth to which its rescue assistance is effective (45 meters in the case on no decompression diving)." Operations were not permitted deeper than the surface tender's rescue capabilities such as attaching "lifting cables, salvage bags, or manipulating external ballast controls. "Specific dive sites were to be approved by the OCMI [Officer in Charge of Marine Inspection]. An operations manual was required which includes listing available phone numbers, and estimated response times."

The NVIC also discusses voluntary reports to the Coast Guard of submersible operations in or near US waters. Such reports are "intended for informative use in search and rescue only. (emphasis included)"

OceanGate and Coast Guard inspectors discussed certification for *Antipodes*. however the NVIC restriction on dives to a maximum 150 feet for small passenger vessels made this unfeasible. The NVIC also required merchant mariner credentials and pre-designated routes which would have restricted OceanGate's business. They were issued an Oceanographic Research Vessel (ORV) letter instead for Puget Sound**.**

Several passenger vessels have been registered in the US, *Atlantis* being the only one currently certified to carry passengers. *Antipodes* and *Cyclops* were both state registered, as was *Cyclops'* LARS. *Titan* was not registered, documented, or inspected by any flag state, nor was it given a HIN.

Regulations for submersibles do not apply solely because they are launched from a US flagged vessel. Regulations specific to the surface tender based on its service such as OSV would apply.

Other flag administrations. Industry leaders testified other nations regulate submersibles to some extent. These include the Cayman Islands, France, The Bahamas, and the United Kingdom. French regulations date from 1996 and apply to submersible operating in French waters. UK regulations additionally apply to submersibles operating from UK surface tenders.

OceanGate inquired about registering *Titan* in The Bahamas in 2019. The Bahamas however required submersibles meet domestic regulations or IMO's MSC/Circ.98. They also required submersibles be classed. *Titan* was therefore never registered in The Bahamas. Specific to Canada, where *Polar Prince* and *Titan*

operated from, industry testified "There is an acute shortage of any clear regulatory language within maritime affairs in Canada at the moment and that's a problem "

A leading submersible manufacturer testified that most clients do not flag their submersibles. The same manufacturer reported though that all of their vehicles do meet Cayman Island regulations and were classed.

3.2.3 Class societies

An industry representative testified that Class rules are "constantly being updated" as technology evolves, including software, power, and propulsion. He elaborated that classification helped ensure equipment met internal recognized standards and that clients had increased confidence in a 50 year track record of safety.

ABS Rules listed various grades of steel, aluminum, titanium, and acrylics as approved materials for pressure hulls. Carbon fiber was not among them. ABS also required two cycles of hydrostatic testing at 1.25 times the design depth, with strain gauges. This was to be followed by NDT such as eddy current or dye penetrant. Surveyors witnessed the test dives, inspected penetrations, welds, and viewports until reaching depth. If test dives did not reach design depth, then that depth became the rated depth.

The operator of a Honduran based submersible testified that he had built his submersibles to class rules, though did not have them classed. He suspected classing the vessel would "double or triple" the cost. His latest submersible, the 13-foot-long *Idabel*, had a designed depth of 915 m (3000 feet) and operated tourist excursions in Roatán.

Antipodes and *Cyclops* were classed by ABS. Although ABS had provisions for alternative designs, those provisions had not been used for carbon fiber hulls. New construction surveys required, among other testing and design approval, impact testing, qualification of weld procedures and welders, post-weld heat treatment, hydrostatic pressure testing, and test dives. An ABS Senior Principal Engineer testified that ABS had classified approximately 100 submersibles since the 1960s. There were 30 ABS classed submersibles as of 2024. DNV, LR and RINA also classed submersibles.[12] The Rules also require an operations manual, and for novel designs, a qualitative and quantitative risk analysis.

OceanGate originally intended *Titan* to be ready for sea trials by spring 2018. It became public in late 2017 that the vehicle would not be classed. According to the original director of engineering, OceanGate considered calling the vessel experimental, a design and testing path allowed for by DNV rules.[13] The CEO

[12] Design depth is the "maximum depth for which a system or vehicle is designed." Rated depth is "the maximum depth reached during a manned test dive" Operating depth is the "depth at which the vessel normally operates."

[13] Den Norske Veritas and Germanischer Lloyd merged in 2013 to form DNV GL. The company changed the name to DNV in 2021.

however abandoned the effort, deciding it would take too long. Two contracted pilots refused to dive in the vehicle due to the decision not to class.

Industry leaders became alarmed with OceanGate's plans to operate an unclassed submersible and drafted a letter in 2018 to the CEO, describing their concerns. In it, they discuss the industry's proven safety record using disciplined engineering and testing. They urged OceanGate to test the vessel to class rules, articulating that third party oversight was critical. They further expressed concern over the "serious consequences for everyone in the industry."

3.2.4 Industry

Recognized industry standards are published by the US Navy, the Society of Naval Architects and Marine Engineers (SNAME,) the American Society of Mechanical Engineers (AMSE), and the Marine Technology Society (MTS), among others. There are no known recognized national or international standards specifically for carbon fiber pressure hulls for submersibles. There are standards for internally pressurized containers which included acceptance criteria for voids and porosity.

Since 1977, AMSE's PVHO committee has published standards for, among others, submersibles, diving bells, and personnel transfer capsules. The CEO showed contempt for the organization stating to the director of marine operations that "It is a volunteer group. It is not like a DOT [Department of Transportation] standard. It is a bunch of volunteers…and I'm going to go prove that, but that is for me to prove. That's why I'm going to do the dive" referring to *Titan*'s planned first dive (as opposed to a tethered unmanned dive.)

ASME allowed for testing for non-standard designs. Such testing includes proof testing and third party witnessing at six times the MAWP, creep testing, cyclical (fatigue) pressure testing, and production testing. ABS had not witnessed any such testing for submersibles.

3.3 Visiting *Titanic*

The R.M.S. *Titanic* Maritime Memorial Act of 1986 authorized negotiation of an international agreement on the preservation of the *Titanic* wreck. Canada, France, the UK, and the US drafted the *Agreement concerning the Shipwrecked Vessel RMS Titanic*. The agreement entered into force in 2019 for the UK and US following the Consolidated Appropriations Act of 2017, Section 113 which required "…no person shall conduct any research, exploration, salvage, or other activity that would physically alter or disturb the wreck or wreck site of the RMS *Titanic* unless authorized by the Secretary of Commerce." This authorization was delegated to NOAA.

The agreement does not specifically address submersible design, construction, or safety.

The agreement applies to any person subject to US jurisdiction. OceanGate applied for such authorization for their 2021, 2022, and 2023 expeditions to *Titanic*. A

federal court however determined that such authorization was not required, given OceanGate's proposed scope of work and "look but don't touch" mission at the site.

3.4 Occupational Safety and Health Administration (OSHA) investigation

In 2017 the former director of marine operations drafted a "quality control inspection report" highlighting operational and safety concerns with *Titan,* then under construction. OceanGate then terminated his employment. He subsequently filed a complaint with OSHA under the Seaman's Protection Act. He told an OSHA investigator in an interview that the carbon fiber segment was like Swiss cheese with delaminations that you could see through.

OceanGate then filed a strategic lawsuit against public participation (SLAPP), citing violation of business confidential information. The former director then dropped the complaint and OSHA closed the case. The OSHA investigator stated letters would go to the U.S. Coast Guard when they opened and closed an investigation but that he could not recall any contact with the Guard for this case. A Puget Sound U.S. Coast Guard inspector, familiar with OceanGate, was not aware of any communications with OSHA regarding OceanGate. He could also not recall any joint inspections or training between OSHA and USCG inspectors. In this case, OSHA only had jurisdiction to investigate the retaliation, not any safety issues. The OSHA investigator could not recall any other investigations of OceanGate.

Washington state later passed anti-SLAPP legislation.

3.5 Mission specialists

US small passenger vessel regulations apply to submersibles carrying at least one passenger for hire. The Passenger Vessel Safety Act of 1993 defines a passenger as, among other things, an individual who is not the vessel owner, the master, or paid crew and who "has not contributed paid consideration."[14] *Titan* was not however inspected as such, referring to their clients as mission specialists instead of passengers. The director of administration understood that mission specialists paid $250,000 to OceanGate Expeditions. She described them not as passengers but as people "curious about deep sea exploration." The CEO would then move funds to OceanGate Inc. to cover expenses. The COO understood mission specialists to be "someone who financially helps support the mission and in exchange comes on the mission, is given tasks to do, jobs to do, trained to do whatever they can be trained to do, sometimes depending on what their background is…"

The plan was always to have paying people aboard *Titan* according to the former director of engineering. The 2017-18 director of finance, also referred to mission specialists as paid customers. According to the operations manager, mission specialists were their clients. It was at the crew's discretion how capable they were in working on the mission, for example painting, doing fiberglass work, or fetching tools.

[14] 46 USC 2101

The CEO also referred to them as clients regarding vehicle safety. “And before we put people in there, particularly clients, it’s going to be a proven design.”

The director of operation told investigators he carried passengers for hire to Alcatraz and to *Andria Doria* aboard *Cyclops*. A mission specialist who had been on expeditions to *Andria Doria*, Puget Sound, and Hudson Canyon testified it was an option to be just an observer.] Another 2021 and 2022 *Titanic* mission specialist testified that he had no emergency duties. During dives he was asked to take observation notes.

Polar Prince could carry twelve passengers per SOLAS and Canadian regulations. The *Polar Prince* captain understood mission specialists to be “non-passengers”. The ship’s crew list on the accident voyage includes 19 OceanGate staff, mission specilists, and family members listed as clients.

3.6 Safety culture

Among the elements of a positive safety culture are welcoming compliance with standards and procedures. OceanGate had a 155-page *Health, Safety and Environment (HSE) Manual*. Most of the manual addressed occupational safety issues such as fall protection, hazard communications, and electrical safety. The manual however did list several management system elements including leadership, hazard identification, compliance, engineering, communication, and management of change. Specific to engineering, the manual stated “Design and construction of new or modified vessels, facilities or structures are based on approved design standards and practices that meet or exceed applicable regulatory requirements.”

The *Polar Prince* captain stated he and his crew were not involved in OceanGate’s dive planning or operations, other than the bridge confirming a “go” or “no go”. The captain also described the OceanGate CEO as “a “visionary” type of leader who sought to inspire his employees and lead by example. He would not let anyone do anything he was not willing to do himself. He appeared organized and meticulous” and the OceanGate staff as “very professional, and safety focused.”

Employees on the accident voyage stated occupational safety was a priority, the biggest hazard being small boat operations shuttling personnel to and from the towed LARS. The operations manager shared safety was “was one of the things [the CEO] preached a lot.” There were frequent safety meetings and briefs to communicate how to prevent injuries” Employees were encouraged to speak up if something was unsafe according to an electrical engineer.

The mission specialist who had been on several expeditions with *Cyclops* and on all three expeditions to *Titanic* testified she felt empowered to raise safety concerns. “I knew the risk I was taking and still decided to go.” Another mission specialist testified that OceanGate was good at “maintaining a culture of safety around a high risk operation.” “It wasn’t supposed to be safe.”He also understood from the CEO that there were limited rescue assets that could reach them in time to be effective.

Multiple employees testified to a working environment where safety issues, particularly design issues, were ignored. A former director of operations told investigators he brought design issues to engineering's attention numerous times and was brushed off. "The atmosphere there, I'm going to say it was toxic." according to him. A deckhand resigned after being screamed at by the CEO following a tow line incident on the Alcatraz expedition. Another deckhand voiced concerning to the CEO and COO regarding compliance with passenger vessel regulations. The CEO "wouldn't hire anybody that disagreed with him" per a former director of engineering

In a recorded interview before releasing the same director of operations, the CEO refused to share design information with Operations Department staff. Among the issues raised were no documentation for the viewport. There were also plunge holes in the face of the titanium ring to machine a dove-tail O-ring grove and there was no drug testing as required by US regulations. The CEO's view however was that "…the reason *Alvin* costs so much is because they spent way too long on stuff that was more about meetings and making sure they had massive consensus as opposed to somebody saying this is the way it's going to be." Following this the director of marine operations was terminated due in part to, "it's clear that there is not al lot of confidence on your part in the engineering that went into this vessel, and that your experience in other vessels gives you serious concerns about the safety of *Cyclops II* [*Titan*] from the very fundamental level".

The COO who joined in 2019, about the time the first *Titan* hull was condemned, confirmed there was bickering between departments which, though not uncommon according to him, was hard in a small company. The director of engineering stated that he would not dive in the submersible, which he helped design, because he did not trust the operations team

An ROV pilot, hired to be a maintainer and surface navigator for the 2022 expedition stated that the operation was "haphazard." She became concerned over the explanation over for the loud bang heard on the July 15 dive.

The company experienced financial difficulties by 2023 when employees were asked to defer payroll checks.

3.7 Training

OceanGate's pilot training consisted of a tiered system which exceeded the 40 hours called for in NVIC 5-93. At the time of the accident, the CEO and director of logistics were the only trained pilots. OceanGate had set up a training scheme using concepts from the aviation industry. The training and task book covered systems, crew tasks, dive theory, and operational task including a four page list of assessments.

Mission specialists received task or dive specific training from OceanGate in morning and evening meetings to go over dive plans. This did not involve the ship's crew.

US regulations require a credentialed master be in charge of small passenger vessels, with the appropriate endorsement for the vessel's route and tonnage. The

CEO held a Merchant Mariner Credential endorsed as master limited to vessels of 25 tons. The other qualified pilot's merchant mariner credential was only endorsed as ordinary seaman.

3.8 Search and rescue

Regarding SAR, NVIC 5-93 states that "although the Coast Guard has statutory responsibility for SAR, it does not have an underwater SAR capability." Submersible industry leaders testified that it was universal practice to not just have adequate rescue resources identified prior to submersible operations but also to notify them and obtain a commitment to respond if needed. The NVIC further discusses that the U.S. Coast Guard would coordinate with the naval and commercial resources that might not be readily available. The onus was therefore on the submersible operator to anticipate casualties and plan a response.

The operations manager told investigators that OceanGate would inform local authorities and the U.S. Coast Guard of dives to avoid calls from good Samaritans about a barge sinking or to avoid security concerns near the Everett Naval Station. *Antipodes* would notify Vessel Traffic Service (VTS) Puget Sound when they were operating there. Likewise, OceanGate staff testified that they had notified U.S. Coast Guard staff in Boston before *Cyclops* dove on the *Andrea Doria* wreck, though not *Titanic*.

The IAMSAR Manual briefly discusses underwater SAR. Volume II (for SAR coordinators) specifically states that "submarine SAR is a highly specialized and time-critical activity reliant on specific capabilities and training."[15] The guidance also refers SAR coordinators to ISMERLO. U.S. Coast Guard specific SAR guidance refers controllers to the US Navy as the primary source of expertise and resources. It discusses passenger-carrying submersibles but not specific response procedures for those vessels. The instruction also encourages those operators to voluntarily inform the Coast Guard of the operations. "Due to the limited capability of Coast Guard resources to respond to underwater incidents, the best response is to plan ahead, to know the limitations, and to know whom to contact for additional assistance." [16]

3.9 Johnson Sea Link

The NTSB investigated the 1973 entanglement of the manned submersible *Johnson Sea Link* near Key West, Florida. The submersible became caught on the wreck of the scuttled destroyer *Fred T. Berry.* Two of the four crew perished from CO2 poisoning before the submersible was recovered in 33 hours. *Johnson Sea Link*,

[15] International Maritime Organization, *International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual,* (2022), 6-13.
[16] U.S. Coast Guard, *Addendum to the United States National Search and Rescue Supplement*, (2013), 6-12.

owned by the Smithsonian Institute at the time, was undocumented and uninspected. The surface tender, *Sea Diver,* was documented as a yacht.[17]

The NTSB made four recommendations in its report, MAR-75-2. One recommendation to the submersible's owners to establish guidelines to prevent entanglements. The recommendation was classified "Closed – Unacceptable Action" in 1976. The other three recommendations addressed SAR and were issued to the U.S. Coast Guard. One was to acquire an "underwater television unit" and was "Closed – Reconsidered" given the development of ROVs. Another recommendation was for the U.S. Coast Guard and U.S. Navy to collaborate on research and development of a civilian submersible rescue capability. That recommendation was "Closed – Acceptable Alternative Action."

The remaining recommendation to the U.S. Coast Guard to "collect information concerning worldwide submersible search and rescue capabilities so that the most effective equipment needed for use in future underwater emergencies can expeditiously be made available." This recommendation was "Closed – Acceptable Action" in 1977 following a survey which was provided to each US RCC. SAR controllers following *Titan's* loss however, testified they were not familiar with this resource.

3.10 Investigation

The U.S. Coast Guard was designated the lead agency for this investigation. NTSB investigators travelled to Newfoundland, Washington state, North Carolina, and Rhode Island to inspect wreckage and exemplar equipment and to interview OceanGate staff. The NTSB also accompanied the USCG to the wreck site to retrieve evidence in September 2023 and participated in the MBI hearings in September 2024.

Recovered wreckage included both titanium domes and rings, the tail cone, an external camera, pieces of the carbon fiber hull, and three PCUs from the aft dome. The PCU's were severely damaged and NTSB staff were unable to extract data from them.[18]

Table 4. Table of injuries[19]

Position	Nationality	Gender/Age	Injury
Pilot and CEO	US	M / 61	Fatal

[17] *Sea Diver,* O.N. 249288, was a 37.0-foot long yacht, renamed the *Ocra*.

[18] See the NTSB *Underwater Camera Specialist's Factual Report*, for information on the SubC Imaging camera retrieved from the accident site.

[19] Title 49 *CFR* Part 830.2 defines a fatal injury as any injury that results in death within 30 days of a casualty. It defines serious injury as that which 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 (except simple fractures of fingers, toes, or nose); 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 percent of the body surface.

***Titanic* wreck specialist**	US	M / 77	Fatal
Mission specialist	US	M / 48	Fatal
Mission specialist	US	M / 19	Fatal
Mission specialist	US	M / 58	Fatal

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